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Key Stakeholders' Perceptions of Stem Education in Zambia: A Mixed Methods Inquiry

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now long gone on the path of the ancestors.
May their *mizimo* (spirits) continue to shine upon the family

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ABSTRACT

In the recent past, the concept of STEM education has become a “buzz phrase” in the Zambian education system, and yet, very little is known about STEM education let alone what those involved in STEM think or know about STEM in the country. The primary purpose of this study was to investigate key STEM stakeholders’ perceptions of STEM education in Zambia. To better understand STEM in the country, it was critical to explore the perceptions of STEM held by STEM teachers, STEM administrators, and STEM policymakers in the perception domains of STEM vision, STEM definition, STEM purpose, STEM relevance, and STEM learning and teaching.

The study used a convergent mixed methods design. Quantitative data were collected through survey questionnaires, while qualitative data were collected through surveys and interviews.

The key findings of the study show that despite minor disagreement within and between stakeholder groups about the understanding of STEM, there was a general agreement between stakeholders about STEM education in the country. The findings revealed cohesion within and between groups regarding STEM education. Furthermore, the results of the study also indicated that there is a general passion among stakeholders to see a successful implementation story of STEM in the country. The results show that the stakeholders expressed their interest in STEM and pointed out that STEM is the way to go if Zambia must traverse the economic, scientific, environmental, technological, and

social-cultural terrains of the 21st century. The findings of this study imply that the study will inform and inspire STEM conceptualization, understanding, and practices in the country. At the level of practice, this study will not only inform the general practices of STEM but also classroom practices and conceptualization for STEM practitioners. Furthermore, the study will guide and inform curriculum development and policy formulation in the country.

CHAPTER I

INTRODUCTION

Overview of Broad Issues

The advent of the 21st century brought with it unique, numerous, complex, global, economic, ecological, health-related, and sociocultural challenges that have never been witnessed before. Global and local economies are becoming more and more information and knowledge-based, hence, challenging our conventional educational pedagogies and consumerism habits. Ecological and environmental concerns are becoming even more visible in the forms of the depletion of natural resources, pollution, environmental degradation, and climate change which in turn question our stewardship of the universe. The socio-cultural and political challenges that are manifested in issues of equity and equality question our traditional conception of social justice and the common good. The ongoing globalization and internationalization entail urbanization and migration which reshape the demographic composition of the world.

In addition to the aforementioned challenges, our world today is becoming more and more technologically and scientifically oriented. The development of new and smart technologies and scientific innovations has put into question future workmanship. These technologies are becoming more and more integrated into our biological, social, physical, and political spaces, changing the way we behave and relate with one another and raising existential questions about what it means to be human. The technological and scientific state of the world describes the new era of the fourth industrial revolution which is upon us. Sometimes referred to as 4IR or Industry 4.0 (Philbeck & Davis, 2019; Shahroom & Hussin, 2018; Sharma, 2019), the phrase fourth industrial revolution was popularized by German scientist Klaus Schwab in 2016 in his book *The Fourth Industrial Revolution.* Preceding the third industrial revolution, the fourth industrial revolution was born at the dawn of the 21st century. It depicts our era with increased connectivity and exponential growth toward automation, smart technology, and machine-to-human interaction. Describing the 4IR, Schwab (2016) states that:

> We stand on the brink of a technological revolution that is fundamentally changing the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before. We have yet to grasp the speed and breadth of this new revolution (p. 1).

Unique to the fourth industrial revolution is where advanced and smart technologies are being infused, integrated, and merged into human lives (Eleyyan, 2021). “A fusion of technologies that is blurring the lines between the physical, digital, and biological domains” (Butler-Adam, 2018). According to Schwab (2016), “it is the fusion of these technologies and their interaction across the physical, digital, and biological domains that make the fourth industrial revolution fundamentally different from previous revolutions” (p. 8). The whole paradigm of 4IR is characterized by advanced robotics, mobile supercomputing, artificial intelligence, quantum mechanics, genetic editing, the internet of things, automation, neuro and nanotechnologies, virtual reality, 3D printing, big data cloud storage, and machine-to-machine interaction.

In the face of these numerous, global, and complex challenges of our time, coupled with the forces of 4IR, the question about school curricula and teaching and learning pedagogies become even more pertinent. Most authors have argued that given the emerging changes in society, culture, economy, and ecological environment, a revolution in teaching and learning pedagogies is eminent (Fomunyam, 2020; Gouedard et al., 2020; Hong, 2017; Menon & Castrillon, 2019; Nadelson & Seifert, 2017; Sabirova et al., 2020; Yang, 2019). According to the Organization for Economic Co-operation and Development [OECD] (2018), "in an era characterized by a new explosion of scientific knowledge and a growing array of complex societal problems, it is appropriate that [school] curricula should continue to evolve, perhaps in radical ways" (p. 3). In this regard, many governments have expedited reviewing their curriculums as a way to equip learners with the skills, knowledge, and competencies needed to stand up to the complex challenges of our time. If we indeed are going to keep up with the forces of the 4IR, education for current and future generations must surely be reimagined. Reading the signs and demands of our time, education must evolve, and a transformation in learning and teaching methodologies is vital so as to embrace a kind of learning outcome based on knowledge, skills, and competencies needed for our time and the future.

It is important now more than ever that our education systems become tools for bridging skills, competencies, and content knowledge to solve real-life problems. Hence, the role of education today goes beyond teaching learners 3rs, how to pass exams, inducting learners for college and career readiness, or teaching them how to become good citizens. Instead, the role of education today should be preparing students who can stand up to and face head-on the complex challenges of our time, meet the demands of an ever-changing and increasingly technologically and scientifically oriented world, and at the same time meet the demands of the evolving and dynamic workforce. Education today can no longer afford the luxury of being a mere tool for social mobility and information amassment. Rather, a tool for nurturing and harnessing creative/critical thinking, collaboration, communication, analytical reasoning, innovation, decision-making, entrepreneurship, and problem-solving. According to OECD (2018):

> Education has a vital role to play in developing the knowledge, skills, attitudes, and values that enable people to contribute to and benefit from an inclusive and sustainable future. Learning to form clear and purposeful goals, work with others with different perspectives, find untapped opportunities, and identify multiple solutions to big problems will be essential in the coming years. Education needs to aim to do more than prepare young people for the world of work; it needs to equip students with the skills they need to become active, responsible, and engaged citizens (p. 4).

To realize this functional goal of education and in response to the global challenges, while adapting to an ever-changing and technologically oriented world, Zambia like many other countries worldwide has turned to science, technology, engineering, and mathematics (STEM) education as one of the areas that can be improved to provide tangible solutions to these challenges. For a few years now, STEM education has been at the center of the curriculum and educational reforms in Zambia as the demand for STEM-related initiatives, careers, mindset, and skills continues to grow and, in the desire, to transition from a natural resource-based economy to a knowledge- and information-based economy. The Zambian government believes that STEM education is part of the answer to the many challenges faced by the country. It is for this reason that Zambia has identified STEM as a new approach to be employed in education to equip current and future generations with much-needed knowledge, skills, and competencies for effectively traversing the 21st century milieu.

World literature has shown that STEM-literate countries are more likely to face global challenges more competently than non STEM-literate countries (Honey, et al., 2014; Park, et al., 2017). As a result, Zambia has felt the need to reinforce STEM-related subjects in schools as an important focus for renewed global competitiveness in the rapidly changing world. This is manifested in growing attention toward STEM in the areas of policymaking, curriculum reform/development, reports, and funding. Zambia's increased attention toward STEM has further been motivated by the projection that future jobs and economic growth will predominantly depend on STEM-related disciplines. According to English (2016), "the jobs of the future are STEM jobs, with STEM competencies increasingly required not only within but also outside of specific STEM occupations" (p. 1). Given this background, the government of Zambia has made significant investments in STEM education largely driven by concerns that the future may lack qualified STEM professionals.

Background and Context

Zambia is among the many countries in the world that have turned to STEM education in an effort to train, equip, and prepare the present and future generations with the skills, competencies, and knowledge needed to competently drive innovation, entrepreneurship, and economic growth in the country. Like any other country in the world, Zambia is faced with multifaceted educational challenges coupled with the familiar faces of economic, ecological, scientific, and sociocultural challenges. Since time immemorial, Zambia's economic growth has been reliant on natural resources, especially copper mining. However, due to the depletion of these natural resources and population increase, Zambia can no longer rely on natural resources to effectively sustain the economy, hence, the need to diversify. In acknowledging this reality, the United Nations Conference on Trade and Development's (UNCTAD) (2022), report on the *science, technology, and innovation policy review of Zambia* noted that:

> The changes in the contribution of industry are largely stagnant and almost entirely related to the prices of copper and the performance of the mining sector and any associated business that services it. While the Zambian economy is fundamentally dependent on copper mining, attempts to use this natural endowment to grow and diversify [the economy] have largely failed (p. 6).

Upon this realization, the government of Zambia identified STEM education among other areas as one of the areas that can be strengthened to help the transition from a natural resource-based economy to a knowledge- and information-based one. This is in line with what UNCTAD (2022) recommended: "this situation is unlikely to change unless Zambia embarks on a broader and more forceful process of technological upgrading – because economic diversification is heavily dependent on science, technology, and innovation" (p. 6).

To bring about the much-needed diversification in the economy, Zambia, through the *Vision 2030* plan and consequently *the Agenda 2063*, has set as one of its goals to invest in human capital through STEM education so as to establish a knowledge- and information-based economy that is fully dynamic, competitive, vigorous and robust in stature. This move was further necessitated by the projection that future economic growth in the country and the world at large will depend profoundly on science, technology, engineering, and math knowledge, skills, and competencies. Furthermore, STEM-related disciplines have been identified as vital in preparing students to be innovators, and creative thinkers, collaborate and communicate across real-life obstacles, and solve complex problems. According to a report on education, science, and technology for the fourth session of the 12th national assembly of Zambia, "the industrialization and diversification priorities depended on improving science, technology, engineering, and mathematics knowledge, which was also critical for responding to the challenges caused by climate change" (National Assembly of Zambia, 2020, p. 5). It is envisaged that Zambian students with STEM skill sets, knowledge, and competencies will help drive innovation and fuel a knowledge-based economy; face head-on the challenges of our time; meet the demands of an ever-changing world; respond to the effects of the 4IR; and, at the same time meet the demands of the evolving and dynamic workforce.

To achieve this goal, the government of Zambia through the Ministry of General Education (MoGE) embarked on a countrywide implementation of a STEM-based curriculum in selected schools. In 2019, the parliament of Zambia approved the establishment and construction of 52 STEM schools across the country. Of these 52 STEM schools, the former technical schools and other already existing schools were converted into STEM schools and an additional more were constructed specifically as STEM schools. In January 2020, the official implementation of the STEM curriculum was launched in 15 pilot schools. Giving a detailed account of the commencement of the implementation of STEM in the country, the MoGE (2020b) stated that:

> Taking a phased approach, in January 2020 implementation of STEM Education started in fifteen schools. To this effect, the Directorate of the National Science Centre (DNSC), which is responsible for STEM education in the country, undertook the training of STEM teachers from the fifteen pilot schools. Thereafter, the actual school implementation of the transitional STEM curricula began in February 2020 which was followed by monitoring to ascertain the effectiveness and management of the teaching and learning processes (p. 1).

A few months after the implementation of STEM was launched, the parliament of Zambia through a National Assembly Committee embarked on evaluating the progress of the implementation process. The findings of the evaluation revealed both positive and negative developments in the implementation of STEM education in schools. Unfortunately, the negatives outweighed the positives. A letter from the Permanent Secretary of General Education showed this concern when it stated:

> The implementation of the STEM Curriculum started in 2020. However, my office has received concerns from different stakeholders regarding the provision of STEM Education. In view of this, a series of consultative meetings on STEM education implementation has been held. During these meetings, both the strengths and weaknesses of the STEM curriculum were identified. It should be noted that the challenges far outweighed the strengths (Letter, May 7, 2021).

