EXPLORING TEACHERS’ AND STUDENTS’ CONCEPTIONS OF STEM EDUCATION AND IMPEDIMENTS TO STEM IMPLEMENTATION IN THE MATHEMATICS CURRICULUM

BY

SIFANA DEWA SITHOKOZILE
(R9914048)

SUPERVISOR: NDEMO Z.

THIS PROJECT IS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE MASTER OF SCIENCE EDUCATION DEGREE (MScED)

SEPTEMBER 2016

APPROVAL FORM
The undersigned certify that they read and recommend to Bindura University the project entitled: Exploring teachers’ and students’ conceptions of STEM education and impediments to STEM implementation in the Mathematics curriculum.

**Supervisor Mr Z. NDEMO**

Signature:____________________  Date:____________________

**Programme Coordinator:____________________**

Signature:____________________  Date:____________________

**External Examiner:____________________**

Signature:____________________  Date:____________________
DEDICATION

This dissertation is dedicated to my family, my parents and my sisters. I am thankful for the loving support and guidance from my family throughout this dissertation writing process. This has truly been a family commitment as we worked to fulfil my goal of achieving a Masters Degree in Science Education. Gift, you willingly provided time for me to study and write while you cared for our children. You supported me each step of the way. I could not have done this without you. To my amazing children, Matthew, Kuzivaishe, Kudakwashe and Gift (Jr), you have been my biggest cheerleaders and sources of inspirations throughout my studies. When exhaustion kicked in, you were able to make me smile and gain energy to keep going. I love you dearly and pray that my perseverance has served as a source of inspiration for you in life.

I am also thankful for my wonderful parents, Jeremiah and Maria, for their continual encouragement and praise each step of the process. Thank you for your words of encouragement and belief in me throughout this journey. As a child, you instilled in me the desire to be the best I can be. For this, I am forever grateful.

Finally, I wish to thank my sisters and friends for believing in me. To my loving sisters, Eunica, Patricia, Virginia, Revesai and Sithembile, thank you for your support and love throughout this process. I could never have completed my degree without the support of each and every one of you!
ACKNOWLEDGEMENTS

I wish to acknowledge the assistance and guidance received from my supervisor, Mr Ndemo. I would like to express a sincere thank you for your continual support throughout this journey. I not only learned about endurance, perseverance and leadership, but how to make this world a better place. Your leadership and guidance will serve me throughout my life. You provided tremendous guidance throughout this dissertation process. Thank you for helping me to see the “bigger picture.” Your wisdom will continue to guide me in my further studies, career and leadership journey as I work to make a positive impact on our educational system. I would like also to express my appreciation to all the respondents whom without their cooperation, the study could not have been successful.
A quantitative nonexperimental survey study was developed to explore A-Level teachers’ and students’ conceptions of STEM education. This study sought to examine the current conceptions of STEM education, current STEM instructional elements implementation practices and the impediments characterising STEM implementation in High Schools. The participating schools were located in the Mashonaland West Province. STEM teachers and A-Level STEM students were surveyed.

The closed and open form survey consisted of thirty-six research items for teachers and thirty-one research items for students. The research items were grouped by three core research questions. Quantitative data for research questions two and three were analysed using single sample t tests. A five point Likert scale was used to measure responses with a 2.5 point of neutrality rating. The open-ended question on definition of STEM was summarised and recorded for frequency.

Research indicated that High School teachers and students do not have a clear conception of the notion of STEM education though they perceive a need for it to a significant extent. This research concluded that there was no common operational definition or conceptualization of STEM in schools. In the findings, most teachers articulated a conceptualization of STEM as related to individual STEM disciplines, thus following the notion that there are silos in the teaching and learning of STEM disciplines. The inter-disciplinary and integration aspects of STEM education were lacking among both teachers and students. The research also concluded that STEM education is not yet substantially implemented since both teachers and students rarely used the core STEM instructional elements like enquiry-based, project-based, innovation and real-world problem solving activities in their classrooms. Challenges facing STEM implementation include; shortage of STEM qualified teachers, lack of exposure and hands-on training of students in STEM fields, lack of collaboration among STEM teachers, use of traditional teacher-led teaching methods and lack of research across STEM fields among others.

The research finally recommended that STEM awareness campaigns should be held in various districts throughout the country and that STEM learning hubs should be established in districts to encourage collaboration amongst STEM teachers and students. Lastly, it is recommended that teacher professional development programs be revamped with the aim to introduce integrated STEM curriculum pedagogies.
# TABLE OF CONTENTS

Dedication ................................................................. i
Acknowledgements ..................................................... ii
Abstract ...................................................................... iii
Table of Contents ....................................................... iv
List of tables .............................................................. vi
List of figures ............................................................. vii

## CHAPTER ONE: INTRODUCTION

1.0 Introduction .......................................................... 1
1.1 Background of the Study ........................................... 1
1.2 Statement of the problem ......................................... 3
1.3 Purpose of the study ............................................... 4
1.4 Research Questions ................................................ 4
1.5 Significance of the Study .......................................... 4
1.6 Assumptions .......................................................... 5
1.7 Limitations of the Study .......................................... 5
1.8 Delimitation of the Study ........................................ 5
1.9 Definition of Terms ............................................... 6
1.10 Chapter Summary ................................................ 6

## CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction .......................................................... 8
2.1 Historical Overview ............................................... 8
2.1.1 The Global Historical Overview ............................ 8
2.1.2 The Zimbabwean Historical Overview....................... 9
2.1.2.1 Major Reforms and Innovations in the Education System 9
2.2 Context of STEM Education in Zimbabwe ................. 11
2.3 The Impetus for STEM Education in Zimbabwe .......... 12
2.4 What is STEM Education ........................................ 14
2.4.1 STEM Instructional Elements ............................... 14
2.5 21st Century Skills Vis-à-vis STEM Goals .................. 16
2.6 STEM Teacher Education ....................................... 18
2.7 Innovation and STEM Initiatives .............................. 20
2.8 Some Barriers to STEM Education Implementation ....... 20
2.9 Conceptual Framework .......................................... 23
2.9.1 Constructivism ................................................. 23
2.9.2 Constructionist Principles ................................... 24
2.9.3 Integration of the Conceptual Framework ............... 24
2.10 Chapter Summary ................................................ 25

## CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction .......................................................... 26
3.1 Research Design ................................................... 26
3.2 Research Instruments ............................................ 26
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Tables</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1: The Constructivist Classroom vs. the Traditional Classroom</td>
<td>24</td>
</tr>
<tr>
<td>Table 2: Participation by School</td>
<td>32</td>
</tr>
<tr>
<td>Table 3: Teacher Definition of STEM Education</td>
<td>33</td>
</tr>
<tr>
<td>Table 4: Student Definition of STEM Education</td>
<td>34</td>
</tr>
<tr>
<td>Table 5: Frequencies of STEM Elements</td>
<td>37</td>
</tr>
<tr>
<td>Table 6: Students’ Assessment</td>
<td>41</td>
</tr>
<tr>
<td>Table 7: Top five Impediments to STEM Implementation</td>
<td>42</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Degree of Perceived Need for STEM Education</td>
<td>36</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Percentage Time Spent on STEM Elements</td>
<td>38</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Teachers Technological Literacy</td>
<td>39</td>
</tr>
</tbody>
</table>
CHAPTER ONE

1.0 Introduction

Science, Technology, Engineering, and Mathematics (STEM) education is a topic of great interest in 21st Century education. Its integration into school systems is fast growing in developed and developing countries. STEM has been adopted by numerous programs as an important focus for renewed global competitiveness for the 21st Century, but conceptions of what it entails often vary among stakeholders. This research examines the conceptions of STEM held by teachers and students and the impediments to STEM implementation in the Mathematics curriculum. STEM education, in the focus of this study, aims to shift teaching practices from traditional discipline-based teaching approaches into integrated teaching and learning approaches, where discipline-specific content is not divided, but addressed and treated as one lively, fluid study of the four disciplines, Science, Technology, Engineering and Mathematics. This is done through using approaches that are inquiry, project-based and problem-solving based in nature. To give an insight of the notion of STEM education, this chapter will look at the background of the study, statement of the problem, purpose of study, research questions, significance of the study, assumptions of the study, limitations and delimitations of the study.

1.1 Background of the Study

Many countries around the world, including global economic powers such as the United States and the European Union (EU) are transforming their educational systems to be competitive in the age of innovation (Fensham, 2008). Some countries embraced STEM earlier than others and Zimbabwe is one of the latest countries to embrace it. Recently, the Zimbabwean government introduced the “2016 A-Level STEM Initiative” as a way to increase the number of A-Level students who take up Mathematics and Sciences (Biology, Physics and Chemistry) in preparation for their entry into university STEM programs. It has been recognized that emphasizing STEM in higher education (tertiary level) may be too late to prepare and attract the new generation of STEM workers (Myers & Pavel, 2011). This realization has spearheaded recent calls for STEM initiatives to begin earlier in high school by the Zimbabwean government.

There is a limited amount of research that examines the prerequisite skills, conceptions and perceptions, knowledge bases, and experiences necessary for teachers and students to
implement integrated STEM education (Fykholm & Glasson, 2005). For integrated Science, Technology, Engineering, and Mathematics (STEM) education, since it is relatively new, this statement rings even more true. STEM Education, being a new initiative in Zimbabwe, there are bound to be various conceptions as well as perceptions by the beneficiaries, implementers, stakeholders and mere observers. Although there is a clear vision by the government of Zimbabwe on the necessity of educational reforms, several stakeholders have criticized the current STEM initiative citing that there has not been any baseline survey to inform the introduction of STEM and neither is there a clear implementation policy, let alone a committee on STEM education working to create a joint national strategy for implementation, (Sunday Mail, 10 April 2016). According to Yagci (2010), criticisms have always been levelled at the rapid introduction of reforms at the macro level with minimal consideration to the difficulties at the micro level. Because of such sentiments by stakeholders of lack of research, an investigation into teachers’ and students’ conception of the notion of STEM education and factors that may hinder or promote STEM implementation is necessary.

Research findings also indicate that science and mathematics teachers lack pedagogical knowledge and efficacy when it comes to STEM education (Deghaidy and Mansour, 2015). This has put demands on the Ministry of Education to come up with teacher capacity development (TCD) programs that address teachers’ content knowledge base and pedagogical skills. Although something has been done to address pedagogical and content knowledge, very little or no research has been done on teachers’ conception of STEM Education as implementers and students’ understanding of this notion as receptors. This research, thus sought to address this knowledge gap.

The introduction of the A-Level STEM initiative is meant to promote the teaching and learning of STEM disciplines which the government has recognised as key drivers for economic growth. Because innovation is largely derived from advances in the Science, Technology, Engineering, and Mathematics (STEM) disciplines (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011), an increasing number of jobs at all levels require STEM knowledge (Lacey and Wright, 2009). Nations need an innovative STEM workforce to be competitive in the 21st century. Therefore, successful implementation of the STEM initiative calls for a thorough investigation into how teachers and students conceptualise the notion of STEM Education.
Science, mathematics, engineering, and technology are cultural achievements that reflect people’s humanity, power the economy, and constitute fundamental aspects of our lives as citizens, workers, consumers, and parents, (NRC, 2010). The government of Zimbabwe has targeted the development of STEM skills as a key part of Zimbabwe’s long-term human capital objectives. Thus the STEM Initiative, if properly implemented, will enable Zimbabwe to harness the talent and potential in its’ young citizens so as to ride on the back of the hard Sciences and Technology to bring to a halt the devastating effects of years of economic stagnation and deterioration.

Strength in STEM related skills is necessary to best prepare our students for success in the global workforce (Lantz, 2009). The goal of STEM education is to provide students with skills necessary for success in today’s workforce. These skills are defined as: real world problem-solving, inquiry, and creative and critical thinking. Society demands these skills to maintain competitiveness in the global economy. Through STEM education, students learn and are taught through constructivist, project based methods aimed to build content understandings and application of knowledge (Lantz, 2009).

Schools must, therefore, be prepared to support student learning in new and different ways that guide preparedness for the global workforce (Glover, 2013). Effective leaders come up with initiatives that support planning for rigorous activities that incorporate STEM education (Glover, 2013). These include paying fees for STEM students as a way to encourage students to take up STEM subjects at A-Level – ‘A-Level STEM Initiative’ and providing professional learning opportunities for teachers to build content knowledge base and strengthen instructional methodologies – Teacher Capacity Development in Zimbabwe.