As a result, on May 7th, 2021, a year and a half into the implementation process, the government called off the implementation of STEM in all schools instructing that the STEM curriculum be suspended for the time being while consultations are ongoing.

Problem Statement

As can be observed from the background and context, there has been back and forth from the MoGE in the implementation process of STEM education in the country. In 2019, the parliament of Zambia approved the introduction of a STEM curriculum in STEM schools. Consequently, the parliament also approved the establishment and construction of 52 STEM schools across the country. In January 2020, the official implementation of the STEM curriculum was launched in 15 pilot schools. However, before STEM was implemented in all 52 schools, the process was halted on 7th May 2021. In the meantime, schools are left to decide whether or not to continue with STEM. This has caused a lot of anxiety and uncertainty among the learners and the general public, especially parents whose children are in these STEM schools.

Moreover, STEM education is a new phenomenon in the country. The country is still grappling with the whole concept of STEM education. Very little if not nothing is researched and written about STEM in the country. Further still, very little is known about STEM in the country – its vision, meaning, purpose, relevance, and practices let alone what key stakeholders think or know about STEM in the country. It was felt that if the general public is to know about the happenings around STEM, the starting point is to investigate key STEM stakeholders' understanding of STEM in the country – what they think and know about STEM in the country. In order to better understand the happenings around STEM education, it was crucial to investigate the perceptions of STEM help by key stakeholders.

The Purpose of the Study

The purpose of this study was to investigate key STEM stakeholders' perceptions of STEM education in Zambia. STEM education became a buzz phrase in the Zambian education system, and yet, very little was known about what those involved in STEM thought or knew about STEM in the country. To better understand STEM in the country, it was critical to explore the perceptions of STEM held by STEM teachers, STEM administrators, and STEM policymakers in the perception domains of STEM vision, STEM definition, STEM purpose, STEM relevance, and STEM learning and teaching. The study compared the perceptions of STEM among STEM teachers, STEM administrators, and STEM policymakers.

Research Questions

The following research questions guided the study:

1. How do STEM teachers, STEM administrators, and STEM policymakers perceive STEM education?

(a) How do they define STEM education?

(b) How do they perceive the purpose of STEM education?

(c) How do they perceive STEM teaching and learning?

2. How do the perceptions of STEM: STEM vision, STEM definition, STEM purpose, STEM relevance, and STEM teaching and learning compare among STEM teachers, STEM administrators, and STEM policymakers?

Significance of the Study

As shall be demonstrated in the literature review, very little or nothing at all of empirical literature is written about STEM education in Zambia – its meaning, purpose, relevance, and practice, let alone its perceptions. Therefore, the significance of this study is that it contributes to the knowledge body and literature on STEM education in the country. Fundamentally, this study informs STEM education at the levels of conceptualization, implementation, practice, and policy and curriculum development. At the level of conceptualization, not much is known about the conception of STEM education among most stakeholders. Therefore, this study pioneers the in-depth conceptualization and theorization of STEM education as it reflects the Zambian context. The study investigated key stakeholders' understanding of STEM, therefore, brings to the fore and shapes the meaning of STEM education among the local population.

At the levels of practice and implementation, this study not only informs the general practice of STEM but also inspires and guides classroom practices and implementation among STEM practitioners. Two unanswered questions have been answered by this study: (a) how does STEM education look like in the Zambian classroom context? (b) how do teachers implement STEM education in a lesson unit? The significance of this study is that it answers these questions by informing and inspiring STEM classroom practices – teaching and learning.

At the levels of policy and curriculum development, this study informs policy and curriculum development in the country. One of the challenges that the Zambian education system faces is the lack of home-grown or locally formulated policies and curricula. To this day, Zambia largely relies on educational policies and curricula left by the colonial systems. The significance of this study is that it closes that loophole by providing home-grown solutions to the problem of curriculum and policy development. In other words, the study provides STEM practitioners with relevant tools for indigenizing STEM policies and curricula.

Ultimately and given that this study is one of its first kind, it informs future research in STEM. It lays the foundation upon which future studies in STEM can be conducted. This study has provoked more topics to be pursued in the future. Topics such as the significance of STEM education to the Zambian economy, the relevance of the Zambian indigenous knowledge system in the study of STEM education, STEM education in early childhood, and many more.

Delimitations

This study aimed at investigating the perceptions of STEM education: STEM vision, STEM definition, STEM purpose, STEM relevance, and STEM teaching and learning held by STEM teachers, STEM administrators, and STEM policymakers. The study was focused on knowing what STEM stakeholders thought and knew about STEM in the country. The study was conducted in Zambian STEM schools and institutions because they had first-hand experience and information about STEM implementation in the country. Using a mixed methods design, the study recruited 20 teachers, 10 administrators, and 10 policymakers. All 40 respondents participated in the survey and only 15 of the 40 were interviewed. The study was conducted at the end of the third school term of the year 2022.

Given that this study was conducted at a time when the initial STEM implementation process was on hold, the study did not intend to evaluate the initial STEM implementation process. The study did not intend to investigate the reasons why STEM implementation failed to take off as intended. Regardless of the stage at which the implementation process was, the study was only limited to exploring stakeholders' perceptions of STEM education in the country. This study was not an evaluation to assess what went wrong in the implementation process from the time it started. Rather, it was only concerned about what stakeholders thought and knew about STEM education in the country.

Positionality Statement

I am not a STEM major. However, I have found myself teaching math and science in four African countries for several years. My passion for STEM-related subjects and especially their applicability dates back to my primary and secondary school days. I have come to understand that STEM-based teaching and learning go beyond teaching math, science, technology, or engineering concepts. It focuses on hands-on learning with real-life applications that help to develop competencies necessary for survival. This is important in developing countries like Zambia where formal and white collar jobs are scarce. With competencies and skills acquired through STEM, there is a likelihood that one can lead a comfortable life without formal employment. STEM skill sets make someone self-employable.

Thus, my personal view of STEM in the context of Zambia is not merely integrating or combining the four STEM domains. Rather, it is strengthening and improving individual STEM domains. One of the challenges we face in the Zambian education system is that STEM disciplines receive less attention. STEM domains are the less passed subjects in schools because of several factors. First of all, few learners are interested in STEM subjects. This makes it even more difficult to have many STEM teachers because there are few STEM majors who would eventually become STEM teachers. Second, technology and engineering subjects are almost non-existent in schools. Mostly, when we talk about STEM in the Zambian context, we are referring to math and science. With these difficulties, it becomes even more challenging to talk about STEM as a whole. This can only happen if individual STEM disciplines are strengthened and improved. If individual STEM subjects are strengthened and improved, only then can we genuinely talk about authentic STEM education in Zambia. In my view, therefore, STEM education in Zambia should focus on improving individual STEM subjects while seeking meaningful and relevant overlaps between, across, and among STEM discipline concepts.

Definition of Terms

Fourth Industrial Revolution

Also known as the 4IR and industrial 4.0, the fourth industrial revolution succeeded the third industrial revolution. It describes the era of time which is characterized by the fusion of advances in the internet of things, genetic engineering, quantum computing, artificial intelligence, robotics, 3D printing, automation, neuro and nanotechnologies, machine-to-machine interaction, machine-to-human interaction, and other smart technologies. It describes the fusion of these technologies and their interaction across the physical, digital, and biological domains (Schwab, 2016).

STEM Education

An interdisciplinary approach to teaching and learning. It entails the intentional, meaningful, and relevant integration of science, technology, engineering, and mathematics, and their associated practices to create a student-centered learning atmosphere in which students explore and engineer solutions to real-world problems, and construct evidence-based explanations of real-world phenomena with a focus on a student's social, emotional, physical, and academic needs through shared contributions of all stakeholders (Honey et al., 2014).

Science: "the study of the natural world, including the laws of nature associated with physics, chemistry, and biology and the treatment or application of facts, principles, concepts, or conventions associated with these disciplines. Science is both a body of knowledge that has been accumulated over time and a process—

scientific inquiry—that generates new knowledge. Knowledge from science informs the engineering design process” (Honey et al., 2014, p. 14)

Technology: tools that have been designed by humans to meet human needs. While not a discipline in the strictest sense, [technology] comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves” (Honey et al., 2014, p.14).

Engineering: a body of knowledge about the design and creation of human-made products and a process for solving problems. Engineering utilizes concepts in science and mathematics as well as technological tools (Honey et at., 2014).

Mathematics: the study of numbers, symbolic relationships, patterns, shapes, uncertainty & reasoning.

STEM Literacy

STEM literacy includes the conceptual understanding and procedural skills and abilities for individuals to address STEM-related personal, social, and global issues. STEM literacy involves the integration of STEM disciplines and four interrelated and complementary components. According to Bybee (2010), STEM literacy refers to the following:

- Acquiring scientific, technological, engineering, and mathematical knowledge and using that knowledge to identify issues, acquire new knowledge, and apply the knowledge to STEM-related issues.

- Understanding the characteristic features of STEM disciplines as forms of human endeavors that include the processes of inquiry, design, and analysis.
- Recognizing how STEM disciplines shape our material, intellectual, and cultural world.
- Engaging in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as concerned, effective, and constructive citizens.

CHAPTER II

REVIEW OF LITERATURE AND FRAMEWORK

There is very little empirical and academic literature about STEM education in Zambia except for a handful of non-peer-reviewed journal papers, blogs, news items, and government reports. Therefore, the literature to be reviewed in this study will come from all over the world. I have chosen to review the literature from around the world to inform the Zambian situation. World literature on STEM will help enlighten the Zambian situation by bringing out the main themes and trends in STEM education around the world. With regard to Zambian literature, I will mostly review government official reports and policy documents about STEM in the country.

Conceptualization of STEM Education

A Google Scholar engine search shows that STEM education is one of the most researched and published topics in education in the recent past. Since its introduction to the educational scene, the concept of STEM education has drawn enormous attention from all over the world. In the past two decades, STEM education has become a buzz concept trending in schools, media houses, government and non-government organizations, and other educational institutions. In almost all countries, governments' educational initiatives, policies, curricula, and legislative reforms have been dominated by STEM education (Freeman et al., 2015). This is confirmed by English (2016) when she argues that:

> International concerns for advancing STEM education have escalated in recent years and show no signs of abating. Educators, policy developers, and business and industry organizations, to name a few, are highlighting the urgency for improving STEM skills to meet current and future social and economic challenges. The almost universal preoccupation with STEM education in shaping innovation and development is evident in numerous reports (p. 1).

STEM's introduction dates to the late 1990s at the National Science Foundation (NSF) of the United State Department of Education (Bybee, 2013; Gulen, 2019; NSF, 2001; Yildirim & Selvi, 2015). By then, the term was known as SMET for science, math, engineering, and technology. However, SMET sounded like "smut", and the acronym was changed to STEM for science, technology, engineering, and mathematics. At that time, the concept was overly used to describe different NSF STEM programs and initiatives. Thus, STEM education was born in quite a simple yet functional origin (Batdi et al., 2019; Bybee, 2010; English, 2016; Holmund et al., 2018; Ortiz-Revilla et al., 2020; Sanders, 2009; Vasquez, 2014).

When STEM initially appeared on the educational scene in the early 2000s, it was confused with stem cells in multicellular organisms. In his testimony, Sanders (2009), says that as recently as 2005, relatively few people knew what STEM meant. Many people at that time asked if STEM education had something to do with stem cell research. However, when STEM eventually took root in education, it spread like wildfire across the globe and has ever since received accelerated prioritization. Since then, the concept has been adopted by many governments and there has been growing global interest in the concept because of the interdisciplinary, multidisciplinary, and transdisciplinary approaches it brings about to education. In Batdi et al.'s (2019) words,

> Although the introduction of STEM dates to the 1990s, it was in 2001 when the term was produced as an educational term by Judith A. Ramaley, an administrator of The National Science Foundation, and since then, it has become widespread rapidly. The increasing importance of STEM education is due to the interdisciplinary interaction it incorporates (p. 383).

According to Yildrim and Selvi (2015), since STEM was introduced at the National Science Foundation, it has been welcomed in many countries and has become a vital subject for researchers.

> Many countries tried and are still seeking to improve the quality of the education given in subjects such as science, technology engineering, and mathematics. Countries developed different methods, ways, and projects to increase the number of well-educated people in these areas and started competing among themselves (Yildrim & Selvi, 2015, p. 1117).

In the last decade alone, a lot has been written and published about STEM education with numerous research journals dedicated to its disciplines.

Despite the increased global and local STEM consciousness, there is still so much disagreement on the conceptualization of STEM education let alone what it means and how it should be applied in a classroom context. According to Ievers and McGeown (2020), despite the increased international investment in STEM education, there is still ambiguity around the exact meaning of STEM education, and confusion remains surrounding its effective implementation. With so many reports and studies that have been conducted on STEM, there is still a lack of a coherent and unified conceptualization of STEM education. Mpofu (2020), sums it up “in most nations, educators lack a cohesive understanding of STEM education and are also deprived of an easy-to-understand STEM education framework that informs classroom practices” (p. 1). Several authors agree that despite the increased attention to STEM in funding, policy, legislature, report, and research arenas, there remains some uncertainty about STEM, the individual subjects, the combination of the subjects, and even what constitutes STEM (Honey et al., 2014; Kelley & Knowles, 2016; Tippett & Milford, 2017). In Sgro’s et al. (2020) words, “one issue surrounding contemporary STEM education is the ambiguity of what constitutes a “STEM” lesson. This ambiguity is in part due to STEM being comprised of four related but distinct fields” (p. 185).

The major problems around STEM education have their origin in the definition itself. Depending on where one goes to seek an answer to the question, “what is STEM education?” answers may differ greatly. For instance, some responses have come from policy perspectives, others from legal perspectives, others from an educational perspective, and others still from out-of-class practice perspectives. A study by Martin-Paez et al. (2018), revealed inconsistencies in STEM language and a lack of definition of STEM terms. Of the articles that they reviewed, 55% failed to explain a single STEM concept. Those that attempted to define STEM concepts used a variety of terms for clarifying the nature of STEM education. They found studies that used concepts such as STEM curriculum, STEM literacy, STEM subject, STEM identity, STEM learning, STEM teaching, and STEM integration to refer to and/or complement the concept of STEM education.

Of the over 80 studies I reviewed for this paper, there is not much agreement or consensus about the definition of STEM and what STEM should constitute (Asunda, 2014; Balka, 2011; Breiner et al., 2012; Bybee, 2010; Deniz et al., 2021; Falloon et al., 2020). A report by the U.S. Department of Education found 105 STEM education programs that experienced frequent programmatic changes with differing definitions of what constitutes STEM curriculums and programs in addition to multiple program goals (U.S. Department of Education, 2007). Deniz et al. (2021), and Bybee (2013) share similar sentiments about the conceptualization of STEM. They point out that even STEM professionals do not have a clear understanding of STEM. They suggest that the meaning of STEM is somewhat ambiguous, and it may vary across different educational settings. It may mean different things to different people at different times. For Bybee (2013), STEM has become the newest slogan in town, and yet critics have noted its ambiguous and ubiquitous use. Sanders (2009) even goes further to argue that STEM is often an ambiguous acronym, even to those who use it.

Another study by Radloff and Guzey (2016) about pre-service teachers' conception of STEM revealed high variations in the conception of STEM education from the 159 participants. The variations were grouped into four categories: instruction, integration, exclusion, and discipline. Even among these categories, there were high variations. In another study by Breiner et al. (2012), 222 participants (faculty) responded to an open-ended question "what is STEM?" The results of the study showed that:

> Although 72% of these faculty members possessed a relevant conception of STEM, the results suggest that they do not share a common conceptualization of STEM. Their conception is most likely based on their academic discipline or how STEM impacts their daily lives (p. 3).

Some authors have also argued that although it is not necessary, or even possible, to coalesce around one common definition of STEM education, the lack of a shared conception or understanding of STEM has sometimes caused difficulties in designing, developing, and implementing a STEM curriculum and instruction to foster successful STEM learning of all learners (Holmlund, 2018).

It must be noted however that, despite the disagreement about the definition of STEM, various broad definitions of STEM education emerge in the literature and policy documents that most authors have appealed to (English, 2016) According to Roehrig (2021):

> Various broad definitions of integrated STEM education exist in the literature and policy documents. For example, Moore, Stohlmann, and colleagues (2014) defined integrated STEM education as “an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems” (p. 38). Similarly, Kelley and Knowles (2016) defined integrated STEM as “the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning (pp. 1-2).

Some authors have simply taken STEM education as separate and distinct S.T.E.M school subjects, teaching each individual subject separately (National Research Council, 2014). The disciplinary approach to STEM takes this path where students learn concepts and skills separately in each discipline (Vasquez, 2013).

Others have proposed that STEM education entails the interaction and integration of two or more STEM subjects. For instance, Kelley and Knowles (2016) defined integrated STEM as “the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning” (p. 3). Similarly, Sanders (2009), argues that “our notion of integrative STEM education includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects” (p. 21).

The other school of thought advocates for a combination and integration of all four STEM disciplines to come up with a single STEM class unit (Burrows et al., 2018; Chandan et al., 2019). Moore et al. (2014), for instance, describe STEM education as “an effort to combine some or all of the four disciplines of [STEM] into one class, unit, or lesson that is based on connections between the subjects and real-world problems” (p. 38). Burrows et al. (2018) acknowledge the power that belongs to the integration of the four disciplines when they argued that “studies show that true integration of the four disciplines is a powerful student learning tool” (p. 1). Tippett and Milford (2017), sum up these schools of thought when they argued that:

> There is imprecision in the usage of the acronym itself; STEM may refer to any one of the four individual disciplines, it might denote the integration of all four disciplines, and occasionally, it denotes the combination of two or more of the individual disciplines (p. 68).

A common trend across all conceptualizations and definitions of STEM is the idea of integration, combining, and making intentional, purposefully, meaningful, and relevant connections between/across/among STEM disciplines in a real-world context to contextualize student learning and solve real-world problems (Kelley & Knowles, 2016). Thus, "the modern definition of STEM education includes the notion of integration by emphasizing logical and conceptual connections across different STEM fields, meaning that STEM is the purposeful integration of the various discipline" (de Melo Bezerra, 2018, p. 313). This is a purposeful and meaningful integration of STEM disciplines as used in solving real-world problems. This STEM perspective involves viewing the distinct STEM disciplines as one unit, thus teaching the integrated disciplines as one cohesive entity. Table 1 presents a comprehensive list of some common definitions of STEM that exist in literature and policy documents.

Table 1

Some STEM Definitions Found in Literature and Policy Documents

Author(s)	**Definition**
fldoe.org	❖ STEM education is the intentional integration of science, technology, engineering, and mathematics, and their associated practices to create a student-centered learning environment in which students investigate and engineer solutions to problems,

		and construct evidence-based explanations of real-world phenomena with a focus on a student's social, emotional, physical, and academic needs through shared contributions of schools, families, and community partners.
Wang et al. (2011)	❖	Therefore, teaching STEM disciplines through integrating them would be more in line with the nature of STEM. As the nature of STEM is an integration of the four subjects, science, technology, engineering, and mathematics, many questions remain indistinct in K-12 STEM education (pp. 1-2).
Walkington et al. (2014)	❖	STEM integration is the intentional integration of content and processes of science or mathematics education with the content and processes of technology or engineering education along with explicit attention to technology or engineering learning outcomes and science or mathematics learning outcomes as behavioural learning objectives (p. 185).
Dalton (2020)	❖	At its core, STEM is a teaching philosophy that integrates all four disciplines together into a single, cross-disciplinary program which offers instruction in real-world (as opposed to purely academic) applications and teaching methods.
	❖	As a philosophy, STEM is meant to create a program that integrates all four disciplines in a way that forces the student to use cross-disciplinary knowledge to solve problems.

Batdi et al. (2019)	❖	STEM can be defined as an education approach in which an integrated education involving the knowledge and skills of four disciplines and in which equipping students with cooperation, systematic thinking, effective communication, research and questioning, creative thinking and problem solving skills, are aimed at (p. 382)
de Melo Bezerra et al. (2018)	❖	The modern definition of STEM education includes the notion of integration by emphasizing logical and conceptual connections across different STEM fields, meaning that STEM is the purposeful integration of the various disciplines as used in solving real-world problems.
	❖	Moreover, STEM education is multi-faceted and goes beyond by supporting the developing of curiosity, inquisitiveness, critical-thinking, innovation and problem-solving capacities (p. 313).
Falloon et al. (2020)	❖	However, reasonable agreement exists that STEM education should have as a principal aim the development of Science, Technology, Engineering and Mathematics concepts, knowledge and process understandings, 'through efforts to combine some or all of the four disciplines into one class, unit or lesson that is based on connections between subjects and real world problems (p. 370).

Holmlund (2018)	❖	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 (p. 2).
Brown et al. (2011)	❖	However, STEM education has been defined as "a standards-based, meta-discipline residing at the school level where all teachers, especially science, technology, engineering, and mathematics (STEM) teachers, teach an integrated approach to teaching and learning, where discipline-specific content is not divided, but addressed and treated as one dynamic, fluid study" (Merrill, 2009) (p. 6).
Bybee (2010)	❖	STEM could mean an integrated curricular approach to studying grand challenges of our era. I am referring to challenges such as: energy efficiency, resource use, environmental quality, and hazard mitigation. The competencies that citizens need in order to understand and address issues such as these are clearly related to the STEM disciplines, which should be understood before addressing other disciplines such as economics and politics (p. 31).

Sanders (2009)	❖	Our notion of integrative STEM education includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects. Just as technological endeavor, for example, cannot be separated from social and aesthetic contexts, neither should the study of technology be disconnected from the study of the social studies, arts, and humanities (p. 21).
Moore et al. (2014)	❖	An effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems” (p. 38).
Kelley and Knowles (2016)	❖	We, however, define integrated STEM education as the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning (p. 3).
Tippett and Milford (2017)	❖	STEM may refer to any one of the four individual disciplines, it might denote the integration of all four disciplines, and occasionally, it denotes the combination of two or more of the individual disciplines (p. 68).

National Science Teaching Association (2020)	❖ provides students with an interdisciplinary approach to learning. ❖ STEM education makes learning “real” and gives students opportunities to see the connection between the content they are studying and the application of that content in authentic and relevant ways. ❖ STEM education is an experiential learning pedagogy in which the application of knowledge and skills are integrated through in-context projects or problems focused on learning outcomes tied to the development of important college and career readiness proficiencies. ❖ Stem education is not a single subject nor is it a curriculum, rather, it is a methodology of organizing and delivering instruction. ❖ STEM education enables analytical and critical thinkers; increases science, mathematics, and technology literacy; fosters the next generation of innovators and entrepreneurs; provides opportunities for students to engage in 21st century skills of teamwork, collaboration, problem solving, communication, and creative thinking; and offers learning experiences in which students apply what they are learning in relevant, meaningful ways.

STEM Classroom Practices

Another gray area of STEM education is classroom practice (Mpofu, 2020; Thibaut et al., 2018). Srikoom et al. (2018), qualify this gray area when they argue that "while there is widespread agreement about the importance of STEM, it remains an ambiguous term, particularly in education. We know little about what integrated STEM instruction looks like in the classroom, and how teachers conceptualize and implement integrated STEM" (p. 313). The question that begs the answer here is how does a STEM lesson look like in a classroom? Or, what constitutes a STEM unit lesson? Holmlund (2018) asks the same question differently, "but what does it mean, at the classroom level, to implement STEM education?" (p. 2). These questions arise because there is no single answer or any agreement about how STEM education must be integrated into a classroom (Srikoom et al., 2018). According to Mpofu (2020):

> Despite the increasing attention to STEM education worldwide, its stakeholders in particular educational institution managers and classroom practitioners are still grappling to come to terms with what constitutes STEM education and how it can move to classroom settings. No clear-cut answer to these issues can be discerned in the literature and discourses among STEM-related communities of practice (p. 2).