1.2 Statement of the Problem

The introduction of the ‘2016 A-Level STEM Initiative’ by the Ministry of Higher and Tertiary Education, Science and Technology Development raised a lot of eyebrows amongst the stakeholders and mere observers. Most people in Zimbabwe have various conceptions with regards to what STEM is, what it is up to, its elements and its sustainability in the harsh economic conditions of the country. STEM is an acronym Science, Technology, Engineering, Mathematics; but the question is, does this acronym say enough? It may appear that STEM is a simple acronym, but do all of the various partners with vested interests understand it in the same way? It seems, generally that, most stakeholders who hold interests in promoting STEM would claim to understand its meaning, yet the finer points of this construct often cause
confusion. Stakeholders may include Zimbabwe’s government officials who are advocating for the ‘2016 A-Level STEM initiative’, teachers in high schools who are expected to teach STEM to their students, parents who may struggle to understand the need for different pedagogies and curricula, businesses that need to invest in their future employment pipeline, and of course the students who are ultimately the product of these efforts. Within such a varied group of stakeholders, “What does STEM look like?” can elicit multiple perspectives. Thus, from an educational perspective, there is need explore the teachers’ and students’ conception of the notion of STEM, its implementation and the impediments that may characterise its implementation.

1.3 Purpose of the Study

The purpose of this research is to explore the current conceptions of the A-Level students and teachers regarding the notion of STEM and the impediments to its implementation. In order to integrate STEM education in the Mathematics curriculum, an investigation into teachers’ and students’ conceptions regarding STEM education and its interdisciplinary nature is necessary. Through the integration of STEM education into the classroom setting for a common cause, schools will be able to provide students with the necessary knowledge for success in universities and/or the workforce in the 21st century.

1.4 Research Questions

In order to provide context into understanding teachers’ and students’ conceptions of STEM education and impediments STEM implementation, this study will be guided by the following research questions:

- What conceptions of STEM are held by secondary school teachers and A-Level students?
- To what extent has STEM education been implemented in Zimbabwean High Schools?
- What challenges/impediments characterize STEM implementation in secondary schools?

1.5 Significance of the Study

Understanding current conceptions of STEM Education instruction in schools is essential for planning purposes in Zimbabwe. As we continue to build understandings of STEM best practices for teaching and learning, we can develop an action plan for success. For instance,
support systems in form of libraries and resource centres can be established in various
districts with the purpose of providing current best STEM practices along with 21st first
century skills.

To best implement STEM instruction, our education inspectors must understand the current
conceptions of teachers and students with regards STEM education and need for
implementation. Thus, the findings of this study will help schools and districts in the
implementation process. As the educational realm focuses more heavily on STEM
instruction, it is essential that knowledge acquired through this study will be applicable to
schools in Mashonaland West province which eases support programmes for schools and
districts in the implementation process. This information will also aid schools in guiding
students towards STEM related careers as well as college and career readiness for societal
success.

1.6 Assumptions

- It is assumed that all respondents answered all survey questions honestly and to the
  best of their abilities.
- The areas focused by the research instruments were of great concern to all
  respondents.
- The selected sample was a true representation of the population under study.

1.7 Limitations of the Study

This study of current conceptions of teachers and students in Mashonaland West province on
the implementation of STEM education was conducted through the use of a survey. Due to
the voluntary nature of the survey instrument, the return rate was less predictable. Also, with
surveying only Mashonaland West province students and teachers, the sample size is slightly
restricted and may not be generalizable to other populations. The limitations of the study are
clarified below:

- Due to a voluntary survey completion, the resulting return rate may be impacted.
- Due to lack of funding, convenience sampling was used for cost effectiveness.
- Due to convenience sampling, the sample was unlikely to be representative of the
  population being studied since the sampling frame was not known and the sample
  was not chosen at random.
1.8 Delimitations of the Study

The study was restricted to Mashonaland West province. Data was collected from students and teachers.

- A specified group of Mashonaland West province consisting of A-Level students and teachers from six high schools were surveyed. Only those involved in Mathematics, Biology, Physics and Chemistry formed the sample.
- A questionnaire was used for manageability.
- The study focussed on two aspects of the STEM components, that is, Sciences (Biology, Physics and Chemistry) and Mathematics.

1.9 Definition of Terms

The following terms are defined for this study. An in-depth review of the origins and motivations of these definitions is provided in Chapter 2.

**Constructivism** - Learning theory based on the idea that knowledge is constructed based on the understanding of the world.

**Constructionism** - Term coined by Seymour Papert, it builds on constructivism but stresses on use of tangible hands-on applications.

**Professional Development:** A comprehensive, sustained, and intensive approach to improving teachers’, heads of schools’ and education inspectors’ effectiveness in raising student achievement.

**Professional Learning Community:** Teachers committed to working collaboratively in ongoing process of collective injury and action research to achieve better results for the students.

**STEM:** “STEM education is an area of study but it is also a way of teaching and learning that is project-based, collaborative, and focused on solving real-world problems. STEM programs educate the whole student, emphasizing innovation, problem solving, critical thinking, and creativity” (TSIN, 2012)

**Twenty-first century skills:** “Advocates of 21st Century skills favour student-centred methods for example, problem-based learning and project-based learning – that allow students to collaborate, work on authentic problems, and engage with the community” (Rotherham and Willingham, 2009, p.2).
1.10 Chapter Summary

This chapter presented an introduction to the study of the conceptions of STEM education of Mashonaland West Provinces’ teachers and students. It also provided the statement of the problem, three research questions, significance of the study, definitions of terms, delimitations and limitations of the study. Chapter 2 provides a review of related literature and research on the topic of STEM education and the implementation of STEM in the school setting.
CHAPTER TWO
LITERATURE REVIEW

2.0 Introduction

This chapter seeks to examine related literature on the conceptions by students and teachers of the notion STEM education. Literature on elements of STEM education and factors promoting and/or hindering STEM education implementation is also examined.

2.1 Historical Overview of Stem Initiatives

2.1.1 The Global Historical Overview

The national focus on ensuring the United States maintains a competitive position in the global economy brought forward a priority for the educational system to provide opportunities for integrated studies incorporating the areas of STEM (Turner, 2013). A demand for a new approach to the instruction of Science concepts has been expressed. The National Research Council stated that “by the end of 12th grade, students should have sufficient knowledge of Science and Engineering to engage in public discussions on Science-related issues, to be critical consumers of Science education related to their everyday lives, and to be able to continue to learn about Science throughout their lives” (Committee on Conceptual Framework for the New K-12 Science Education Standards, National Research Council, 2012, p. 1). The National Research Council (2012) developed the goals of increased number of students in STEM related fields, expansion of the STEM workforce, and increased Science literacy to meet the current demands of global competitiveness. These are the same goals underlying the 2016 A-Level STEM initiative in Zimbabwe which goals have raised alarm considering the harsh economic conditions of the country.

A national focus on preparing students for global competitiveness began as early as 1940 with an emphasis on developing standards for ensuring military and technological preparedness (Turner, 2013). As a result, increased importance of Science and Mathematical content was brought to the forefront of education. The 1957 launch of the ‘Sputnik I’ by the Soviet Union produced additional concern for the United States’ educational system and the current Mathematical and Science standards (Turner, 2013). The United States responded to Sputnik with the National Defence Education Act (NDEA) of 1958 that provided $887 million dollars toward Mathematics, Science, and foreign studies and research over a 4-year period (Armstrong, 2006). “NDEA was passed because of the perceived connection between
education and efforts to counter the Soviets” (Zhao, 2010, p. 31). With the fear of losing global competitiveness, the United States revised Science and Mathematical standards with the goal of integrating scientific principles through constructive learning (Turner, 2013). Similarly, policy makers in Zimbabwe also felt that there was need to equip its learners with knowledge and values that guarantee economic growth and increased opportunities for employment creation; creating well rounded citizens who are relevant nationally and competitive globally.

Studies of Science and Mathematics moved to the forefront (Armstrong, 2006) with the expectation for students to apply their knowledge in meaningful ways. As we moved into the 21st century, our nation was again portrayed as behind in Science and Mathematical performance (Manzo, 2000). In 1969 the National Assessment of Educational Progress (NAEP), also known as the “Nation’s Report Card,” was developed to measure United States’ Science, Mathematics, and reading achievement (Armstrong, 2006). As a result of this political view of the United States’ educational system, a focus on national academic standards with a common curriculum was established (Armstrong, 2006).

2.1.2 The Zimbabwean Historical Overview

A critical look at our education system shows that Zimbabwe has hitherto been held hostage to its own academic dynamics and architecture. The missing link has always been STEM which is set to grant the country an industrial breakthrough of a revolutionary magnitude.

In November 2008, Zimbabwe attended an International Conference on Education (ICE) where two main topics were discussed:

1. The education system facing the challenges of the twenty-first century: an overview.
2. Inclusive education: The way of the future.

In light of the first topic, this study focused on the major reforms and innovations in the education system that is, Ministry of Primary and Secondary Education and Ministry of Higher and Tertiary Education, Science and Technology Development.

2.1.2.1 Major reforms and innovations in the education system

The National Report (2008) pointed out that the ministry of primary and secondary education continued to view the provision of relevant quality education and life skills to all citizens, especially children as a top priority, more so as the nation faces the challenges of the 21st
century. It also indicated that, to enable the nation to be an active member of the global
culture, the Ministry has embarked on promoting and strengthening the teaching of science
and technology. Thus the ministry focus on ensuring that Zimbabwe maintains a competitive
position in the global economy has brought a priority for the educational system to provide
opportunities for integrated studies incorporating the areas of STEM.

The Education Policy Objectives were formulated from the Education Act (1987) and several
amendments to the Education Act (2006). These objectives among others included:

- Increasing access and participation to education at all levels including Early
  Childhood Development (ECD)
- Providing relevant curricula including the two pathways of technical/ vocational/ business/ commercial and academic
- Promoting ICT, computer education and e-governance
- Strengthening the teaching of Maths/ Science and Tech/ Voc subjects
- Greater participation of financing/ funding of education
- Decentralisation of supervision of schools and education personnel monitoring and
  evaluation of education programs and projects. (National Report, 2008)

Clearly, the thrust of these objectives aimed to stimulate the generation of scientific and
technological capabilities in all sectors of the economy. Zimbabwe should therefore
implement science and technology policies and programmes (STEM) that will assist
graduates with opportunities to apply their skills in initiating development projects that can
help the country in its vision for sustainable economic and national development. In
concurrence, (Armstrong, 2006), reiterated that we must prepare students so they all have a
strong foundation in STEM and are able to pursue it, and we must inspire students so that all
are motivated to learn STEM and many are excited about entering STEM fields.

In September 2015, the Cabinet and President of Zimbabwe endorsed the Zero Draft
Curriculum Framework. The Zero Draft Curriculum Framework for Primary and Secondary
Education is an education blueprint meant to guide teaching and learning standards in the
country’s education sector. The Curriculum will prepare learners for life and work in an
indigenised economy and increasingly globalised and competitive environment and ensuring
learners demonstrate desirable literacy and numeracy skills, including practical competences
necessary for life. The new Curriculum Framework will also prepare graduates of the
education system to have the following skills: critical thinking, problem solving abilities,
leadership skills, good communication skills, team building and technological skills. Engaging students in work that results in their need to learn material that is essential to their education as citizens in a democracy and to their right to claim to be well educated human beings is the primary business of schools (Schlechty, 2011). Thus, the new curriculum in short, is advocating for STEM education in order to equip young Zimbabweans with modern skills which will make them competitive globally.

In an effort to accrue the benefits that are associated with STEM, Government has since gone into overdrive as it seeks to promote this noble idea that will empower Zimbabweans to become globally competitive. The Ministry of Higher and Tertiary Education, Science and Technology Development announced that free education will be offered to all pupils in public schools who register for A-Level STEM subjects when they enrol for Advanced level in 2016; Government will pay for their full school and boarding fees. It is therefore imperative to have a focus on creativity and innovation necessary for new learning for the nation’s future. According to Frey (2014), sixty percent of the jobs in 10 years from now haven’t been created yet. Thus, a strategic approach to that task is a requirement – STEM initiative is no compromise. It is therefore necessary to explore the teachers’ and students’ conceptions of the new STEM initiative in the early stages.

Overall, for the two ministries involved in Zimbabwean education system, STEM is more than just mere teaching of Science, Technology, Engineering and Mathematics. Rather it is the systematic unpacking and application of those knowledge bodies premised on scientific principles underlying the systematic resolution of everyday life problems, needs and wants. Hence a demand for a new approach (STEM Education) to the instruction of Science and Mathematics concepts is evident.

2.2 Context of STEM Education in Zimbabwe.

Science and Mathematics in Zimbabwe are taught from the primary school through secondary ordinary level as compulsory subjects for all students. At A-Level (advanced level), secondary stage, students are taught Sciences (Biology, Physics and Chemistry) and Mathematics only if they choose the scientific track. As for teacher education, teacher education programs are discipline-oriented, each in their silos. Science and Mathematics teachers are usually trained at various teacher training colleges and universities majoring as primary or secondary teacher.
Labov, Reid, and Yamamoto (2010) reiterated that the most important modern conception of STEM education might be the notion of integration—meaning that STEM is the purposeful integration of the various disciplines as used in solving real-world problems (Sanders, 2009). This STEM education perspective involves viewing the separate disciplines of science, technology, engineering, and mathematics as one unit, thus teaching the integrated disciplines as one cohesive entity. Research indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners (Furner and Kumar, 2007). Other benefits that have been found are that it is student centred, improves higher level thinking skills and problem solving, and improves retention. This integration that is aimed at the removal of the traditional teaching styles erected between the four disciplines is now branded as one-STEM (Morrison, 2008).

However, when it comes to implementation and teacher practices in Zimbabwean schools, it is noticed that classroom teaching is mostly done independently as teachers prepare and deliver their lessons individually. This in itself sets the tone for a certain culture in the school of how teachers work and how they interact together within and across disciplines. It is not common practice, therefore, that Science and Maths teachers, for example, sit together and identify cross-cutting content or skills. Accordingly, the three possible models of instruction of an interdisciplinary curriculum (parallel, cross-disciplinary and infusion), (Deghaidy and Mansour, 2015), do not exist in current practices. As for the practical side of science teaching at A-Level, most schools, in general, are equipped with science labs where students can carry out hands-on activities.

2.3 The Impetus for STEM Education in Zimbabwe.

Why must we focus on the implementation of the STEM Initiative? Today’s change is cruising on the bleeding edge of technology fostered by scientific research and development. Countries that have overcome extreme poverty, massive disease burdens, unemployment, political turmoil and social disorientation, have embraced STEM without excuses (Wood, 2014). Scientific and technological advances trend towards a future where those who ignore STEM will, indeed, run out of wealth of relevant knowledge, skills and natural resources before they themselves run out of life, both personal and societal (Ed. Wood and London Futurists, 2014).

The idea of STEM is about addressing a Zimbabwean historical imbalance where the majority of university graduates has always been heavily skewed towards arts and commercial
subjects. It is, therefore, prudent as a condition precedent to industrialisation, to deliberately
decide to focus on STEM education beginning with the Sciences and Mathematics at A-Level.
Countries are investing in innovation to create value-added jobs and industries in the 21st
century economy. Innovation, utilization of new knowledge that transcends science,
technology, engineering, and mathematics (STEM), involves a multidisciplinary approach
with a tight connection to life (Organisation for Economic Co-operation and Development
[OECD], 2010a). Likewise, STEM education, which transcends A-Level STEM subjects,
particularly mathematics, science, and technology, establishes the missing link between life
and axiomatic disciplines (National Science Board, 2010). While the overarching goal of
STEM education is to raise the current generation with innovative mind-sets, specific goals of
STEM education include “to increase advanced training and careers in STEM fields, to
expand the STEM-capable workforce, and to increase scientific literacy among the general
public” (National Research Council [NRC], 2011, p. 4). Countries that invest in STEM
education can create a nation of innovative minds and hence, achieve a sustainable economic
growth in the 21st century.

The debate over determining a solution for guiding the Zimbabwean educational system back
to global competitiveness continues to exist. Zhao (2010) argued that a paradigm shift is
necessary for education reform. “Rather than limiting an examination of what might be with
our assumption of superior knowledge, a new, postmodern search for wisdom can reveal
possible futures and enable the development of the requisite variety need for participation in a
society that must continually adapt” (Glover, 2013, p. 88). With a search for wisdom,
individuals are continual learners, hence the need for a research on the conceptions of STEM
by students and teachers.

The Educate to Innovate initiative presented by President Obama declared a need for a focus
on the development of problem solving, critical thinking, collaboration and open-ended
inquiry skills necessary for preparedness in the 21st century workforce (Dejarnette, 2012).
Gates and Mirkin (2012) recommend that active learning, discovery-based research, rigorous
mathematics instruction is needed to prepare student. Today’s technologically driven
workforce demands that individuals be able to solve real-world problems through the
processes of investigation, model building, data analysis, presentation of evidence-based
reasoning, and communication of findings (Moon & Singer, 2012). Glover (2013) described
classrooms where the teacher is involved in understanding the interests and thoughts of the
students in order to develop engaging learning.
The National Research Council, USA, developed the goals of increased number of students in STEM related fields, expansion of the STEM workforce, and increased science literacy to meet the current demands (NRC, 2012). The goal of STEM education is to provide students with skills necessary for success in today’s workforce. These skills are defined as: real-world problem solving, inquiry, and creative and critical thinking. Society demands these skills to maintain competitiveness in the global economy. Through STEM, students are taught through constructivist methods aimed to build 22 content understandings and application of knowledge (Lantz, 2009). “Critical thinking skills, skills in collaboration, and skills for working in groups are not only work skills; they are, as they have always been, essential citizenship skills as well” (Schlechty, 2009, p. 15). Thus, it is imperative that the Zimbabwean education system embarks on STEM education now in order to match the global competitiveness.

2.4 What Is STEM Education

STEM education is a ‘meta-discipline’ and this means the creation of a discipline based on the integration of other disciplinary knowledge into a new ‘whole’ rather than in bits and pieces (Morrison, 2008). It is an interdisciplinary approach (Morrison, 2008; Tsupros 2008) to learning by integrating the four disciplines into one cohesive teaching and learning paradigm. This integration that is aimed at the removal of the traditional barriers erected between the four disciplines is now branded as STEM (Morrison, 2008). According to Tsupros (2008), STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply Science, Technology, Engineering, and Mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy. According to Brown, Brown, Reardon and Merrill (2011), STEM education has been defined as a standards-based, meta-discipline residing at the school level where teachers, especially in Science, Technology, Engineering, and Mathematics, STEM teachers, use an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one lively, fluid study. It is therefore clear that in STEM education, the four disciplines should not be taught separately in silos, rather an integrated approach should be used.
2.4.1 STEM Instructional Elements

Many of the ideas and instructional approaches employed in STEM education predate the STEM movement (LaForce, Noble, King, Holt and Century, 2014). They posit that educational philosophers such as Dewey, Piaget, Vygotsky and Bruner have advocated for inquiry and constructivist approaches for over a century now. These philosophers argued for student autonomy, relevance, collaboration with peers and learning-by-doing. They encouraged teachers to view students as active participants in their own learning and considered citizenship, creative and inventive thinking to be important students’ outcomes (LaForce et al, 2014). None of them called it ‘STEM’, but the approaches and end-goals for students advocated by such philosophers are strictly similar to what STEM education mean today.

Morrison (2008) outlined some elements of STEM education as;

- Problem-solving – ability to define questions and problems, design investigations to gather data, collect and organize data, draw conclusions, and then apply understandings to new and novel situations.
- Innovation – creative use of Science, Mathematics and Technology concepts and principles by applying them to the Engineering design process.
- Invention (Project-based learning) – recognizing the needs of the world and creatively design, test, redesign, and then implement solutions (engineering process).
- Self-reliance – ability to use initiative and self-motivation to set agendas, develop and gain self-confidence, and work within time specified time frames.
- Critical and Logical thinking – ability to apply rational and logical thought processes of Science, Mathematics and Engineering design to innovation and invention.
- Technological literacy – understanding and explaining the nature of technology, developing the skills needed, and apply technology appropriately. The teacher uses current and emerging technologies in instruction; students use technology as intended for learning purposes in simulating and designing.
- Rigorous Learning – rigorous and challenging learning including cognitive demand. Students make connections between what they are learning and real world experiences, current events and / or their daily lives. Teachers and or administrators create all or parts of the school curriculum, this includes creating specific projects.
• Reflective learning – students use thinking and process skills. This includes considering alternative arguments or explanations making predictions, interpreting their experiences, analysing data and explaining their reasoning and supporting their conclusions with evidence.

These STEM elements, thus reflect on such ideas as: embracing problem and project-based approaches, personalising students’ learning, equipping students with modern technologies and creating a sense of community and family belonging.

2.5 21st Century Skills Vis-À-Vis STEM Goals

There are three broad and widely espoused goals for STEM education in the United States which capture the breadth of the purposes for STEM education as identified by the National Research Council (2011). These goals are to increase advanced training and careers in STEM fields, to expand the STEM-capable workforce, and to increase scientific literacy among the general public. As such, these goals are in one way or the other related to the 21st Century skills.

Increasing STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines is one of the goals for STEM education. 21st Century skills are core components of STEM education which support students in the level of knowledge application necessary for success in STEM related fields. “Advocates of 21st Century skills favour student-centred methods, for example, problem-based learning and project-based learning – that allow students to collaborate, work on authentic problems, and engage with the community” (Rotherham and Willingham, 2009, p. 2). Thus, increasing STEM literacy for all students is a positive measure towards collaboration of students in problem solving.

The Partnership for 21st Century Skills described 21st century skills as:

• Core Subjects (English, reading or language arts, world language, arts, mathematics, economics, science, geography, history, government, and civics) and 21st century themes (global awareness; financial, economic, business, and entrepreneurial literacy; civic literacy; health literacy)

• Learning and Innovation Skills (creativity and innovation skills, critical thinking and problem-solving skills, communication and collaboration skills) Information, Media,
and Technology Skills (information literacy, media literacy, ICT [information and communication literacy] literacy).

- Life and Career Skills (flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, leadership and responsibility) (Zhao, 2010, p. 134-135).

Another goal for STEM education is to expand the STEM-capable workforce and broaden the participation of women and minorities in that workforce. In comparison, twenty-first century skills define a globally competent person as one who is able to function in an interdependent world, allowing individuals to communicate and respect diverse cultures and gender. The global world breaks down the barrier of distance and gender, allowing for continual interaction within the global community. “We need citizens who can lead global efforts to reduce distrust and fear among different people” (Zhao, 2010, p. 155). Thus both STEM goals and 21st Century Skills advocate for a common cause of an improved globally competent workforce.

In addition, STEM education goals involve expanding the number of students who ultimately pursue advanced degrees and careers in STEM fields. Relatively twenty first century skills require that students be actively engaged in the learning process, constructing their knowledge with the teacher as the facilitator of learning. Glover (2013) stated that the constructivist framework of Pragmatism will guide America into the future. The focus on practice supports the construction of knowledge through experience. “Pragmatists must build on their knowledge by extending and trying to understand personal experience. They must live questions. They must try to learn” (Glover, 2013, p. 53). Schlechty (2011) defines engagement by the following four components:

1. The engaged student is attentive, in the sense that he or she pays attention to and focuses on the tasks associated with the work being done.
2. The engaged student is committed. He or she voluntarily (that is, without the promise of extrinsic rewards or the threat of negative consequences) deploys scarce resources under his or her control (time, attention, and effort, for example) to support the activity called by the tasks.
3. The engaged student is persistent. He or she sticks with the task even when it presents difficulty.
4. The engaged student finds meaning and value in the tasks that make up the work.
Therefore 21st Century Skills and STEM goals call for increased number of students to wholly engage and commit themselves in advanced STEM degrees.