For Thibaut (2018), the implementation of STEM education is proving to be difficult because of the lack of consensus about instructional practices in integrated STEM.

Amidst the lack of a cohesive and shared understanding of STEM classroom practices, several pedagogical approaches, themes, characteristics, understandings, and practices about STEM have emerged in the literature. Pedagogically, STEM approaches seek to eliminate the traditional barriers of separating the four domains of STEM by introducing approaches that encourage connectivity, inquiry, exploration, discovery, and experimentation among learners (Vasquez et al., 2013; Wang et al., 2011). These are integrative approaches that come in the form of interdependence, disciplinary, multidisciplinary, interdisciplinary, transdisciplinary, interconnectedness, and combination of the STEM subjects, which is essential to the implementation of STEM as a “meta-discipline” (Vasquez, 2014). Of these integrative approaches, the interdisciplinary approach has been the most identified in the literature (Asunda, 2014; Ciftci et al., 2020; Falloon, et al., 2020; Mohr-Schroeder, 2020; Moore et al., 2020; Roehrig et al., 2021). Batdi (2019) could not have put it better when he argued that there are different approaches to STEM in the literature. However, the common ground of these approaches is that STEM is an interdisciplinary approach and is used in a real-life context. Srikoom et al. (2018) express this point even better when they point out that:

> While definitions vary, however, there are areas of commonality. For example, most definitions include descriptions of 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 and community (p. 313).

Interdisciplinary approach to STEM is where “students learn concepts and skill from two or more disciplines that are tightly linked so as to deepen knowledge and skills” (Vasquez et al., 2013).

These integrative approaches further seek to eliminate the conventional teacher and lecture-based pedagogies replacing them with learner-centered and inquiry-based pedagogies. The learner-centered pedagogies use problem-based and project-based strategies to produce results. There is overwhelming evidence from the literature that problem-based and project-based pedagogies are regarded as appropriate approaches to teaching and learning STEM education (Han, 2013). Problem-based and project-based are sister approaches to educational instruction where students work on an open-ended assignment or authentic question to solve real-life challenges. In problem-based learning, learners are presented with clearly defined complex and authentic real-life problems where they are required to devise a real-life solution. In project-based learning, learners are actively engaged to produce an artifact to demonstrate their mastery of the content area. Both approaches are learner-centered and inquiry-based that promote skills and competencies such as critical thinking, problem-solving, collaboration, and communication. STEM education classroom practices use these approaches in a classroom context. A cross-sectional analysis of different countries around the world reveals that "within the best practice of STEM education, there has been a significant development of inquiry-based learning, which conflicts with traditional mechanisms of high-stakes testing to be found elsewhere" (Ievers et al., 2020; Kearney, 2016). Fomunyam (2020), observed that in recent years, research on STEM education has revealed that many pedagogical approaches and strategies are used by teachers when teaching STEM disciplines in schools. These approaches are largely learner-centered. These are outcome-based approaches aimed at solving real-world problems.

International Trends in STEM Education

The introduction of the concept of STEM on the educational scene has drawn attention from all over the world. STEM education has been trending on the world map since its inception. Almost all countries in the world today are in one way or another involved with STEM education (English, 2016). The literature agrees that since STEM education came to the fore, there have been worldwide initiatives and efforts to implement it around the global (Asanda, 2014; Baldi et al., 2019; Ciftci et al., 2020; English, 2016; Falloon et al., 2020; Kanadli, 2019; Mohr-Schroeder et al., 2020; Roehrig 2021). It would not be an exaggeration to argue that in the past two decades, the acronym STEM has been at the forefront of many government education initiatives and efforts (English 2016; Freeman et al., 2015; Holmlund, 2018; ICASE, 2013; Ievers & McGeown, 2020; Kearney, 2016; McDonald, 2016; Mpofu, 2020; Kelley et al., 2021). McDonald (2016) argues that recent global education initiatives and reforms have focused on increasing the number of students pursuing STEM subjects, and ensuring students are well-prepared and suitably qualified to engage in STEM careers. STEM is a major emphasis in global initiatives seeking to enhance economic prosperity via a highly educated workforce. As a result, many countries have made considerable investments in STEM education initiatives largely driven by fears that the future may lack qualified STEM professionals. The conference held by the International Council of Association for Science Education (ICASE) in Kuching Malaysia in 2013 represented by several countries reinforced this point when it decreed that “we, the conference participants from

34 countries, believe that science and technology education at all levels should prepare students for their future lives as global citizens" (ICASE, 2013).

While each country may have its own trajectory of STEM reforms, some similar patterns, practices, and initiatives can be observed in several countries. Some of the similarities that can be observed in several countries include the emphasis on equipping learners with 21st life skills, competencies, and knowledge; the ability to address complex, authentic, or real-world problems; the emphasis on student-centered teaching strategies of learning, and content integration; only to name a few. These similarities as well as the differences in curriculum reform between different countries demonstrate a wider complexity of STEM curriculum reform, which concerns the interplay of global and local influences. Curriculum reform is meant to be a local or national affair, as it is expected to reflect and define local context, knowledge, pedagogies, and abilities that are seen to be most relevant in society and essential in preparing future generations. Having said this, it cannot be denied that curriculum reform can also be influenced by global trends, such as migration, globalization, and internationalization (Gouedard, 2020).

This global consciousness towards STEM is widely witnessed through the release of national STEM policy documents worldwide (Australian Curriculum, Assessment, and Reporting Authority, 2016; European Commission, 2015; Hong, 2017; National Research Council (NRC), 2012; Sengupta & Shanahan, 2017). Research has shown that many countries worldwide have established policies and legal frameworks to guide the teaching and learning of STEM (Honey et al., 2014; Navy et al., 2020). According to Freeman et al. (2015), these policies vary in terms of focus, target, level of education, and other associated matters. They are frequently expressed in terms of human capital and are aimed at fostering the STEM labor market and consequent economic outlook for the respective countries.

Many driving factors have sparked the urgent emergency of STEM education worldwide. The frequent recurring ones in the literature include economic global competitiveness (Beede et al., 2011; Breiner, 2012; de Melo Bezerra, 2018; Thibaut et al., 2018; Kelley et al., 2021), training future STEM workforce (Asanda, 2014; de Melo Bezerra, 2018; Holmlund, 2018; Ievers et al., 2020; Kanadli, 2019), imparting 21st century skills and competencies to future generations (Badti et al., 2019; Bybee, 2010; Mpofu, 2020; National Science Teaching Association (NSTA), 2020; Sahin et al., 2014; Kelley et al., 2021), and to meet the challenges of our time (Asanda, 2014; Bybee, 2010; Ciftci et al., 2020; English, 2016; Fomunyam, 2020; Gouedard, 2018; NSTA, 2020; Mpofu, 2020); to build STEM literacy.

The first is economic global competitiveness. Economic global competitiveness is one of the major driving forces that has compelled many countries, especially developed countries to adopt STEM education. It is evident from many studies that STEM disciplines are strong drivers of competitive national economies (Breiner, 2012; Beede et al., 2011; de Melo Bezerra, 2018; Thibaut et al., 2018; Kelley et al., 2021). This is why throughout the world, many countries are urgently investing in STEM education hoping to groom innovative mindsets to spearhead the development and sustainable growth of their economies (Mpofu, 2020). For fear of falling behind in terms of STEM disciplines, many countries have embarked on pushing for graduating more students in STEM to maintain their economic strongholds and positions in the world. According to Breiner et al. (2012), de Melo Bezerra et al. (2018), and Beede et al. (2011), many countries have adopted STEM as an important focus for renewed global competitiveness. STEM workforce is essential for countries to increase innovation and in return meet economic needs and reach global competitiveness. As evidenced in our societies today, countries' economies are becoming more and more knowledge-based and multifaceted (Asanda, 2012; Ciftci et al., 2020). Therefore, STEM education has been identified as one of the forces that can contain knowledge-based and multifaceted economies. In qualifying this position, Thibaut et al. (2018), argue that "qualified STEM professionals are needed to remain economically competitive in the global market and to fill contemporary demands such as ensuring sufficient and sustainable energy, efficient healthcare, and well-considered technology development" (p. 1).

Another driving factor that has sparked the urgent emergency of STEM education across the globe is the need to train a qualified STEM future workforce. One of the goals of STEM education is to strengthen and expand a STEM-related workforce (Holmlund, 2018; Kanadli, 2019). This is because there is a projection that future jobs, be they STEM-related or non-STEM-related, will require at least someone with STEM skills and knowledge. In the U.S. for example, the 2013 report from the Committee on STEM Education stressed that "the jobs of the future are STEM jobs, with STEM competencies increasingly required not only within but also outside of specific STEM occupations" (English, 2016, p. 1). In the past decade alone, STEM jobs grew three times more than non-STEM jobs (Ciftci et al., 2020). This trajectory is poisoned to continue in the future.

The U.S Bureau of Labor Statistics (2021), reports that between 2020 and 2030, STEM-related occupations are projected to grow by 10.5% compared to 7.5% for non-STEM occupations. It also lists median annual wages of $89,780 for STEM jobs compared to $40,020 for all jobs. This will require more STEM workforce to occupy these jobs. As Gouedard et al. (2020), rightly put it, "countries have increasingly considered reviewing the curriculum as a way to equip children with the knowledge, skills, and competencies needed for tomorrow" (p. 7).

Another driving factor that has sparked the urgent emergency of STEM education worldwide is the need to equip learners with 21st century skills and competencies so as to meet the challenges of our time. According to the National Science Board (US) (2007):

> In the 21st century, scientific and technological innovations have become increasingly important as we face the benefits and challenges of both globalization and a knowledge-based economy. To succeed in this new information-based and highly technological society, all students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past. A particular need exists for an increased emphasis on technology and engineering at all levels in our Nation's education system (p. 2).

For starters, the 21st century is faced with complex and multifaceted challenges be they economic, ecological, scientific, health-related, or sociocultural (OECD, 2018). "Climate change and the depletion of resources question our consumption habits, the development of artificial intelligence and new technologies challenge our traditional conception of work, and ongoing globalization entails migration, urbanization, and increasing diversity shaping countries and economies" (Gouedard, 2020, p. 7). With these new trends, if education continues to be approached the way it was years back, it will not be able to prepare young people to face these challenges. The 21st century challenges, require the integration of multiple STEM concepts (Wang et al., 2011) to provide a new kind of skill set to be able to navigate the 21st century terrain. Because of these global trends, many countries worldwide have increasingly considered reforming their curriculum as a way to equip young people with 21st century skills, competencies, and knowledge needed for the future (Gouedard, 2020; OECD, 2018). For example, more than 40 member countries of the OECD, launched *The Future of Education and Skills 2030 Project* in an effort to explore competencies and skills that are needed for students to thrive in the 21st century. Similarly, to attain the 4th sustainable development goal (SDG), many United Nations member countries have turned to STEM education for 21st century skills and competencies. Most studies agree on 21st century skills that students need to navigate the challenges of our time. These skills include critical thinking, imagining, entrepreneurship, discovering, problem-solving, analytical thinking, creative thinking, collaboration, teamwork, and communication.

STEM education has become desirable such that some practitioners are beginning to build an entirely new STEM literacy (Balka, 2011; Mohr-Schroeder, 2020). STEM literacy is a new phenomenon and has not yet been well defined, but literature has demonstrated that it is gaining traction so fast in many countries (Deniz et al., 2021; Falloon et al., 2020; Gonzalez & Kuenzi, 2012; McDonald, 2016; Zollman, 2012). Traditionally, literacy has been thought of as the ability to read and write. STEM literacy goes beyond the traditional understanding of merely reading and writing by embracing the idea that “STEM literacy is the ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and to innovate to solve them” (Balka, 2011, p. 7). Many countries have sought to build a new kind of literacy that seeks not only to understand individual STEM disciplines' literacy but also an integrated and cross-sectional STEM literacy.

Significance of STEM Education to the 21st Century

If there is one thing about STEM that most studies agree upon is its importance in the 21st century. Surprisingly, studies may not agree on the conceptualization of STEM, its definition, implementation, and what it constitutes, but they largely agree on its significance and relevance in equipping learners with the skills, competencies, and knowledge required to survive the challenges of our time. Numerous studies conducted in many countries have underscored the significant role of STEM in developing human capital in areas important to a nation’s global competitiveness and prosperity (Kayan-Fadlelmula et al., 2022). STEM skills are imperative to navigate or respond to the demands and forces of the 4IR. STEM has been identified as one of the appropriate approaches to teaching and learning in our time. According to Fomunyam (2020):

> Today’s educational system is tasked with preparing this generation and the next to thrive in the face of these projections that would change the world, and STEM education is the answer. A relationship between STEM education and 4IR should be fostered so as to produce scholars with twenty-first-century skills that can solve real-life problems such as collaboration skills, communication skills, critical

> thinking skills, problem-solving skills, and all-around creativity. To achieve this, STEM education must be fully integrated into the school curriculum such that regardless of the course of study, each individual is prepared for the future workplace (p. 4).

Internationally, the emphasis on STEM education is recognized as embedded in solutions to many societal problems like the depletion of natural resources and issues related to climate change. The recognition of STEM disciplines as economic drivers motivated the initiation of STEM education in both developed and developing nations. This is based on the thinking that effective STEM education is a vehicle for developing in students the much desired 21st century competencies (Mpofu, 2020).

In the times that countries' economies are becoming more and more knowledge and information-based, STEM education becomes the vehicle to drive future economies. According to Mataka and Sikapizye (2020), STEM subjects are also critical in transforming the economies of countries from natural resource-based to knowledge-based ones. The US National Science Board (2007) articulates this point even better.

> In the 21st century, scientific and technological innovations have become increasingly important as we face the benefits and challenges of both globalization and a knowledge-based economy. To succeed in this new information-based and highly technological society, all students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past. As mentioned earlier, future jobs are STEM jobs. Even jobs outside STEM fields will depend heavily on STEM literacy. Therefore, all citizens must

> have basic STEM literacy in order to be full and active participants in our increasingly technology-based democracy (National Science Board, 2007).

Overall, STEM is important to the 21st century because it provides skills that make people employable today, it enhances teamwork and communication, it provides sustainable solutions to today's challenges, and it teaches critical thinking and innovation.

Most importantly, the significance of STEM in the early years of a person's learning cannot be overemphasized. Several studies have demonstrated that STEM plays a critical role in enhancing student academic performance, especially in early childhood education (ECE) (Simoncini & Lasen, 2018). The significance of STEM in ECE is supported by neuroscience research findings, that, the early experiences of young people, play a critical role in their brain architecture (Sripada, 2012). The quality of young people's learning environments and experiences at an early age influences later academic success and future life achievement (Tippett & Milford, 2017). Early experiences in STEM increase the chances that young people would be successful in STEM-related subjects. According to Kermani and Aldemir (2015), young learners' attitudes toward scientific concepts are essentially developed at an early age in their education, such that it becomes difficult to change when they grow older. Similarly, early mathematics knowledge in young people becomes a stronger predictor of their future skills of critical thinking, comprehension, understanding, and problem-solving. Further still, early technological skills help children in inquiry-based learning, giving them early strong cognitive development, focused attention, and collaborative skills. And finally, early engineering knowledge imparts to young people math and science concepts as well as technological skills.

Overall, early knowledge in STEM becomes a strong predictor of young people's future ability in problem-solving, and analytical thinking, and provides them with well-rounded cognitive development. In one of their studies, Kermani and Aldemir (2015) and Tippett and Milford (2017) found that implementing a vigorous early childhood education curriculum focusing on STEM subjects could bring a positive change in children's overall performance in these subject areas.

Gaps in STEM Literature

One of the major gaps I have identified in STEM literature is the lack of unified and comprehensive conceptual and theoretical perspectives to ground STEM research. Of all the literature that I have reviewed for this study, there is little mention of a theoretical or conceptual framework. Bussey et al. (2020), "observed that research published in various fields in STEM education utilizes a broad range of stated theoretical frameworks. However, there does not seem to be a single set of theoretical frameworks from which all STEM education research is conducted" (p. 52). Almost a decade ago, Asunda (2014) observed that most school districts had not put in place curricula and standard frameworks to guide STEM teaching and learning.

> Additionally, states had no consensus on what key STEM concepts students should master and whether those concepts should be included in the curriculum at a certain grade level or within a specific content area. Likewise, state assessments of student achievement vary widely (National Science Board, 2007, p. 5).

Interestingly, individual STEM disciplines have longstanding and well-defined theoretical frameworks that guide research studies in those respective disciplines. For example, “deductive reasoning in mathematics, design thinking in engineering, inquiry in the sciences, and computational thinking in the fields of technology” (Glancy & Moore, 2013, p. 16). This does not seem to be the case with STEM as a unit. There are a lot of STEM studies in the recent past, and yet, there are no agreements in most of these studies about the theoretical perspectives to guide STEM research. Researchers have argued that there is a continuing need to clearly define a theoretical framework for STEM integration that may be the basis for comprehension of curricular and classroom practices (Martin-Paez, 2019; Bussey et al., 2020).

STEM Education in Zambia

Overview

In recent years, the Zambian education system has experienced widespread attention and prioritization of STEM education in public schools (Mwale et al., 2020). This is witnessed in growing attention to STEM in the areas of policy and legal framework settings, curriculum reforms, and other STEM activities and initiatives across the country (Ministry of Education, 2013). However, it must be noted that despite the growing attention and prioritization of STEM education, very little is written about STEM education in the country to support its applicability. The Google engine search and other available research methods about STEM in Zambia yield very little. There is only a handful of official government reports on STEM in Zambia and a few studies. The few studies do not delve into the nature, scope, and practicability of STEM. They merely consider areas such as leadership in STEM (Mwale et al., 2020), teachers' preparedness, and the effect of Covid 19 on STEM (Sintema, 2020). Due to the lack of empirical and academic studies in STEM education, the literature review in this section will take a different approach. I will review the historical development of STEM education in the country. I will further review official government reports and policy documents about STEM education in the country.

Depending on how far back one may want to go, early efforts to implement STEM subjects in the country can be traced to the 1990s. Since then, the government has put in place legal and policy frameworks to govern and guide the teaching and learning of STEM subjects in learning institutions. Some of the major policy frameworks that the government has put in place include the National Policy on Education of 1996, the National Science and Technology Policy of 1996, the Zambia Education Curriculum Framework of 2013, the Education and Skills Sector Plan of 2017, the National Higher Education Policy of 2018, and Vision 2030 for Zambia.

Policy Frameworks

The National Policy on Education of 1996

Despite being the third major educational policy document in the history of the country, the national policy on education of 1996 was the first to lay the foundation for teaching and learning what was to be STEM education. Among its goals, the policy was to develop analytic, innovative, creative, and constructive mindsets through the teaching and learning of science and technology in schools. In order to advance STEM subjects in schools, the policy provided for the construction of standard science laboratories in schools and universities, and to prepare competent STEM teachers. The policy held that if science, technology, and practical subjects are to be properly taught and meaningfully learned in schools, they will require not only teachers who are competent to teach these subjects but also schools that are adequately equipped and supplied with equipment and apparatus (Ministry of Education, 1996a). The policy also provided for the regulation of the conduct of the teaching of STEM subjects through the establishment of STEM focused associations such as the Zambia Association of Science Educators (ZASE) as a way of improving the delivery of STEM subjects as well as sharing experiences in the teaching profession (National Assembly of Zambia, 2020).

The National Policy on Science and Technology of 1996

Born out of the national policy on education of 1996, the national policy on science and technology of 1996 provided for the promotion of science and technology subjects in schools by making these subjects compulsory for all learners (National Assembly of Zambia, 2020). The policy began by acknowledging the important role that science and technology play in the socio-economic development of the country. The purpose of the science and technology systems was to serve individuals' socioeconomic well-being and to foster the use of natural resources to improve and enhance the quality of life among the citizens. The main goal of the policy was to "embed Science and Technology as part of the culture of the key sectors to promote competitiveness in the production of a wider range of quality goods and services" (National Assembly, 2017, p. 9). Its mission was "to promote and exploit science and technology as an instrument for developing an environmentally friendly indigenous technological capacity in sustainable socio-economic development to improve the quality of life for Zambia" (Ministry of Education, 1996b, p. 5).

The Zambia Education Curriculum Framework of 2013

The Zambia education curriculum framework of 2013 took a bold step in setting up two curriculum or career pathways – one academic and the other vocational. Both pathways emphasize STEM subjects by making science, technology, engineering, and math subjects compulsory in both primary and secondary schools (Ministry of Education, 2013).

The Education and Skills Sector Plan 2017 – 2021

The education and skills sector plan policy identified the shortage of qualified STEM teachers. According to a report of the committee on education, science, and technology for the first session of the twelfth national assembly, STEM in Zambia is faced with the biggest shortage of teachers, especially at the secondary school level. The present decline in recruitment of science teachers in Zambia is evident and stems from the low number of students with scientific backgrounds who can pursue teaching after completing secondary school (The National Assembly of Zambia, 2017). The motivation and driving thrust of the policy are grounded in the national vision as articulated in the Seventh national development plan (7NDP). The 7NDP which took a radical departure from the previous development plans identifies education as one of the critical ingredients of socioeconomic development and cultural transformation of the country. The 7NDP also emphasizes the development of a high-quality research base with a critical mass of highly qualified human resources and modern equipped infrastructure to popularize STEM subjects for promoting and creating a national culture of research and innovation (Mataka & Sikapizye, 2020). To achieve this goal, there requires a well-trained and equipped teaching force, especially in STEM subjects. As such, the policy provided for capacity building of STEM teachers to curb the persistent lack of competent STEM teachers (The Ministry of General Education & The Ministry of Higher Education, 2017).

The National Higher Education Policy of 2018

The national higher education policy of 2018 pushed for STEM education at the highest learning institutions in the country. The policy is aware of fewer students who venture into and graduate with STEM qualifications. It is noted that the number of STEM learners reduces as they progress towards college and university. Even more distressing, the number of women in STEM disciplines in higher education is very small. The policy, therefore, contains aspirations that seek to leverage STEM advancement in the provision of higher education in the country. Further still, the policy provides for reducing the gap between males and females in STEM in higher education (Ministry of Higher Education, 2019).

Vision 2030: A Prosperous Middle-Income Nation by 2030

Adopted in 2006, vision 2030 "is Zambia's first-ever written long-term plan, expressing Zambians' aspirations by the year 2030. It articulates possible long-term alternative development policy scenarios at different points which would contribute to the attainment of the desirable social-economic indicators by the year 2030" (Ministry of National Planning, 2006, p. 6). The goal of the policy is to make Zambia become a prosperous middle-income nation by 2030. To achieve this goal, the policy focuses on industrialization and diversification. The policy acknowledges that industrialization and diversification will depend heavily on STEM subjects, skills, and knowledge. A nation in which science, technology, and innovations are the driving forces in national development and compete globally by 2030. This would require acquiring and upgrading the infrastructure required for training in science and technology and other academic institutions, establishing and strengthening the practical application of science and technology in all areas by 2030 (Ministry of National Planning, 2006).