The teacher is responsible for designing innovative lessons based on student interests and real world topics and becomes a guide, leading the students to high levels of learning (Schlechty, 2011). A focus on metacognition, real world questions, problem solving, creativity, inquiry, improvement of solutions, and collaboration supports students in their acquisition of knowledge. Inquiry guides students to high levels of learning resulting in a “discipline based” way of thinking (Stephenson, 2012). Benjamin Bloom designed a framework for high levels of learning known as Bloom’s Taxonomy. These learning objectives help to define levels of learning that “... goes deep into the cognitive frames students use to organize their world” (Schlechty, 2011, p.23). The following criteria are used to design learning activities that support application of knowledge:

- Creating – putting together ideas or elements to develop an original idea or engage in creative thinking.
- Evaluating – judging the value of ideas, materials, and methods through the development and application of standards and criteria.
- Analysing – breaking information down into its component elements.
- Applying – using strategies, concepts, principles, and theories in new situations.
- Understanding – inferring, exemplifying, classifying, and comparing
- Remembering – recalling and recognizing given information (Schlechty, 2011, p.22).

When students have commitment to their learning, they are more apt to put energy and effort into the learning process. With a search for understanding comes motivation (Brooks and Brooks, 1999). “Rather than viewing schools as teaching platforms, schools must be viewed as learning platforms” (Schlechty, 2011, p. 9). The focus is on providing engaging work that stimulates high levels of understanding and application. When students are able to assume subject matter in meaningful ways, they are better able to apply their knowledge to new situations.

Schlechty (2009) advocated that the type of learning necessary to contribute to society is engaging students with some work. “What is needed are schools that are organized to liberate minds and inspire performance rather than organizations that are designed to ensure compliance with little attention to meaning and value” (Schlechty, 2009, p. 112). Glover (2013) supported this thinking when he described learning that supports diversity. Thus,
basing on the skills required for the 21st century, there is need to develop teacher’s instructional skills and knowledge base so that students are taught the 21st century way. It is also important that students and teachers have a correct concept of the concept STEM education.

2.6 STEM Teacher Education

STEM teacher education has been anchored in a normative view of effective STEM education. In many studies, effectiveness of the programs was aligned with what policy suggested (Wilson, 2011). In addition, researchers mentioned the need for good metrics for making decisions about program effectiveness (Wilson, Floden, and Ferrini-Mundy, 2001). STEM teacher education needed empirical studies that would establish a measure of program effectiveness.

Content knowledge courses have been suggested as critical to effective STEM teacher education. For example, National Academy of Education (2009) associated more content courses for entry or exit levels of the STEM education programs with effective teacher preparation (Corlu, 2012). In line with this, the Zimbabwean government through the Ministry of Primary and Secondary education, late 2014, started the Teacher Capacity Development Programme offered at Bindura University of Science and Technology, one of the State Universities.

A recent major cross-national study of teacher education found that future elementary teachers in high-achieving countries, achievement was measured in terms of content knowledge (CK) and pedagogical content knowledge (PCK) of teacher candidates, were given more opportunities to learn university and school level Mathematics (Corlu, 2012). Same study also concluded that male teachers had higher means on content knowledge than females (Tatro and Senk, 2011). Reporting out on the same study, other researchers indicated that “[g]eneral ability seemed to be an important predictor of achievement in teacher education” (Blomeke, Suhl, and Kaiser, 2011, p.166). Content knowledge in teacher education programs, particularly with an emphasis on Mathematics, emerged as a strong predictor of future teachers’ competency in STEM education.

Some researchers suggested teacher education programs with an integrated curriculum emphasis. In early studies, teacher educators assessed poor emphasis on integrated curriculum to be a major limitation of Mathematics and Science teacher education programs in the U.S. (Mason, 1996). Teacher educators recommended a reorganization of the teacher preparation
programs to introduce integrated curriculum pedagogy to the pre-service teachers (Lonning and DeFranco, 1997). More recently, researchers found evidence that an integrated Mathematics and Science teacher education program increased pre-service teachers’ awareness on the challenges of STEM education (Berlin and White, 2010). In another recent study, researchers concluded that if pre-service teachers did not observe and experience integrated curriculum, after becoming comfortable in traditionally departmentalized curriculum, they would become more reluctant to make changes (Schlechty, 2011). STEM education with the goal of raising innovative minds could only be realized if STEM teachers were provided with in-service and pre-service education that fostered integrated approaches. However, in Zimbabwe, there is need to understand the current teachers’ understanding of STEM education and their current position of integrating STEM disciplines.

### 2.7 Innovation and STEM Initiatives

Innovation is critical for countries to achieve sustainable economic growth in the 21st century. Organisation for Economic Co-operation and Development (OECD, 2010a) describes innovation as the broad utilization of new knowledge that transcends science, technology, engineering, and mathematics (STEM). Innovation, which is derived from STEM advances, (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011), is critically important for the prosperity of nations because innovation creates jobs in the 21st century economy (Lacey and Wright, 2009). Innovation is tightly connected to life and innovation occurs as a result of the interdisciplinary work.

STEM education’s foremost aspiration is to develop innovative minds. To achieve this goal, STEM education needs well-educated teachers, who are able to provide students with learning opportunities that transcend isolated STEM subjects (National Research Council, 2011). From this perspective, STEM education is integrated and differs from teaching STEM subjects as disparate curricular subjects (Jardine, 2006). STEM teachers, who are equipped with integrated teaching knowledge, can facilitate STEM education by integrating their subject area with other STEM subjects, so that students can learn how to utilize STEM knowledge (Corlu, 2012). STEM education therefore casts the teacher in the role of a STEM education facilitator who raises the current generation with a capacity to innovate.

### 2.8 Some Barriers to STEM Education Implementation

For STEM education initiative to be adopted by any society, the STEM educator should assume the new role of a facilitator in the classroom or laboratory. As such, it is necessary to
address and reduce the barriers to successful implementation of STEM education. (Ejiwale, 2013) identified the following barriers to STEM education that are attributable to the loss of interest in STEM disciplines by students who would have become future scientists, engineers, and technologists.

1. **Poor preparation and shortage in supply of qualified STEM teachers**

   The quality of teacher preparation is crucial to helping students reach higher academic standards. Unfortunately, many classrooms today are filled with under-prepared individuals because they have received poor quality training or none at all (Rule and Hallagan, 2006).

2. **Lack of investment in teachers professional development**

   The lack of investment in the professional development of teachers for strong knowledge base has been attributed to poor student performance. As inspired teaching inspires students, new teachers need professional internships for clinical training following completion of degree. The National Council on Teacher Quality reported that all but a quarter of the student-teaching practices program in 134 educational schools earned a “weak” or “poor” rating (Sawchuk, 2011). According to Hibpshman (2007), ongoing professional development activities in Mathematics and Science should be extended to improve the content knowledge and pedagogical skills of elementary teachers and Mathematics and Science teachers.

3. **Poor preparation and inspiration of students**

   According to a new STEM study released by Microsoft and Harris Interactive, most college students studying for degrees in Science, Technology, Engineering or Mathematics make the decision to do so in high school or before. However, only 20 percent say they feel that their education before college prepared them “extremely well” for those fields (Ejiwale, 2013). The 2011 STEM Report from the Department of Commerce, U.S.A, indicate that job opportunities in Science, Technology, Engineering, and Mathematics fields (STEM) are increasing in America. This report also state that STEM workers earn 26% more on average than their non-STEM counterparts and it provided data to support the need for a highly educated STEM workforce (Ejiwale, 2013).
4. **Lack of connection with individual learners in a wide variety of ways**

   Ejiwale, (2013) reiterated that to enhance students’ performance in STEM programs, individual learners should be connected to a wide variety of ways to improve their learning in STEM fields. Current research in project-based learning demonstrates that projects can increase student interest in STEM because they involve students in solving authentic problems, working with others, and building real solutions (Fortus, Krajcikb, Dershimerb, Marx, & Mamlok-Naamand, 2005).

5. **Lack of support from the school system**

   It is important to ensure that education leaders are knowledgeable about STEM education so as to cultivate rich STEM learning experiences and expertise in their schools.

6. **Lack of research collaboration across STEM fields**

   Many STEM educators have failed in their efforts to collaborate with other STEM educators that teach other STEM disciplines. This has resulted in poor skill development in giving learners adequate sense of direction and purpose for effective learning and choice of career in STEM related fields. Since STEM education is an integration of many disciplines with their differences and similarities, a normal approach to teaching and learning should be devised through collaboration of the educators involved.

7. **Poor Content preparation, content delivery and method of assessment.**

   STEM educators should endeavour to understand the available methods and teaching strategies and select from them according to the demand of the lesson at hand with attention to the diverse nature of the students in the classroom, their learning styles and abilities. It is suffice to say that in STEM education, ‘one size fit all’ approach to teaching and learning will not work.

8. **Poor Condition of laboratory facilities and instructional media**

   Many schools are not equipped with the needed facility structure, tools and equipment and required instructional media. The government vis-à-vis school authorities should
employ adequate STEM educators for teaching and learning STEM. When teaching materials are insufficient, teachers should learn to improvise.

9. **Lack of hands-on training for students**

Another feasible approach to implement STEM education successfully is to provide hands-on training for the young engineers needed by the industries of tomorrow. This is an opportunity for engineering students to take practical action for the future. Through this approach, students are going to understand what STEM area careers are by employing the machines used in the laboratories that are just similar to the ones they would use on the job.

2.9 **Conceptual Framework**

Given the nature of STEM Education and its applications to teaching and learning, the conceptual framework underlying this study is rooted in the constructivist approach and constructionist principles. The premises of the conceptual framework are summarised below.

2.9.1 **Constructivism.**

Constructivism is based on the belief that the learner must actively build knowledge and skills (Huit, 2003). It is the learners’ processing of stimuli that produce the adaptive behaviour in this paradigm. As such, constructivism seeks to promote a learner-centred classroom and to that end, according to Jonassen, Marra, and Palmer (2004), the constructivist learning environments should:

- Provide multiple representations of reality to avoid oversimplification and represent the complexity of the real world.
- Emphasize knowledge construction instead of knowledge reproduction.
- Emphasize authentic tasks in a meaningful context rather than abstract instruction out of context.
- Provide learning environments such as real-world settings or case-based learning instead of predetermined sequences of instruction.
- Encourage thoughtful reflection on experience.
- Enable context and content-dependent knowledge construction.
- Support collaborative construction of knowledge through social negotiation, not competition among learners for recognition.
Table 1 below shows a comparison of constructivist and traditional classrooms as compiled by Brooks and Brooks (1993). Based on the comparative analysis of constructivist and traditional classrooms, constructivist instructional activities are well-suited for teaching with technology where the teacher takes the primary role of facilitator (Nanjappa & Grant, 2003). Thus, STEM education enables students to ponder, explore, and test alternative solutions to problems and help them arrive at their own understandings as a stepping-stone to producing their own knowledge.

Table 1. The Constructivist Classroom vs. the Traditional Classroom (Source: Martin-Stanley & Martin-Stanley, 2007).

<table>
<thead>
<tr>
<th>Constructivist Classroom</th>
<th>Traditional Classroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students collaborate of tasks.</td>
<td>Students primarily work alone.</td>
</tr>
<tr>
<td>Student input is highly valued in the teaching-learning process.</td>
<td>Adherence to the established curriculum is highly valued.</td>
</tr>
<tr>
<td>Students are treated as thinkers with the ability to construct new knowledge.</td>
<td>Students are treated as empty vessels into which information is poured by the teacher.</td>
</tr>
<tr>
<td>Teachers partner with students in the classroom.</td>
<td>Teachers are the experts, disseminating information to students.</td>
</tr>
<tr>
<td>Teachers seek students’ feedback in order to better understand student learning</td>
<td>Teachers seek the “correct” answer to validate student learning.</td>
</tr>
<tr>
<td>Assessment of student learning is integral to the teaching-learning process.</td>
<td>Assessment of student learning is separate from teaching.</td>
</tr>
</tbody>
</table>

2.9.2 Constructionist principles.

Constructionism is an approach to learning developed by Seymour Papert representing both a learning theory and a strategy for education based on Piaget’s theory of constructivism (Papert and Harel, 1991). Papert’s notion of constructionism included everything associated with Piaget's constructivism, but went beyond it to assert that constructivist learning works especially well when people are engaged in constructing something to create their own knowledge (Papert & Harel, 1991; Han & Bhattacharya, 2001). In his works, Papert explains that the “v” in constructivism is the theory that knowledge is built not by the teacher, but by the learner. In constructionism, he argued, the “n” is an expression of an idea when the learner
is engaged with something that is constructed and shareable (Papert and Harel, 1991). Therefore, given the fact that students engage in a design and construction process, constructionism allows for immediate and ongoing feedback, and encourages collaboration and sharing.