Legal Frameworks

In addition to the policy frameworks, the government also put in place two major legal frameworks that guide the implementation of STEM subjects in schools. The first is the Science and Technology Act, No. 26 of 1997. Grounded in the national policy on education of 1996 and the national policy on science and technology of 1996, the Science and Technology Act provides a legal framework for the promotion of STEM subjects in schools by making the subjects compulsory for all students at both primary and secondary levels. The Act further established the creation of the National Science and Technology Council (NSTC) which is a statutory body created under the Science and Technology Act and whose main function is to promote science, technology, and innovation in order to create wealth and contribute to the improvement of the quality of life in Zambia (Science and Technology Act, 1997).

The second defining legal framework is the Education Act, No.23 of 2011. The Education Act of 2011 provides a legal framework that enables changes in the educational institutes and the curricula used by various training institutions in the country. The Act provides a legal framework for teaching and learning STEM subjects as well as the teaching and learning of other subjects (The Education Act, 2011).

Practical Measures to Promote STEM Education

In addition to these legal and policy frameworks, the government also instituted measures, guidelines, programs, projects, and initiatives to enhance the teaching and learning of STEM subjects in schools and other learning institutions. Key among these measures include:

(a) The Construction of Technical Schools Across the Country

To enhance the teaching and learning of STEM subjects, the government created technical schools for both girls and boys across the country. Most interesting, the government constructed girls' technical schools across the country. "These girls technical schools provided a platform for addressing the challenge of the low number of girls taking up STEM subjects and ultimately STEM careers" (National Assembly of Zambia, 2020, p. 7). Some national technical schools include Hillcrest Technical Secondary School, David Kaunda Technical School, Solwezi Boys Technical Secondary School, Ndola Technical Secondary School, and Chizongwe Technical Secondary School. Some girls' technical schools include Ndola Girls Technical Secondary School, Kapiri Mposhi Girls Technical Secondary School, Lufunsa Girls Technical Secondary School, and Mushindamo Girls Technical Secondary School. These technical schools focus on STEM subject delivery as they were equipped with laboratory facilities to support the teaching and learning of STEM subjects.

(b) Establishment of the National Science and Technology Council (NSTC)

In accordance with the Science and Technology Act of 1997, the government established the National Science and Technology Council (NSTC) to oversee all the activities of science, technology, engineering, and math in schools and the country at large. As a statutory body, the council's main function as enshrined in the Act is to promote science, technology, and innovation in the country as a driving factor of socio-economic development. Other functions of the council as prescribed in the Act include (a) promoting the development of an indigenous and environmentally friendly technological capacity; (b) regulating research in science and technology in Zambia; (c) advising the Government on science and technology policies and activities in Zambia; (d) liaising with Government, industries, and centers and institutes in science and technology; (e) mobilizing and distribute financial, human and other resources to management boards for science and technology research; (f) promoting the use of science and technology in the industry; (g) ensuring that gender concerns are integrated at all levels of science and technology development; (h) creating science and technology centers and institutes; (i) taking all measures that are necessary to popularize science and technology.

Per its mandate, the council embarked on establishing centers of excellence in the country to enhance and strengthen the teaching and learning of STEM subjects. The first center to be opened in 2012 is Nkandabwe Primary and Secondary School in Sinazongwe district Southern Province of Zambia. A science laboratory was set up with the necessary apparatus for chemistry, physics, biology, and mathematics. A school library with teachers' and pupils' STEM books was also put in place. The center was also allocated computers to enhance computer science. Another center with similar arrangements and setup was opened in 2019 at Kasempa Day Secondary School in Kasempa district of Northwestern Province of Zambia. These and other planned centers are meant to increase the teaching and learning of STEM subjects in the country.

(c) Creation of the National Science Centre

The National Science Centre (NSC) was established in conjunction with the United Nations Development Programme (UNDP) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO) for the purpose of making science tools and apparatus for use in school laboratories. It was observed that school laboratories lacked proper management. Hence, the NSC conducts training and workshops for lab assistants to equip school laboratories with competent support personnel. Within the confines of NSC, the government constructed a STEM training center to expand and expedite specialized in-service training and capacity building of STEM teachers and lecturers. The in-service teachers' program is aimed at supporting, training, and equipping in-service teachers with the necessary knowledge, skills, and competencies to help them engage with students and the content.

(d) Strengthening the Junior Engineers, Technicians, and Scientists Club

The Junior Engineers, Technicians, and Scientists (JETS) Club have been in existence since 1968. However, in 2017 the government revamped its curricula approach and aligned it with the NSC directorate. This initiative is meant to promote innovation and creativity in STEM subjects among students. The mission is to develop and nurture the human capital of knowledgeable and skilled young scientists, mathematicians, and technologists that will provide service and leadership to the nation and pursue creative research and strive for innovations in STEM fields to enhance sustainable development in the country. The club's primary goal is to become a national leader in research, innovation, and product development in scientific, mathematical, and technological fields in schools and colleges as well as among out-of-school youth to support youths' success in their STEM careers. One of the club's primary objectives is "to promote creativity and innovation in Science, Mathematics, Engineering, and Technology among learners in schools, students in Colleges of Education, and teachers" (MoGE, 2020b, p. 8).

(e) Other measures

Other measures put in place to guide the teaching and learning of STEM subjects include (a) the creation of the Zambia Education Material Project (ZEMP). In collaboration with the Finish government agency, the Zambia government created the ZEMP to support and develop capacities in Zambian scholars/academicians and institutions to venture into writing and publishing STEM books. (b) fast track teacher education program (FTEP). In 2007, the MoGE created the FTEP to facilitate fast-tracking the upgrading of diploma-qualified STEM teachers to first-degree levels to address the critical shortage of STEM teachers. These and other government initiatives, programs, and projects are aimed at creating a strong background in the teaching and learning of STEM subjects in schools and other training institutions.

Recent Efforts

The actual implementation of STEM education as we know it today in the integrative and acronym S.T.E.M. started in January 2020. In 2019, the government approved the establishment and construction of 52 STEM schools across the country. Of these 52 STEM schools, the former technical schools were converted into STEM schools and an additional more were constructed specifically as STEM schools. Taking a phased approach, in January 2020 implementation of the STEM curriculum started. A STEM curriculum was enforced in all STEM schools around the country. The beginnings were uncertain and even now 2+ years down the line, STEM education implementation is not stable.

Barely a year and a half after, and despite the strides made this far, on May 7th, 2021, the MoGE called off the implementation of the STEM curriculum in all STEM schools. The MoGE instructed that the STEM curriculum be suspended for the time being while consultations are ongoing. To this very day, the implementation of STEM in Zambian schools is quite fragmented. Some schools reverted to the old and non-STEM curriculum, while others are trying to hold on to some elements of the STEM teaching approach in their teaching of STEM disciplines.

Theoretical Framework

Given the complexity of the individual STEM subjects even before putting them together, the theoretical framework that guided this study was also complex so as to capture all four domains of STEM equally. Literature has shown that in the past, when authors developed STEM education frameworks, or when they talked about STEM education, they meant a framework that represented only one or two domains (Bybee, 2013). Most often, when STEM is mentioned, it would refer to either science or mathematics, science and mathematics, and science and technology. Rarely do STEM conceptualizations capture all four domains, especially technology and engineering. This is why the framework that was used intended to capture all four domains so as to remain true to the nature and scope of STEM in which science, technology, engineering, and mathematics are purposefully and intentionally integrated and applied to solve real-world situations.

A synthesis of the STEM literature reviewed demonstrated that STEM content and pedagogies are coherently understood and grounded in constructivist perspectives. Most of the studies that were reviewed did not present an explicit statement of their conceptual or theoretical perspective. However, reading between the lines, the background literature provided the framing and backing for methodology and content that were constructivist. This was evident in the interdisciplinary and integrative nature of STEM content and pedagogies which tended to be constructivist. In this study, I used a hybrid of cognitive constructivism. Hybrid in the sense that the framework bridges the benefits of the findings of cognitive science research and the tenets of constructivism. Cognitive constructivism is an appropriate and convenient framework to guide STEM studies because it is reflected in all the domains of STEM whereby: science = inquiry approach; technology = computational thinking; engineering = design reasoning; and math = deductive reasoning.

The bridging or combining of cognitive science and the tenet of constructivism brings the strengths of both fields into perspective by pruning extreme components of either field. To begin with, cognitive scientists are concerned about how students learn, remember, and interact with the environment. They often put a strong emphasis on mental processes. Cognitive science is a scientific interdisciplinary study of the mind – intelligence and intelligent systems (Friedenberg et al., 2021). Cognitivism as a theory of learning has a rich history in the studies of STEM domains, for instance, science and mathematics. In the course of history, STEM subjects have benefited from the findings of cognitive science. Research in the cognitive sciences has demonstrated unique and critical insights into how the human mind works – that is; receives, represents, processes, and constructs STEM concepts and procedures (Geary et al., 2017).

Pioneered by Jean Piaget (1896-1980), and later championed by Jerome Bruner (1915-2016) and Levy Vygotsky (1896-1934), cognitivism is a learning theory that emphasizes the acquisition, organization, storage, and retrieval of information (Clark, 2018). According to Ertmer and Newby (2013), cognitive theories "focus on the conceptualization of students' learning processes and address the issues of how information is received, organized, stored, and retrieved by the mind" (p. 51). In this view, learners are actively involved in processing information. According to Piaget,

> Humans cannot be 'given' information which they immediately understand and use. Instead, humans must 'construct' their own knowledge. They build their knowledge through experience. Experiences enable them to create schemes – mental models in their heads. These schemes are changed, enlarged, and made

> more sophisticated through two complementary processes: assimilation and accommodation (Kumar & Gupta, 2009, p. 39).

On the other hand, constructivism is also another learning theory that has a rich history in the teaching and learning of STEM domains. It describes both what knowledge is and how one comes to acquire knowledge. Technically speaking, constructivism originates from cognitive science in that it views learning as a result of mental construction. That is, learning takes place when new information is added to prior knowledge and experience. Students learn by actively constructing their own meaning and understanding. The constructivist approach to learning has been attributed to Piaget and Vygotsky, who both believed that people are actively involved in their own learning and discovering of things. While Piaget put more emphasis on the interaction between the individual and the environment, Vygotsky placed more emphasis on social interaction. Constructivism, therefore, rests on the assumption that knowledge is not static for an object, rather, people learn by actively constructing knowledge as they attempt to make meaning out of their experience (Larochelle & Bednarz, 1998). Stressing this point, Koumi (2006) argued that "roughly speaking, constructivism asserts that knowledge is not passively received but actively built up by the learner who selects information and organizes it in a way that is individually meaningful" (p. 104). In this case, students are not tabula rasa or empty vessels waiting to be filled with knowledge. Rather, they are active organisms seeking meaning.

Combining cognitive science and the tenets of constructivism, forming cognitive constructivism has a high chance of transforming the study of STEM education.

According to Zuljan (2021), for learners to obtain high-quality and enduring knowledge, it is imperative that the teaching and learning of STEM subjects are based on cognitive constructivist approaches. Cognitive constructivism is a learning theory based on the assumption that students learn by actively constructing meaning. The theory focuses on how students construct sophisticated mental representations and problem-solving (Felix, 2005). In as much as cognitive constructivists are concerned with mental representations of students, their overall conception of the purpose of learning is not only to acquire knowledge but also to enable students to construct new knowledge, building on previous knowledge from past experience. Cognitive constructivists, therefore, view knowledge as:

> Actively constructed by learners and that any account of knowledge makes essential references to cognitive structures. Knowledge comprises active systems of intentional mental representations derived from past learning experiences. Each learner interprets experiences and information in the light of their extant knowledge, their stage of cognitive development, their cultural background, their personal history, and so forth. Learners use these factors to organize their experience and to select and transform new information (Kumar, & Gupta, 2009, p. 43).

For Garrison (1993), knowledge is not static but is negotiated between teacher and learner. In general, knowledge is a social artifact and in education, it is the outcome of the interaction between students and the environment.

Given that knowledge is actively constructed by learners, learning is presented as a process of active inquiry and discovery. The role of the teacher in cognitive constructivists' view is not to drill knowledge into students through consistent memorization, repetition, or recitation. Rather, the role of the instructor is to guide and facilitate the meaningful construction of knowledge by continually monitoring students' cognitive processes. Since learning is an act of active discovery and inquiry, the role of the teacher is to facilitate this discovery and inquiry by providing necessary information and materials and by guiding students as they attempt to make new meaning. Teachers make an effort to recognize and appreciate the knowledge that learners come with – their cultural background, their stage of cognitive development, and personal history (Kumar, & Gupta, 2009). The classroom must provide a conducive atmosphere where students can observe, critique, explore, work, and interact. Learners must be allowed to raise questions and solve problems.

Cognitive constructivism's approaches to education have a rich history in the teaching and learning of individual STEM subjects. Therefore, if students are to obtain authentic, high-quality, and far-reaching STEM knowledge, skills, and competencies, STEM education must be taught based on cognitive constructivism approaches. This is because, at the heart of STEM learning, students are actively engaged in constructing STEM knowledge while solving real-life problems. STEM instruction helps support the construction of knowledge as learners are guided through their learning and problem-solving processes. Han (2013) once argued that teaching STEM education is grounded in the principles and theoretical background of cognitive constructivism where learners are actively engaged in different aspects of problem-solving and interactive activities. This is to argue that STEM policies, programs, initiatives, and implementation should be grounded in the tenets of cognitive constructivism. This is because authentic STEM learning happens when (a) learning is seen as an active, constructive process, and not a receptive one (b) learning is presented as a process of active discovery and inquiry (c) learners are actively engaged in constructing STEM knowledge, skills, and competencies (d) learners are allowed to take charge of their own learning (e) learners' beliefs and motivation are integral to cognition processes (f) social interaction is fundamental to cognitive development (g) knowledge is contextualized in the learning experience (h) the role of prior knowledge in the acquisition of new knowledge requires that effective educational regimens are graduated in design and (i) the teacher facilitates student construction of STEM knowledge. The implication of this is that any formulation of STEM policy, legal frame of reference, and initiative must consider that authentic STEM learning is grounded in the tenets of constructivism supported by the findings of cognitive science (NSTA, 2020).

One of the core arguments of this study is that STEM education must take root in the Zambian context. From my analysis thus far, this has not been the case. Employing cognitive constructivism would be one of the ways that can aid STEM workable in the country. The MoGE (2020a), acknowledged the importance of constructivist approaches to teaching and learning STEM education when it argued that "STEM education curriculum emphasizes the acquisition of scientific skills. To ensure these skills are acquired, STEM advocates the use of constructivist learning approaches that demand learners to take center stage in the learning process" (p. 5). Since STEM seeks to elicit skills, knowledge, and competencies that are desirable in the socio-economic setup of the country, constructivist learning approaches become vital in STEM education. Employing constructivist learning approaches to STEM, "STEM curriculum seeks to develop learners who are: (i) critical, creative, and analytical thinkers (ii) able to relate thinking with real-world situations (iii) problem solvers, and (iv) responsible citizens" (MoGE, 2020a, p. 3). In this way, constructivist approaches attend to the socio-cultural realities of the country in that they are hands-on and project and problem-based pedagogies that train learners to develop skills and competencies needed to solve local problems.

CHAPTER III

METHODOLOGY

Research Design

Given the complexity of STEM education and particularly the topic under investigation, this study utilized a mixed methods design – that is, combining both quantitative and qualitative research procedures to understand the research problem. Mixed methods designs are considered to be suitable for studying complex topics because they provide the opportunity to look at the issue under investigation from multiple methods and perspectives (Merten & Wilson, 2019). According to Creswell and Plano Clark (2018), complex research problems call for answers that go beyond simple words in a qualitative sense or numbers in a quantitative sense. Rather, an integration of both qualitative and quantitative data provides the most complete overview of complex issues.

Believed to have rapidly evolved in the 1970s and 1980s as a response to the emerging complexity of research problems, mixed methods design is a procedure for gathering, analyzing, interpreting, mixing, and/or merging both qualitative and quantitative research methods in a single study to have a comprehensive understanding of a research problem (Creswell, 2012). Creswell (2021) sees mixed methods design as:

> A methodology and method to research in the social, behavioral, and health sciences in which the investigator gathers both quantitative (close-ended) and qualitative (open-ended) data, integrates or combines the two, and then draws

> inferences (called meta-inferences) from the integration that provides insight beyond what can be learned from the quantitative or qualitative data (p. 2).

In this case, combining both qualitative and quantitative procedures go beyond simply the collection of demographic data from the qualitative interview participants or, the inclusion of open-ended questions in a quantitative survey tool. Rather, the combination of qualitative and quantitative procedures involves the explicit integration of quantitative and qualitative components in a single study. "It is this integration that characterizes the mixed methods approach, as distinct from a 'combined approach' whereby qualitative and quantitative elements are used together but not integrated" (Halcomb, 2019, p. 499).

A core assumption of mixed methods design is that when a researcher combines both statistical trends (quantitative data) with stories and personal experiences (qualitative data), the collective strengths of both methods provide a better understanding of the research problem than either type of data alone (Creswell, 2021). This is in no way belittling the importance of choosing either a qualitative or a quantitative method when it is merited by the situation (Creswell & Plano Clark, 2018).

Defining mixed methods design from core characteristics points of view and philosophical orientation perspectives, Creswell and Plano Clark (2018), argue that mixed methods research occurs when the research: (a) collects and analyzes both qualitative and quantitative data rigorously in response to research questions and hypothesis; (b) integrate (mixes or combines) the two forms of data and their results; (c) organizes these procedures into specific research designs that provide the logic and procedures for conducting the study; and (d) frames these procedures within theory and philosophy.

One major justification or rationale for using mixed methods in this study is seeking the comprehensiveness of the findings of the study – that is, the need to obtain more complete and corroborated results. Both qualitative and quantitative methods have their unique limitations. However, integrating the two strands bring together the strengths of the qualitative method (e.g., breadth and depth, subjective interpretation, and small sample size) and the quantitative method (e.g., objective measures, generalizability, and large sample size). According to Creswell and Plano Clark (2018), "the limitation of one method can be offset by the strengths of the other, and the combination of qualitative and quantitative data provides a more complete understanding of the research problem than either approach by itself" (p. 8). Dawadi et al. (2020), confirm this point when they argued that:

> A mixed methods research approach helps to obtain more rigorous conclusions by employing two methods in such a way that the strengths of the qualitative methods offset the weaknesses of the quantitative methods and vice versa. This implies that a quantitative method can be strong in those areas where a qualitative method is weak and vice versa. Putting it in another way, one method is more suitable to answer one type of question and another method is more suitable for another type of question. Mixing the two methods, therefore, offers the possibility of combining two sets of strengths while compensating at the same time for the weaknesses of each method. Thus, the combination of quantitative and qualitative

> methods is often proposed on the grounds that a researcher can utilize the respective strengths, escape the respective weaknesses of the two approaches and produce a more accurate conclusion (p. 28).

Therefore, the purpose of mixing in this study was threefold: complementarity, triangulation, and expansion.

Complementarity seeks elaboration, illustration, enhancement, and clarification of the results from one method with the results from the other method. Furthermore, complementarity seeks to increase the interpretability, meaningfulness, and validity of results (Greene et al., 1989, p. 259). What this means is that qualitative and quantitative approaches have values that complement each other. Because of this complementarity, integrating the two methods helped to produce a more complete picture of the phenomenon of study. "Additionally, findings from mixed-methods research offered a holistic view of a phenomenon and provided additional insights into different components of a phenomenon which might help for generating substantive theories" (Dawadi et al., 2020).

Triangulation seeks corroboration, convergence, and correspondence of results from both qualitative and quantitative procedures. In other words, "triangulation seeks to increase the validity of the research constructs" (Greene et al., 1989, p. 259). According to Dawadi et al. (2020):

> Data triangulation in a mixed-methods study is generally accepted as a strategy for validating results obtained with the individual method. In other words, collecting diverse types of data offers greater insights into a phenomenon that the

> methods individually cannot offer, and therefore, provides more valid and stronger inferences than a single method does. Thus, data triangulation leads to a well-validated conclusion and also promotes the credibility of inferences obtained from one approach (p. 28).

Expansion, on the other hand, seeks to widen the range of inquiry with breadth and depth by using different methods for different inquiry components (Schoonenboom & Johnson, 2017). In this case, the quantitative approach brought breadth to the study, while the qualitative approach brought depth to the study.

Given that both qualitative and quantitative data were collected and analyzed at the same time, but independently, this study took the form of a convergent mixed methods design. Convergent design, also known as concurrent parallel design (Teddie & Tashakkori, 2010), is a mixed methods design in which a researcher collects both qualitative and quantitative data concurrently and then analyzes the two databases separately - and then finally mixes the data sets by merging the results to compare, interpret, or combining the results (Creswell & Plano Clark, 2018). In a convergent design, two types of data sets were gathered at the same time, and secondly, they were analyzed individually using qualitative and quantitative analytical approaches (Schoonenboom & Johnson, 2017). The integration of both data sets in convergent design helped the investigator to gain a complete understanding of the findings than would be from one method alone. In this way, the convergent design provided a complete picture of the problem under investigation. According to Creswell and Plano Clark (2018), “Integration in a convergent design intends to develop results and interpretations that expand understanding, are comprehensive, and are validated and confirmed” (p. 221).

The research followed the following procedures. First, both qualitative and quantitative data were collected at the same time “concurrently or parallel” – that is, the data of one method did not influence or inform the procedure of the other. In this way, both methods carried equal importance in addressing the research questions no data set or method was prioritized over the other.

Second, both data sets were analyzed separately and independently using appropriate analytical tools. In the third phase, once the two sets of initial results were completed, the results were presented as they are and merged where necessary. The final phase included discussing, interpreting, and summarizing the findings. This stage involved determining to what extent the two sets of results converged or diverged from each other. The point of integration and mixing occurred in the third and fourth stages, where results were jointly displayed in tables and figures. Figure 1 depicts a convergent mixed methods design and its procedures used in this study.