2.9.3 Integration of the conceptual framework.

The conceptual framework for this study integrates the theoretical roots of constructivism and constructionism in the context of STEM education concepts. Based on this conceptual framework, it will be posited that high school students interacting in project-based learning (designing and simulating) will be more engaged in their own learning and knowledge production. This experience creates greater motivation as a result of interacting with designed educational models, compared to students receiving instruction from the teacher without real models. Students will create their own ‘world’ as they use this framework to solve real world problems.

2.10 Chapter Summary

This chapter has looked at literature related to what STEM is, historical overview of STEM Education, elements of STEM, barriers of STEM implementation and the conceptual frameworks underlying this research. The next chapter looks at the research methodology.
CHAPTER THREE
RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the methodology of the project. It looks at the research design used, described it and rationalised its appropriateness to this study. The chapter also gives an overview of the composition of the population from which the sample of respondents was drawn. Data collection procedures, instruments used in carrying out the research, data presentation and analysis are also examined in this chapter.

3.1 Research Design

A quantitative descriptive survey approach was used to investigate teachers’ and students’ conceptions of STEM education and the impediments to STEM implementation. This study was undertaken with a quantitative approach using a survey research methodology. The survey consisted of closed-ended questions and one open-ended question to support an understanding of individual conceptions.

Groves, Fowler, Couper, Lepkowski, Singer and Tourangeou (2004) noted that a survey is a systematic method for gathering information from (a sample of) entities for the purposes of constructing quantitative descriptors of the attributes of the larger population of which the entities are members. The survey research methodology was deemed appropriate for this study because the goal was to collect information from teachers and students regarding their conceptions of STEM and factors that hinder the implementation of STEM education. In addition the survey was used because it can be used for descriptive, explanatory and exploratory research (Groves et al, 2004). A survey is used to collect original data for describing a population too large to observe directly. Furthermore, a survey obtains information from a sample of people by means of self-report, that is, the people respond to a series of questions posed by the researcher. A descriptive survey was selected because it provides an accurate portrayal or account of the characteristics, for example behaviour, opinions, abilities, beliefs, and knowledge of a particular concept, situation or group (Groves et al, 2004).
3.2 Research Instruments

Questionnaires were chosen as data collection instruments. A questionnaire is a printed self-report form designed to elicit information that can be obtained through the written responses of the subjects. The information obtained through a questionnaire is similar to that obtained by an interview, but the questions tend to have less depth (Groves et al, 2004).

Data was collected with the aid of questionnaires to explore the conceptions held by teachers and students about STEM and the impediments to STEM implementation. Questionnaires were decided upon because of the following:

- They ensured a high response rate as the questionnaires were distributed to respondents to complete and were collected personally by the researcher.
- They required less time and energy to administer.
- They offered the possibility of anonymity because subjects’ names were not required on the completed questionnaires.
- There was less opportunity for bias as they were presented in a consistent manner.
- Most of the items in the questionnaires were closed, which made it easier to compare the responses to each item.

However, apart from the advantages that have been listed above, questionnaires have their weaknesses, for example, there is the question of validity and accuracy (Grove et al, 2004). The respondents might not reflect their true opinions but might answer what they think will please the researcher, and valuable information may be lost as answers are usually brief.

Two questionnaires were designed, one for each respondent group. The questionnaires were self-completion in design. These questionnaires consisted mostly of closed-ended questions and two open-ended questions, as these provided more diverse detail. In the open-ended questions, the respondents were required to respond in writing, whereas closed-ended questions were mostly of Likert scale type and respondents were required to tick the appropriate response. A Likert scale was used to measure responses with a mean of 2.5 for the categories of Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree and the categories of Not at all, A little bit, Sometimes, Quite often and Always. The open-ended question focused on defining STEM education and was summarised and recorded for frequency. Question 36 rated top 5 responses on factors hindering STEM education and was recorded for frequency. The surveys are located in Appendix A. Open-ended questions were
included because they allow respondents to respond to questions in their own words and provide more detail. Closed-ended questions were included because they are easier to administer and to analyse. They are also more efficient in the sense that the respondent is able to complete more closed-ended items than open-ended items in a given period of time (Groves et al, 2004)

Both student and teacher questionnaires consisted of sections A, B, C and D. Questions were based on information gathered during the literature review to ensure that they were representative of the students’ and teachers’ conceptions of what STEM education entails. Section A aimed at gaining demographic data such as level of education, gender and working experience for teachers. This information could assist the researcher when interpreting the results, for example, whether teachers could not implement STEM education because they lacked content and/or pedagogical knowledge base. Section B aimed at determining the knowledge and views of teachers and students on the concept of STEM. Section C aimed at examining teachers’ and students’ views of STEM elements. Section D was on STEM implementation and hindering factors in schools. Instruction guidelines were attached to the questionnaires to guide the subjects to tick the chosen responses. Alternative response choices were added to the closed-ended questions to provide for meaningful data analysis.

3.3 The Study Population and Sample

The study population consisted of all teachers and students in STEM high schools offering Maths and Sciences (Biology, Physics and Chemistry) in Mashonaland West Province’s seven districts. Grove et al, 2004 defined population as all elements (individuals, objects and events) that meet the sample criteria for inclusion in a study. There were thirteen STEM high schools throughout Mashonaland West Province offering STEM subjects (Maths, Biology, Physics and Chemistry).

A convenient sample of 150 respondents comprising STEM teachers (24) and STEM students (126) was selected from the seven districts in Mashonaland West Province. (Grove et al, 2004) defined a sample as elements selected with the intention of finding out something about the total population from which they are taken. A convenient sample consists of subjects included in the study because they happen to be in the right place at the right time (Turner, 2013). The sample included twenty-four teachers and one hundred and twenty-six STEM students. In one of the schools where the number of students in the STEM class exceeded the required number for that school, the researcher used systematic sampling to come up with the
desired sample. Names for all STEM students in that school were written down and the first student was picked at random. Then every fifth pupil from the first picked was included in the required sample.

Convenience sampling was used as a sampling technique for ‘convenience’ as it were. It is a type of non-probability sampling technique. Non-probability sampling focuses on sampling techniques that are based on the judgement of the researcher (Turner, 2013). In short, a convenience sample is simply one where the units that are selected for inclusion in the sample are the easiest to access. For purposes of this study, Chikangwe High, Karoi High, Chinhoyi High, Nemakonde High, Kutama College and Jameson High Schools were easily accessible to the researcher. This is in stark contrast to probability sampling techniques, where the selection of units is made randomly. Convenience sampling was used in this study for reasons that:

- It is very easy to carry out with few rules governing how the sample should be collected.
- The relative cost and time required to carry out a convenience sample are small in comparison to probability sampling techniques. This enabled the researcher to get the sample size required for study in a relatively fast and inexpensive way since the schools were easily accessible to the researcher.

Whilst convenience sampling should be treated with caution, its low cost and ease of use makes it the preferred choice for a significant proportion of researchers at undergraduate and masters level dissertations (Turner, 2013). This research used convenience sampling on cost effective and time management bases. However since the sampling frame is not known, and the sample is not chosen at random, the inherent bias in convenience sampling meant that the sample was unlikely to be representative of the population being studied. This undermined the researcher’s ability to make generalisations from the chosen sample to the population under study.

Subjects included in the sample were selected to meet the following criteria

- be of either sex or any race
- be doing a combination of any of the subjects Maths, Physics, Chemistry, Biology, Computer Science or any science subject (for students)
- for teachers; -be teachers of any of the subjects above
3.4 Data Collection Procedures

A research proposal was submitted to the project supervisor of Bindura University of Science Education and approved before beginning the research process. A letter seeking permission to carry out the research survey was mailed to the Education Director of Mashonaland West Province. Upon receipt of permission from the provincial education office, the developed survey was distributed personally to the selected schools for voluntary completion. The survey was anonymously completed to maintain confidentiality. An estimated completion time of fifteen minutes was established. A survey window of two weeks was determined.

Data was collected with the aid of questionnaires. Prior to the actual survey, pilot surveys were carried out. The surveys were piloted in one of the high schools in July 2016 prior to being rolled out to the other five high schools. Teachers, students and school heads were provided with feedback forms to evaluate the pilot surveys. This information resulted in some minor changes and improvements being made to the questionnaires prior to the main fieldwork stage. Questionnaires were then distributed personally to the schools by the researcher for the main study. These questionnaires were the source of quantitative data collection. The questionnaires were self-completion in design.

The surveys (student and teacher) were then undertaken in five of the six high schools in total. The questionnaires were distributed to the school head in each school. The heads of departments (HODs) took responsibility (with guidance from the researcher) for co-ordinating the dissemination of questionnaires to target groups and returning of completed forms to the researcher.

3.4.1 Student Survey

The school head was requested to arrange for all students in lower six and upper six to complete the survey, either during lesson time or other appropriate sessions ensuring that there were no duplicate completions. Students completed the questionnaires individually, and returned their completed questionnaires to the school head who sealed them in an envelope to ensure confidentiality.

3.4.2 Teacher Survey

The teachers of STEM subjects (Mathematics, Biology, Physics, and Chemistry) were included in the sample. A self-completion questionnaire was given to relevant members of
staff who were given the option to either return the completed questionnaire to the head of the school (in a sealed envelope) or return the questionnaire directly to the researcher.

3.5 Data Presentation and Analysis Procedures

After the data was collected it was organised and analysed. A quantitative nonexperimental descriptive survey study was used to provide the most in-depth understanding of conception of STEM education in Mashonaland West province High Schools. The quantitative data analysis was divided into four major sections, one for each research question, and was based on survey completion.

The survey requested the following demographic information of all teacher participants; years of experience, highest level of education held, subject taught and subject area/speciality. Descriptive statistics was used to summarize and analyse the data. The Statistical Package for the Social Sciences (SPSS) was used for data analysis using single sample t tests. Descriptive statistics was also used to summarize additional insight into demographic questions. Patterns, conceptions and perceptions identified through the open-ended and ranking questions on definition of STEM and factors hindering STEM implementation were recorded for frequency. For the research question on definition of STEM education, the researcher compared the student and teacher definitions to the previously determined STEM definition of; ‘STEM education is an area of study but it is also a way of teaching and learning that is project-based, collaborative, and focused on solving real world problems. STEM programs educate the whole student, emphasizing innovation, problem solving, critical thinking, and creativity’ (Tennessee STEM Innovation Network, 2012). The most frequently occurring terms were recorded for frequency and ranked in order of occurrence.

For analysis of closed-ended questions, the researcher used SPSS. Data was analysed by using descriptive statistics. Frequency tables were drawn and from these the data was presented in pie-charts and bar graphs.

3.6 Chapter Summary

This chapter described the research design, including the population, sample, data collection procedures and instruments used to collect data. Data presentation and analysis procedures were also described. The next chapter will look at data presentation, analysis and discussion of the research findings.
CHAPTER FOUR
DATA PRESENTATION AND ANALYSIS

4.0 Introduction

The previous chapter focused on research methodology and a description of all procedures for data collection including instruments used to collect data. This chapter dwells on data presentation, analysis and discussion of research findings. Frequency tables, bar graphs, pie charts and descriptive narrations is used for data for presenting data. Data will be analysed for each research question.

4.1 Survey Participation

Table 2. Participation by school

<table>
<thead>
<tr>
<th>Name of school</th>
<th>Number of participants (n)</th>
<th>No. of teachers</th>
<th>No. of students</th>
<th>Percentage survey completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chikangwe High</td>
<td>30</td>
<td>6</td>
<td>24</td>
<td>100</td>
</tr>
<tr>
<td>Chinhoyi High</td>
<td>24</td>
<td>3</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>Jameson High</td>
<td>20</td>
<td>2</td>
<td>18</td>
<td>100</td>
</tr>
<tr>
<td>Karoi High</td>
<td>16</td>
<td>2</td>
<td>14</td>
<td>100</td>
</tr>
<tr>
<td>Kutama College</td>
<td>28</td>
<td>6</td>
<td>22</td>
<td>100</td>
</tr>
<tr>
<td>Nemakonde High</td>
<td>32</td>
<td>5</td>
<td>27</td>
<td>100</td>
</tr>
</tbody>
</table>

Survey completion was 100% in all schools under study.

4.2 Data Presentation and Analysis

Research Question 1: What conceptions of STEM are held by secondary school teachers and A-Level students?

This open form survey question revealed the following definitions of STEM education when coded for frequency. The most frequently occurring terms were recorded for frequency and ranked in order of occurrence in table 3 and table 4.

4.2.1. Teacher Conception of STEM

Most frequently occurring terms were recorded for frequency and the information is shown in the table below.
Table 3: Teacher Definition of STEM Education (n=24)

<table>
<thead>
<tr>
<th>Defining Term</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acronym Science, Technology, Engineering and Maths</td>
<td>11</td>
</tr>
<tr>
<td>45.8%</td>
<td></td>
</tr>
<tr>
<td>Inco-operating Technology in Learning of Science and Maths</td>
<td>5</td>
</tr>
<tr>
<td>20.8%</td>
<td></td>
</tr>
<tr>
<td>Hands-on</td>
<td>3</td>
</tr>
<tr>
<td>12.5%</td>
<td></td>
</tr>
<tr>
<td>Project-Based</td>
<td>2</td>
</tr>
<tr>
<td>8.3%</td>
<td></td>
</tr>
<tr>
<td>Blank Space (Unanswered)</td>
<td>2</td>
</tr>
<tr>
<td>8.3%</td>
<td></td>
</tr>
<tr>
<td>Integration</td>
<td>1</td>
</tr>
<tr>
<td>4.2%</td>
<td></td>
</tr>
</tbody>
</table>

The researcher compared teachers’ definitions to the previously determined STEM definition of ‘STEM education is an area of study but it is also a way of teaching and learning that is project-based, collaborative, and focused on solving real-world problems. STEM programs educate the whole student, emphasizing innovation, problem-solving, critical thinking, and creativity’ Tennessee STEM Innovation Network, (2012). Common terms were recorded for frequency.

From the table, most teachers (45.8%) showed the understanding that, STEM education is just an acronym for Science, Technology, Engineering and Mathematics. There was no elaboration. It appeared from the definitions that STEM is a simple acronym, but the question remained, does this acronym say enough? One of the definitions given by teachers was, ‘It is the acronym for Science Technology Engineering Mathematics, and it is an initiative which promotes the learning of Sciences and Mathematics’. Some teachers understood it as some kind of education involving learning of Sciences and Mathematics (20.8%), for example one of the definitions stated that ‘…education which has strong bias towards the learning of Sciences and Mathematics in order to spearhead development’. Few teachers (25%) in total had their definitions closer to the TSIN which said, ‘It is the study of Sciences and Mathematics which is practical (hands-on) (12.5%) and project-based (8.3%), it is meant to integrate (4.2%) modern Technology and Engineering’. Only two teachers (8.3%) did not
attempt defining STEM education. Leaving blank spaces showed that these teachers did not know what STEM education is and what it entails.

4.2.1. Student Conception of STEM

Table 4: Student Definition of STEM Education (n=126)

<table>
<thead>
<tr>
<th>Defining Term</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promotion of A-Level Sciences and Maths by paying fees</td>
<td>40</td>
<td>31.7%</td>
</tr>
<tr>
<td>Blank Space/ don’t know</td>
<td>28</td>
<td>22.2%</td>
</tr>
<tr>
<td>Acronym Science, Technology, Engineering and Maths</td>
<td>24</td>
<td>19.0%</td>
</tr>
<tr>
<td>Learning of Sciences and Maths using Technology</td>
<td>19</td>
<td>15.1%</td>
</tr>
<tr>
<td>Critical thinking and reasoning</td>
<td>10</td>
<td>7.9%</td>
</tr>
<tr>
<td>Unclassified definition</td>
<td>5</td>
<td>4.0%</td>
</tr>
</tbody>
</table>

Most students (31.7%) defined STEM education as ‘…a program by which the Government pays fees to promote A-Level Sciences and Mathematics’. Although students have an idea that STEM education has to do with Maths and Science, they also take as a mere fees payment program. This means that the finer aspects of STEM education which include; real-world problem solving, critical thinking, innovation and integration of STEM disciplines are lacking among students. A considerable number (22.2%) of the students did not know what STEM education meant. They either left the space blank or indicated ‘don’t know’ in the answer space. However, a reasonable number (32%) in total had some idea of what STEM education; 19% defined it as just the acronym for Science, Technology, Engineering and Maths, while 15.1% defined it as the learning of Science and Maths and 7.9% defined it as
‘...the study of Science and Maths which require critical thinking and reasoning’. 4% of the students gave somewhat wild definitions which could not be classified. Some of the unclassified definitions were ‘It is a stupid program which forces students to do difficult subjects yet good teachers are not found in ordinary schools’; ‘...a program by which politicians get an opportunity to favour their children by giving them laptops and i-pads’. These wild definitions simply revealed that some students have no idea as to what STEM education entails.

Therefore, the main concern with regard to STEM is that there exists a knowledge and communication gap between policy makers, schools, and the general public, e.g., parents. It appears that both students and teachers do not have an interdisciplinary and integration understanding of STEM education. In addition, the concept that STEM education entails collaboration and real-world problem solving did not come out of the teachers and students definitions. Angier, (2010) pointed out that everybody who knows what it means knows what it means, and everybody else doesn’t. This is particularly true when it comes to schools’ and their authorities’, parents’ and business partners’ understanding of the notion and need for STEM education.

4.2.2. Degree of need for STEM education

From the above analysis of definition of STEM education, it was seen that both teachers and students have no finer conception of STEM. From some of the definitions given by students, it seemed that STEM was coming as a forced program. To further understand teachers and students’ perceptions of STEM, this research sought to investigate the perceived need of STEM in secondary schools. Single sample t tests were carried out.

H₀₁₁: Students do not perceive a need for STEM education to a significantly positive or negative extent.

H₀₁₂: Teachers do not perceive a need for STEM education to a significantly positive or negative extent.

Two single sample t tests were conducted using SPSS to evaluate whether there is a significant difference in the mean for the perceived need for STEM education rating and the 2.5 point of neutrality, which was the test value. The grouping variables were students’ perceived need for STEM education and teachers’ perceived need for STEM education. The students’ test was significant, t (125) = 6.81, p < 0.001. Therefore H₀₁₁ was rejected. The
teachers’ test was also significant, \( t (23) = 6.102, p < 0.001 \). Therefore, \( H_0 \rightarrow H_1 \) was rejected. The students’ average score (\( M = 3.42, SD = 0.515 \)) and teachers’ average score (\( M = 3.00, SD = 0.832 \)) were significantly higher than the 2.5 point of neutrality. The 95% confidence interval for the difference in means ranged from 0.50 to 1.24 for the students test. The 95% confidence interval for the difference in means ranged from 0.35 to 0.65 for the teachers’ test. Thus the research significance demonstrated that both students and teachers perceive a need for STEM education in the agree to strongly agree range.

**Figure 1. Degree of perceived need for STEM education**

![Bar chart showing the percentage distribution of responses among teachers and students.](image)

Of teacher survey participants, 76.6\% indicated they strongly agreed to a need for STEM education, while 19.6\% indicated they agreed to a need for STEM instruction. In total 96.2\% were positive about the need for STEM instruction. This shows that a very big number of teachers in High Schools are very much in need for STEM education. Very few teachers showed that they were negative about a need for STEM education, 0.2\% strongly disagreed to a need for STEM education and 0.5\% disagreed to a need for STEM education while 3.1\% were neutral. A similar trend was also observed with student survey participants, 38.2\% agreed to a need for STEM instruction and 56.4\% strongly agreed to a need for STEM education. Figure 1 represents these data. Although, both students and teachers have a haze conception of STEM education as was shown by results in question 1 analysis, this information on perceived need for STEM education shows that students and teachers are very
interested in this notion despite little knowledge of what it entails. Hence the introduction of the ‘2016 A-Level STEM initiative’ will be very welcome in High Schools.

4.2.3 Implementation of STEM instructional elements

Research Question 2. To what extent has STEM education been implemented in Zimbabwean High Schools?

4.2.3.1 Teachers’ position on STEM instructional elements

Descriptive statistics were used to identify the most often used STEM instructional elements in the classroom setting. Of the teacher survey, a five point Likert scale was used. The table below shows a summary of the findings.

Table 5. Frequencies of STEM elements

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th></th>
<th>A little bit</th>
<th></th>
<th>Sometimes</th>
<th></th>
<th>Quite often</th>
<th></th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>freq.</td>
<td>%</td>
<td>freq.</td>
<td>%</td>
<td>freq.</td>
<td>%</td>
<td>freq.</td>
<td>%</td>
<td>freq.</td>
<td>%</td>
</tr>
<tr>
<td>Problem-solving</td>
<td>6</td>
<td>25</td>
<td>11</td>
<td>45.8</td>
<td>3</td>
<td>12.5</td>
<td>3</td>
<td>12.5</td>
<td>1</td>
</tr>
<tr>
<td>Enquiry-based learning</td>
<td>8</td>
<td>33.3</td>
<td>10</td>
<td>41.7</td>
<td>5</td>
<td>20.8</td>
<td>1</td>
<td>4.2</td>
<td>0</td>
</tr>
<tr>
<td>Project-based learning</td>
<td>7</td>
<td>29.2</td>
<td>7</td>
<td>29.2</td>
<td>6</td>
<td>25.0</td>
<td>3</td>
<td>12.5</td>
<td>1</td>
</tr>
<tr>
<td>Critical/Logical thinking</td>
<td>3</td>
<td>12.5</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>41.7</td>
<td>6</td>
<td>25.0</td>
<td>5</td>
</tr>
<tr>
<td>Rigorous learning</td>
<td>5</td>
<td>20.8</td>
<td>2</td>
<td>8.3</td>
<td>5</td>
<td>20.8</td>
<td>10</td>
<td>41.7</td>
<td>2</td>
</tr>
<tr>
<td>Reflective learning</td>
<td>2</td>
<td>8.3</td>
<td>3</td>
<td>12.5</td>
<td>4</td>
<td>16.7</td>
<td>11</td>
<td>45.8</td>
<td>3</td>
</tr>
<tr>
<td>Innovation</td>
<td>2</td>
<td>8.3</td>
<td>11</td>
<td>45.8</td>
<td>7</td>
<td>29.2</td>
<td>3</td>
<td>12.5</td>
<td>1</td>
</tr>
</tbody>
</table>

Form the table above, it can be seen that aggregately, most teachers do not implement such STEM instructional elements as problem solving, enquiry-based learning, project-based and innovation. For instance, problem solving had 70.8%, enquiry-based had 75%, project-based had 58.4% and innovation had 54.1% teachers who rarely (Not at all/A little bit) used these STEM instructional elements. Fairly used (Sometimes/Quite often) STEM instructional elements were critical/logical thinking with 66.7%, rigorous learning with 62.5% and reflective learning with 62.5%.
To further understand how teachers often employ the STEM instructional elements in a nine-week program, the researcher also examined the percentage of time spent on the aforementioned elements in the classroom setting. The amount of time was given as frequency per nine-week period for each STEM instructional element. Figure 2 shows the percentage time spent.

**Figure 2. Percentage time spent on STEM elements**

From the results, it was observed that the least times were spent on project-based (2%), enquiry-based (3%), and innovation (7%) respectively. Problem solving was given a fairly improved amount of time of 16%, reasonably fair times were given to critical/logical thinking (26%), rigorous learning (24%) and reflective learning (22%). All percentages were given to the nearest whole number.

**4.2.3.2 Teachers’ technological literacy**

Descriptive statistics was used to classify teachers for technological literacy. Teachers were classified as either, not yet familiar, beginner with support, self-confident or capable of teaching others. Figure 3 below shows the percentages for each class.

From the graph, it can be seen that most teachers are technologically literate with 21% being confident on their own and 8% are even capable of teaching others. However majority of the
teachers (63%) are beginners of using technology with support. This might impact STEM lessons delivery since STEM education entails integration of disciplines including Technology. Only 8% of the teachers are capable of teaching others which seems too small a percentage considering that STEM students need to be taught to use technology for research, designing and simulations. This showed that teachers did not have sufficient understanding of the ‘T’ in STEM. It also suggested that Science teachers may not have an adequate understanding of the nature of science and technology and the interactions between these two disciplines, when and if integrated.

Figure 3. Teachers’ technological literacy

4.2.3.3 Students’ position on STEM instructional elements

The researcher also examined the extent to which STEM instructional elements are developed among students. The elements included problem solving, critical/logical thinking, reflective learning, project-based learning, enquiry-based learning, rigorous learning, innovation, and technological literacy. Questions were grouped according to which STEM element they best describe. The subgroups were:


Each question was analysed separately as shown in table 5 below. Students were asked to respond with reference to STEM education. In order to maximize effectiveness of each STEM instructional element, we would expect students’ average scores to exceed 4.0. Thus, from the assessment table below, five elements, whose mean was above the expected, were assessed as ‘Good’ (questions 15, 21, 22, 23, 24). Four elements (questions 17, 18, 19, 20) required ‘Attention’, their means were below expectation but above lower reference line of 3.5. Two elements (questions 16 and 25) required immediate ‘Action’ since their means were below the reference line of 3.5 and the expected mean of 4.0.

One of the elements which required action was question 16. Most of the students agreed to strongly agree (54%) that teachers chose topics or projects for them to investigate. This is contrary to the constructivist learning approach which advocates for student knowledge construction instead of the traditional teacher-led instruction. Another element which was assessed for immediate action was question 25 on the use of technology for designing and simulation. Students strongly disagreed – disagree (52%) to using technology for designing and simulations in their STEM education. This meant that ‘Technology’ was not wholly integrated in STEM education. STEM elements focusing on critical/logical thinking, problem solving and innovation required attention. This meant that teachers should dwell more on these teaching instructional elements to help students develop them.
<table>
<thead>
<tr>
<th>STEM element</th>
<th>Mean, n=126</th>
<th>Assessment</th>
<th>Strongly Disagree</th>
<th>2 (Disagree)</th>
<th>3 (Neutral)</th>
<th>4 (Agree)</th>
<th>strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. My STEM teacher(s) tells me how to improve my work.</td>
<td></td>
<td>Good</td>
<td>2%</td>
<td>3%</td>
<td>14%</td>
<td>40%</td>
<td>42%</td>
</tr>
<tr>
<td>16. My teacher lets us choose our own topics/projects to investigate.</td>
<td>3.44</td>
<td>Action</td>
<td>7%</td>
<td>11%</td>
<td>28%</td>
<td>32%</td>
<td>22%</td>
</tr>
<tr>
<td>17. In STEM education, I work out explanations on my own.</td>
<td>3.65</td>
<td>Attention</td>
<td>1%</td>
<td>5%</td>
<td>36%</td>
<td>41%</td>
<td>16%</td>
</tr>
<tr>
<td>18. In STEM, I back my ideas with information from research</td>
<td>3.87</td>
<td>Attention</td>
<td>2%</td>
<td>6%</td>
<td>25%</td>
<td>38%</td>
<td>29%</td>
</tr>
<tr>
<td>19. In STEM education, we plan and do our own projects and/or experiments</td>
<td>3.76</td>
<td>Attention</td>
<td>3%</td>
<td>8%</td>
<td>27%</td>
<td>33%</td>
<td>29%</td>
</tr>
<tr>
<td>20. In STEM, we work on real-world problems.</td>
<td>3.90</td>
<td>Attention</td>
<td>3%</td>
<td>7%</td>
<td>22%</td>
<td>34%</td>
<td>34%</td>
</tr>
<tr>
<td>21. In STEM, I find new or better ways to solve problems</td>
<td>4.27</td>
<td>Good</td>
<td>2%</td>
<td>3%</td>
<td>13%</td>
<td>32%</td>
<td>51%</td>
</tr>
<tr>
<td>22. We investigate to see if our ideas are right.</td>
<td>4.05</td>
<td>Good</td>
<td>1%</td>
<td>3%</td>
<td>22%</td>
<td>36%</td>
<td>37%</td>
</tr>
<tr>
<td>23. In STEM education, I put my ideas in order of importance.</td>
<td>4.35</td>
<td>Good</td>
<td>1%</td>
<td>2%</td>
<td>13%</td>
<td>32%</td>
<td>53%</td>
</tr>
<tr>
<td>24. In STEM, I give reasons for my opinions.</td>
<td>4.23</td>
<td>Good</td>
<td>1%</td>
<td>2%</td>
<td>16%</td>
<td>37%</td>
<td>45%</td>
</tr>
<tr>
<td>25. In STEM, I use technology for designing and simulation.</td>
<td>3.41</td>
<td>Action</td>
<td>28%</td>
<td>24%</td>
<td>16%</td>
<td>20%</td>
<td>12%</td>
</tr>
</tbody>
</table>
Reference lines were set at 3.5 and 4. Assessment: Good=Above 4.0; Attention=Below 4.0; Action=Below 3.5.

### 4.2.4 Impediments to STEM implementation

**Research question 4:** What challenges/impediments characterize STEM implementation in secondary schools?

$H_02_1$: Teachers in Mashonaland West High Schools do not face challenges in implementing STEM education.

$H_02_2$: Students in Mashonaland West High Schools do not face challenges in implementing STEM education.

Two single sample t tests were conducted to evaluate whether there is a significant difference in the perceived impediments to STEM implementation rating and the 2.5 point of neutrality, which was the test value. The grouping variables were the students’ perception of STEM implementation rating and the teachers’ perceptions of the impediments to STEM implementation rating. The students’ test was significant, $t (123) = 4.99$, $p < 0.01$. Therefore, $H_02_2$ was rejected. The teachers’ test was also significant, $t (23) = 3.047$, $p =0.003$. Therefore $H_02_1$ was rejected. The teachers’ average score ($M = 3.68$, $SD = 0.669$) was significantly greater than the 2.5 point of neutrality. The 95% confidence interval for the difference in means ranged from -0.241 to 0.508 for the teachers’ test. The students’ average score ($M = 3.30$, $SD = 0.875$) was significantly above the 2.5 point of neutrality. The 95% confidence interval for the difference in means ranged from -0.229 to 0.280 for the students’ test. Thus, the research demonstrates that both students and teachers agree to strongly agree to impediments to STEM education above the neutrality rating of 2.5.

Teachers were also asked to rate top 5 factors hindering STEM education implementation and responses were recorded for frequency. Table 6 shows the percentage frequencies.

**Table 7. Top five impediments to STEM implementation**

<table>
<thead>
<tr>
<th>Impediment</th>
<th>frequency</th>
<th>% frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Shortage of STEM qualified teachers</td>
<td>14</td>
<td>58.3</td>
</tr>
<tr>
<td>2. Lack of exposure and hands-on training of students in STEM fields.</td>
<td>11</td>
<td>45.8</td>
</tr>
<tr>
<td>3. Lack of collaboration among STEM teachers</td>
<td>9</td>
<td>37.5</td>
</tr>
</tbody>
</table>
From the table, it can be seen that teachers ranked shortage of STEM qualified teachers as the most challenge to STEM implementation. They also identified the use of traditional teacher-led teaching methods as a cause of concern in implementing STEM education. The least ranked challenge for STEM implementation was lack of research across STEM fields.

4.3 Chapter Summary

This chapter looked at data presentation and analysis. Data was presented in tables, frequency tables, pie-charts and bar graphs. Descriptive statistics was used to analyse data and SPSS was used to analyse closed-ended questions data. The next chapter looks at the research summary, conclusions and recommendations.
CHAPTER FIVE
SUMMARY CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter comprises a summary of the study and conclusions reached on the basis of the research findings obtained in chapter 4. Recommendations were presented as ideas or suggestions that would go a long way in successful implementation of STEM education.

5.1 Summary of the Study

Current Zimbabwean Education policies are grounded in a belief that STEM programs will enhance the ability of schools to provide the skills and knowledge students will need for success in tertiary education and the workplace (industry). A quantitative nonexperimental research survey study was developed to investigate teachers’ and students’ conception of STEM education. The survey provided the quantitative conception of STEM by teachers and students along with one open-ended questions to support an understanding of individual conceptions. The Statistical Package for the Social Sciences (SPSS) was used for data analysis. Patterns and conceptions identified through the open-ended question were recorded for frequency.

The current conceptions of High School teachers and students regarding STEM education were examined. Three research questions focusing on what STEM education is, implementation of STEM instructional elements and impediments to STEM implementation were examined. Perceived need for STEM education was also examined to best understand STEM conceptions. Patterns and conceptions identified through the open-ended research question based upon the definition of STEM were ranked for frequency for question 1.

Descriptive statistics were used to identify the most often and the least used STEM instructional elements in the classroom setting to answer research question 2. Two single sample t tests were used to determine significance between teachers’ perception of the impediments to STEM education rating compared to a 2.5 test value representing neutrality and students’ perception of the impediments to STEM education rating compared to a 2.5 test value representing neutrality to answer question 4.

Chapter one looked at background of the study, statement of the problem, research questions, assumptions, significance of the study, definition of terms, limitations and delimitations.
Chapter two reviewed related literature to the study. Related literature included global and Zimbabwean historical overview of STEM, STEM Teacher education, 21st Century STEM skills, STEM elements and factors hindering STEM implementation. Chapter three was on research methodology. The research employed a quantitative non-experimental research survey. Convenience sampling together with systematic sampling were used to get the required sample for the study. Chapter four looked at data presentation and analysis. Data was presented in tables, bar graphs and pie-charts. Chapter five presented the research summary, conclusions and recommendations.

5.2 Research findings

This research study was focused on four research questions. The four questions and findings are discussed below.

Research Question 1

How do teachers and students in High Schools define STEM education?

Research participants were asked to define STEM in their own words. The researcher then compared recorded definitions with the previously determined definition and recorded for frequency. The following commonalities and frequently used terms were identified in order of frequency. Teacher survey uncovered the following commonalities Acronym Science, Technology, Engineering and Maths (45.8%), Inco-operating Technology in Learning of Science and Maths (20.8%), Hands-on (12.5%), Project-Based (8.3%), Integration (4.2%). 8.3% of the teachers left the answer space blank. Blank spaces showed that some teachers lacked understanding of the notion of STEM.

Of the student data, analysis revealed that most students (31.7%) have the understanding that STEM education is a program in which the government promotes the learning of A-Level sciences through payment of fees. A considerable number of students (22.2%) left blank spaces which meant that students did not know the meaning of STEM education. Students had similar definitions to teachers’ when they defined STEM education as an Acronym for Science, Technology, Engineering and Maths (19.0%) and as the Learning of Sciences and Maths using Technology (15.1%). However some students gave some wild definitions of STEM, for example, ‘It is a stupid program which forces students to do difficult subjects yet good teachers are not found in ordinary schools’.
Further analysis of the perceived need for STEM education revealed that there was a significant difference between the mean score of both student and teacher perceived need for STEM education rating and the 2.5 point of neutrality. The mean score for students was 3.42 and teachers score was 3.0 compared to the 2.5 point of neutrality rating. With scores above the 2.5 neutrality rating, students and teachers agree to strongly agree to a need for STEM instruction.

*Research Question 2*

To what extent has STEM education been implemented in Zimbabwean High Schools?

The research assessed the implementation of STEM education using STEM instructional strategies. The research uncovered that the least used STEM instructional elements were enquiry-based learning, project-based learning, problem solving and innovation. To further understand the implementation of STEM instructional elements, the researcher examined the percentage of time spent on each of the STEM elements in a nine-week working period in the classroom setting. It was observed that teachers spent little time on enquiry-based learning, project-based learning, problem solving and innovation. The assessment of the students’ use of STEM elements showed that the mean for elements such as technological literacy, innovation, project-based learning, and enquiry based learning were below the expected mean of 4. Hence attention and action were required on these elements. Also analysis of the teachers’ use of technology revealed that most teachers are beginners with support.

*Research Question 3*

What challenges/impediments characterize STEM implementation in secondary schools?

There was a significant difference between the mean score of both student and teacher perceived impediments to STEM education rating and the 2.5 point of neutrality. The mean score for students was 3.30 and teachers mean score was 3.68 compared to the 2.5 point of neutrality rating. With scores above the 2.5 neutrality rating, students and teachers agree to strongly agree to the perceived STEM implementation impediments.

An option for providing top five challenges to STEM implementation in rank order was provided. The researcher found the following ranking; Shortage of STEM qualified teachers (58.3%), Lack of exposure and hands-on training of students in STEM fields (45.8%), Lack of collaboration among STEM teachers (37.5%), Use of traditional teacher-led teaching
methods (33.3%) and Lack of research across STEM fields (20.8%). Teachers also identified some challenges to STEM implementation such as; lack of support from school systems, poor conditions of laboratory, poor pupils backgrounds, large teacher pupil ratios, lack of investment in teacher professional development and inadequate resources for STEM implementation.

5.3 Research Conclusions

Research participants were asked to provide their personal definitions of STEM. The researcher then compared participants’ definitions to the TSIN definition. Teachers’ and students’ definitions of STEM were found to incorporate some common key terms of STEM such as: Science, Technology, Engineering and Mathematics; Learning of Science and Mathematics, Hands-on, Project-based, and Integration. This identification of commonalities in key terms as compared to the definition of STEM illustrates some level of understanding of the meaning of STEM education. However, although there was some understanding of STEM education displayed, the inter-disciplinary, integration, collaboration, innovation and real-world problem solving aspects of STEM education were silent. This study therefore concluded that both teachers and students have no clear conception of STEM education.

The research uncovered a perceived need for STEM education by A-Level students and teachers. However, on implementation of STEM instructional elements, it was concluded that both students and teachers rarely employed such STEM instructional elements as problem solving, project-based learning, enquiry-based learning and innovation. The research also uncovered that 63% of the teachers are beginners with support in using technology and that students are not familiar with designing and simulations using technology. It was therefore concluded that teachers’ and students’ competencies in technology are lacking. Also, lack of use and familiarisation of the higher-order thinking STEM elements would not seem to support learners in an increasingly complex world. In addition, lack of use of the STEM instructional elements may not support proper student learning that will not prepare them for the 21st century and a complex world.

Top five challenges facing STEM implementation included: Shortage of STEM qualified teachers, lack of exposure and hands-on training of students in STEM fields, lack of collaboration among STEM teachers, use of traditional teacher-led teaching methods and lack of research across STEM fields. Research participants also identified some challenges to STEM implementation such as; lack of support from school systems, poor conditions of
laboratory, poor pupils backgrounds, large teacher pupil ratios, lack of investment in teacher professional development and inadequate resources for STEM implementation. These resources include professional development and access to STEM assets such as libraries, agencies, professionals, and museums.

Overall, this research concluded that there was no common operational definition or conceptualization of STEM in schools. In the findings, most teachers articulated a conceptualization of STEM related as to individual STEM disciplines, thus following the notion that there are silos in the disciplines. Only one teacher discussed the integrated nature of STEM, while many others (students included) failed to demonstrate an understanding in either of these areas. Given the nature of this survey, it was not surprising that there appeared to be a challenge in changing the paradigm from departmentalised academic disciplines to the integration of these disciplines, since the current education system has strong bias of the traditional departmentalised disciplines taught in silos.

5.4 Recommendations

This research found out that both teachers and students have no clear conception of the notion of STEM education although they perceive a need for it. It is recommended that administrators in collaboration with policy makers should come up with programs for STEM awareness campaigns in districts and schools throughout the country. In addition, since the inter-disciplinary and integration aspects of STEM education were also lacking, a reorganisation of teacher professional development programmes to introduce integrated STEM curriculum pedagogy should be enforced as policy since some traditionally departmentalised curriculum teachers may become reluctant to make changes.

This study also found significance to a positive extent in High School teachers’ and students’ perceived need for STEM education with an average response of agree to strongly agree. However, only 36% of teachers said they were prepared for the implementation of STEM. The researcher recommends a clear vision for STEM implementation for schools, providing a pathway for necessary support and resources to guide both students and teachers toward STEM implementation. Within this vision professional development designed to support teachers with STEM instructional strategies and the availability of STEM assets should be outlined.

Support in how to better incorporate STEM assets and technology into classroom instruction will also be beneficial for teachers. Research data indicated that 63% of the teachers were
beginners with support in using technology while an assessment of students’ ability to use technology for designing and simulations was far below expectation, it is recommended that teachers should be supported with programs which foster on use of technology in STEM education. Teachers in turn would train their students. It is also recommended to involve schools administrators at all levels of teacher professional development since research found out that lack of support from school systems is one of the impediments to STEM implementation. This is done to build commitment to the purpose of the work. Institutional leaders will be critical to this work as they involve teachers in the planning for implementation.

This research also found that pupils’ backgrounds and large teacher pupil ratios are some of the impediments to STEM implementation. It is recommended that all stakeholders should be involved in the STEM implementation plan to build a coherent focus and commitment to the vision. STEM education is no longer viewed as the instruction of STEM subjects in isolation, yet the subjects of Science, Technology, Engineering, and Maths are integrated with a focus on real-world problem solving (Saunders, 2009). The researcher recommends the construction of professional learning communities involving the content areas of Science, English and Maths to best communicate instructional objectives to develop cross-curricular units of study.

To best include stakeholders and community members in a district’s STEM implementation, the researcher recommends an increased use of Business and STEM professionals. Partnerships with STEM professionals should provide students with opportunities for working alongside professionals in their STEM careers, project-based activities based upon STEM expertise, awareness of possible STEM professions, and sharing of resources to support classroom instruction. Communicating district needs with community stakeholders will greatly support this work. The Ministry of Education should establish a STEM Learning Hub resource centre designed to provide a communication network to enhance sharing of expertise and strengthening existing collaboration while building new partnerships as well as connect regional STEM assets with the business community.

Teachers reported that they observe/ employ STEM instructional elements a little bit–sometimes, while students reported they rarely implement STEM instruction like problem solving, enquiry based, project based and innovation. However, STEM instructional strategies of reflective and rigorous learning were reported to be used quite often by teachers.
This discrepancy in perception leads the researcher to believe that a clear understanding of STEM instruction is not developed for the surveyed schools. The researcher recommends that a clarification in STEM instructional elements and instructional strategies would benefit both teachers and students. A clear, common definition of STEM instruction will support teachers with new understandings and build commitment toward the work.

Finally, an increased focus on STEM professional learning will also support teachers as they work towards implementation. Professional learning should be intensive, on-going, and connected to practice. It should be focused on student learning and address the teaching of specific curriculum content as well as align with school improvement priorities and goals. Also, awareness of availability of STEM assets and teacher involvement in resource purchasing will support teachers with classroom instruction.

5.5 Recommendations for Further Research

Further research should be conducted on existing STEM identified schools in Mashonaland West Province and core programs to identify effective strategies that support student learning. It would also benefit schools to analyse data from these programs to identify specific learning gains. An analysis of instructional strategies and the implementation of project-based learning based upon the integration of Science, Technology, Engineering, and Maths disciplines would likely support to various districts as they implement STEM instruction across all disciplines.

Furthermore, research into community/business partner communication and relationships would benefit schools as they continue to build partnerships that support student learning. The above recommendations will provide information to High School teachers and students as they begin and/or continue the implementation of STEM instruction.

5.6 Chapter Summary

This chapter looked at a summary of the study, research findings, conclusions and recommendations.
REFERENCES


Zhao, Y. (2010). *Catching up or leading the way*. Alexandria, VA: ASCD.
Appendix A: Student Questionnaire: STEM Survey

Section A

1. Name of School: …………………………………………………………………

2. Level: (tick)  
   Lower Sixth    ☐  Upper Sixth    ☐

3. Subject combination (tick)  
   ☐ Mathematics  ☐ Physics  ☐ Biology  
   ☐ Chemistry  Other (specify)…………………………………

4. How interested are you in science, technology, engineering, and/or maths (STEM)?
   Please mark on a scale from 1 (not interested) to 5 (very interested).

<table>
<thead>
<tr>
<th>Subject</th>
<th>Not interested</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Very interested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maths</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Section B: Conception of STEM

Respond to the following

<table>
<thead>
<tr>
<th>Number</th>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>I perceive a need for STEM education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>I feel prepared enough for the implementation of STEM education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>There is need for STEM specialised teachers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Technology should be used throughout STEM programs and lessons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>More time should be allocated for STEM subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Business and industry partners should be involved in STEM education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11. There are differences in coursework due to introduction of STEM education

12. STEM education is multidisciplinary & includes lessons that are integrated

13. Every school should have a special STEM lab?

14. STEM education requires critical thinking & reasoning

15. In your own words, define STEM education

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

Section C: STEM Elements/Skills

Please mark answer on a scale from ‘Not at all’ to ‘Extremely well’

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little well</th>
<th>Pretty well</th>
<th>Extremely well</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. How well can you work as part of a team on a project?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. How well can you get along with other students?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. How well are you familiar with designing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. How well can you solve unexpected problems or find new or better ways to do things?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. How well can you develop a plan that identifies the steps you need to follow to get something done?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. How well do you use trial and error to figure out if something is going to work or not?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. How often do you think of possible results before you take action?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. When facing a problem, how well do you identify solution options?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. How well can you express your thoughts on a problem?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. How well can you give reasons for your opinions and ideas?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. How well do you put your ideas in order of importance?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. How well do you back your decisions with</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28.</td>
<td>How well do you listen to ideas of others even if you don’t agree with them?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29.</td>
<td>How well do you keep your mind open to different ideas when planning to make a decision?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.</td>
<td>How well can you determine the best way to handle a problem?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.</td>
<td>How well do you make sure the information is correct?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thank you
Appendix B: Teacher Questionnaire: STEM survey

Please tick

1. Highest level of education
   - [ ] Diploma
   - [ ] Degree
   - [ ] Degree + PGDE/grad CE
   - [ ] Masters Degree
   - [ ] Doctorate Degree

2. Years of experience
   - [ ] 2 or less
   - [ ] 3-7
   - [ ] 8-15
   - [ ] 16-20
   - [ ] 21+

3. I teach
   - [ ] Mathematics
   - [ ] Biology
   - [ ] Physics
   - [ ] Chemistry
   - [ ] Other (specify) ……………………………………………

4. My subject area/speciality is
   - [ ] Mathematics
   - [ ] Biology
   - [ ] Physics
   - [ ] Chemistry
   - [ ] Other (specify) ……………………………………………

Section B: Conception of STEM Education

5. In your own words define STEM education…………………………………………
   ……………………………………………………………………………………………………………
   ……………………………………………………………………………………………………………

6. As a technology user, I classify myself as:
   - [ ] Not yet familiar
   - [ ] Beginner with support
   - [ ] Confident on my own
   - [ ] Capable of teaching others

7. When students use technology to do class work, they mostly:
   - [ ] Work individually
   - [ ] Work in pairs
   - [ ] Work in small groups
   - [ ] Not doing this at this time
   - [ ] Other (specify) ……………………………………………

8. In order for my students to use e-mail for learning/working:
- They use a shared account provided by the school
- They use an individual address assigned by the school
- They do not have a need for e-mail access at this time
- They are presently not being given e-mail access

Respond to the following

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.</td>
<td>I perceive a need for STEM education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>I feel prepared enough for the implementation of STEM education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>There is need for STEM specialised teacher</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>STEM education require the use of alternative instructional techniques</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Technology is often used throughout STEM programs and lessons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>More time should be allocated for STEM disciplines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Business and industry partners should be involved in STEM education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>There are differences in coursework and instruction due to introduction of STEM education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>STEM education is multidisciplinary and includes lessons that are integrated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>Should every school have a special STEM lab?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.</td>
<td>We often meet with other STEM discipline teachers planning projects together</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Section C: STEM elements

How often do you implement/observe the following STEM elements?

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little bit</th>
<th>Sometimes</th>
<th>Quite often</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.</td>
<td>Problem-solving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.</td>
<td>Enquiry-based learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.</td>
<td>Project-based learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.</td>
<td>Critical/Logical thinking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24.</td>
<td>Rigorous learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.</td>
<td>Reflective learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.</td>
<td>Innovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Section D: Impediments to STEM implementation

Do the following factors hinder STEM implementation?

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.</td>
<td>Shortage of STEM qualified teachers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28.</td>
<td>Lack of investment in teacher professional development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29.</td>
<td>Lack of inspiration of students</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.</td>
<td>Lack of exposure of students in STEM related fields</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.</td>
<td>Lack of support from school systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32.</td>
<td>Lack of research collaboration across STEM fields</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.</td>
<td>Poor content preparation and delivery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34.</td>
<td>Poor condition of laboratory and instructional media</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
35. Lack of hands-on training for students

36. Suggest any other factors which may hinder successful implementation of STEM education in your school?

i. ..............................................................................................................

ii. ..............................................................................................................

iii. ..............................................................................................................

Thank you