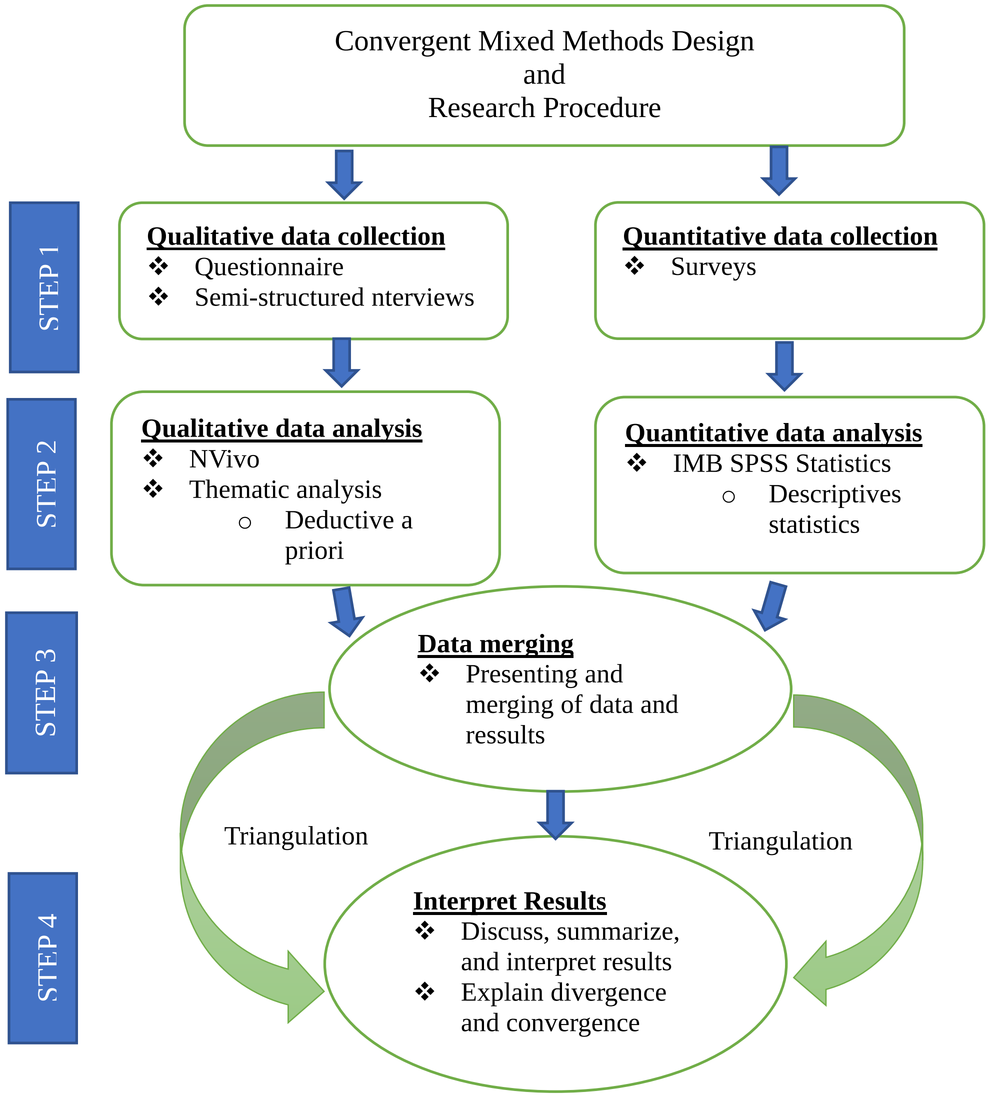

Figure 1. Convergent Mixed Methods Design

Sampling Methods

Site selection: This study took place in seven purposefully selected secondary schools and three STEM institutions in Zambia. These schools were selected because they were part of the 15 pilot STEM schools where the STEM curriculum was implemented before it was suspended. To make sure that the whole country was represented, the schools selected were scattered across all the regions of the country, from all seven linguistic and cultural regions of the country, and from different socioeconomic statuses, that is, rural and urban. In addition to secondary schools, three STEM institutions/centers were also purposefully selected. These institutions were selected because (a) they are government statutory bodies charged with the responsibility to oversee and promote STEM activities and initiatives in schools (b) they formulate STEM policies and curriculum, and (c) they regulate research in STEM disciplines. As such, they had first-hand knowledge and information about STEM education in the country.

Participants*:* The participants of the study were 20 STEM teachers, 10 STEM administrators, and 10 STEM policymakers. STEM teachers are those in-service teachers teaching STEM subjects such as biology, chemistry, physics, math, computer science, agricultural science, engineering, and technology. They teach grades 8 through grade 12. STEM administrators are those individuals who are headteachers, deputy headteachers, and heads of departments in STEM schools. STEM policymakers are those individuals working in STEM institutions/centers and careers. These are the individuals who are tasked by the government to oversee the implementation of STEM in schools, and they are responsible for STEM curriculum and policy development. These participants were purposefully selected because they had first-hand information, knowledge, and experience about STEM education in the country. The criterion for choosing these participants is that they have at some point engaged in STEM education, either in the implementation process, policymaking, advocacy, teaching, or curriculum development.

Data Collection

Data collection for both qualitative and quantitative took place at the same time. This is in line with the convergent or concurrent parallel design which was used in this study. Quantitative data were collected through surveys. The survey used was designed specifically for this research although inspired by Navy, et al. (2020). The survey was organized into four perception domains: STEM definition, STEM purpose, STEM learning, and STEM teaching. The survey questionnaire included 20 items, five items for each perception domain group. The 7-point Likert-type scale ranged from strongly disagree (1) to strongly agree (7) was used. See Appendix C for the survey questionnaire.

The survey included four qualitative open-ended questions to consolidate the responses. In addition to these four open-ended questions, qualitative data were collected through semi-structured interviews. The interview questions contained six questions covering the six perception domains of STEM vision, definition, purpose, relevance, teaching, and learning. See Appendix D for the interview protocol. The survey was first administered to all 40 participants after which 15 participants of the 40 were interviewed – five participants for each stakeholder group.

Data Analysis

After collecting both qualitative and quantitative data, the two data sets were analyzed separately and independently following the convergent mixed methods.

Quantitative data analysis

The data analysis began with quantitative analysis. The data was imported from Qualtrics into SPSS. The results from the Shapiro-Wilk test indicated that the test of normality assumption was not met, $p < .05$ for each perception domain. Descriptive statistics were run for each group and perception domain to determine and examine the central tendencies (mean and standard deviation) of the data. This allowed me to examine the means of each stakeholder group and observe how the participants rated their understanding of STEM. The means of each stakeholder group were compared to determine the differences between each stakeholder group.

Qualitative data analysis

By nature of the convergent mixed methods design, qualitative data were analyzed concurrently with the quantitative data. The open-ended responses from the survey were imported from Qualtrics together with the interview transcripts into Nvivo. The three stakeholder groups (teachers, administrators, and policymakers) were in separate folders in Nvivo. Within each folder, codes were developed using deductive reasoning. First and foremost, for qualitative data analysis, I immersed myself in the data – by reading and re-reading all participants' interview transcripts both from the survey questionnaires and interview protocol. In the process, I transcribed the data gathered to get a general sense of the whole story and ideas presented. Next, I extracted from the transcripts the most important statements, words, and phrases describing the phenomenon of study – STEM education. I coded these sentences, phrases, and words that were standing out in describing the phenomenon. From these important statements, words, and phrases, I formulated meanings. Then, out of the formulated meanings, I used color code to organize these meanings into themes. These themes helped me to perform preliminary analysis. Triangulation was used to build comprehensible validation of the themes.

Finally, from the themes, I wrote up comprehensive and holistic descriptions of STEM education as perceived by the participants.

Interpretation procedure and criteria

Given that the study did not end with data collection and analysis, the study engaged in data interpretation. Data interpretation involves making value judgments of the whole research process. In order to engage in comprehensive data interpretation, the research questions guided the entire process. Based on the findings of the analysis of the research questions, I made value judgments according to the study criteria put in place. The major criteria that I use in this study to interpret the data are the impact, effectiveness, and relevance of the study. These criteria are embedded in the research questions. While the analysis aspect of this study focused on making sense and meaning out of the data collected, the interpretation aspect focused on identifying findings that can be used to improve the situation at hand. Data interpretation involved deciding which aspects of the findings are the most important and interesting. Out of the interpretation, conclusions and recommendations were made.

Reporting the findings

Quantitative findings were reported first followed by qualitative findings. However, this does not mean that quantitative findings were prioritized over qualitative findings. As mentioned earlier, no data set was prioritized over the other. All data sets were equally prioritized. The findings were presented according to the perception domain. I mostly used tables and figures to present the findings. The findings were, however, discussed according to research question.

Issues of Validity and Trustworthiness

Validity and trustworthiness in this study were determined using strategies to verify the accuracy of the findings. According to Ravitch and Carl (2016), “validity in qualitative research, refers to the ways that researchers can affirm that their findings are faithful to participant’s experiences. Put another way, validity refers to the quality and rigor of a study” (p. 186). To achieve quality and rigor, this study adhered to the principles of credibility, transferability, dependability, and confirmability (Ravitch & Carl, 2016). Triangulation from different research methods was used to build a comprehensible justification for the themes. According to Bergman (2008), data triangulation in mixed methods research is generally accepted as a strategy for validating results obtained through cross-verification from different data sources.

> In other words, collecting diverse types of data offers greater insights on a phenomenon that the methods individually cannot offer, and therefore, provides more valid and stronger inferences than a single method does. Thus, data triangulation leads to a well-validated conclusion and also promotes the credibility of inferences obtained from one approach (Dawadi, 2020, p. 28).

Member checking was also used to determine the correctness of the results by sending the rough draft to participants to determine the accuracy of their responses. Since this report fulfills a doctoral research requirement, the data analysis portion of this report was scrutinized and validated by the researcher’s graduate supervisor and the dissertation committee members, and critical friends' feedback.

Ethical Considerations

This study sought to solicit sensitive and personal information from participants. Hence, the need to respect participants' privacy. I was mindful and anticipated any ethical issues that might have arisen. Therefore, participants were protected by developing trust, promoting the integrity of research, and guarding against any misconduct and impropriety. First and foremost, I had the moral obligation to respect the freedom, needs, rights, desires, and values of the participants. To protect the interests of participants, the following were put in place: (a) participants were advised in writing that they could withdraw from the study at any time they feel not comfortable without any penalty; (b) participants were advised not to answer any question that they did not feel like answering; (c) participants signed a written consent form; (d) participants were informed about all the proceedings of the research; and (e) the rights and privacy of participants were considered first before anything else.

CHAPTER IV

RESULTS

Given that this was a convergent mixed methods study, quantitative and qualitative data were analyzed at the same time although independently without any dataset influencing the other. The data analysis began with quantitative data followed by qualitative data. Table 2 presents the demographic composition of the participants.

Table 2

Demographic Composition of the Participants

		Gender	
Stakeholder groups	**Total**	**Males**	**Females**
Teachers	20	17	3
Administrators	10	8	2
Policymakers	10	5	5

STEM Definition Domain Results

Quantitative STEM Definition Results

In Table 3 are the items representing definitions of STEM education that participants were asked to rate how much they agree or disagree with each statement. The scale ranged from strongly disagree (1) to strongly agree (7).

Table 3

Items Representing the Definition of STEM Education

Below are items that represent definitions of STEM Education. Please rate how much you agree or disagree with each statement. Strongly Disagree (1) to Strongly Agree (7)	
Definition 1	STEM education entails the purposeful and meaningful teaching of each STEM subject separately
Definition 2	STEM education is the purposeful and meaningful integration of two or more STEM subjects into a single STEM class unit
Definition 3	STEM education is the purposeful and meaningful combination of all **FOUR** STEM subjects in a single STEM class unit
Definition 4	STEM education entails an applied knowledge and skills approach to teaching
Definition 5	STEM education entails an interdisciplinary approach to teaching and learning

Teachers' Quantitative Results on STEM Definition

Table 4 presents full details of descriptives results of teachers' definition of STEM education.

Table 4

Statistics for STEM Definition for Teachers

		Definition 1	**Definition 2**	**Definition 3**	**Definition 4**	**Definition 5**
N	Valid	20	20	20	20	20
	Missing	0	0	0	0	0
Mean		5.20	5.45	5.30	6.15	5.85
Median		6.00	6.00	6.00	6.50	6.00
Mode		7	7	6	7	6
Std. Deviation		1.936	1.761	1.867	1.348	1.461
Range		5	5	6	5	6

Descriptives results for teachers about the STEM definition revealed that teachers did not agree among themselves about the definition of STEM education. For the first three definitions, there is a clear divide among teachers on what STEM education should be defined. For instance, for definition 1, 75% of the teachers agreed that STEM education entails the purposeful and meaningful teaching of each STEM subject separately, while 25% did not agree. About definition 2, 70% agreed that STEM education is the purposeful and meaningful integration of two or more STEM subjects, while 30% disagreed. About definition 3, 70% of the teachers agreed that STEM education is the purposeful and meaningful combination of all FOUR STEM subjects, 15% neither agreed nor disagreed, while 15% disagreed.

Concerning definitions 4 and 5, there was strong agreement among teachers about the definition of STEM education. 95% of teachers agreed that STEM education entails an applied knowledge and skills approach to teaching and learning, and only 5% disagreed. Similarly, 90% of teachers agreed that STEM education entails an interdisciplinary approach to teaching and learning, and only 10% somewhat disagreed. Overall, teachers are saying that STEM education is more of definitions 5 and 4 than definitions 1, 2, and 3. Figure 2 presents teachers' ratings of STEM definitions.

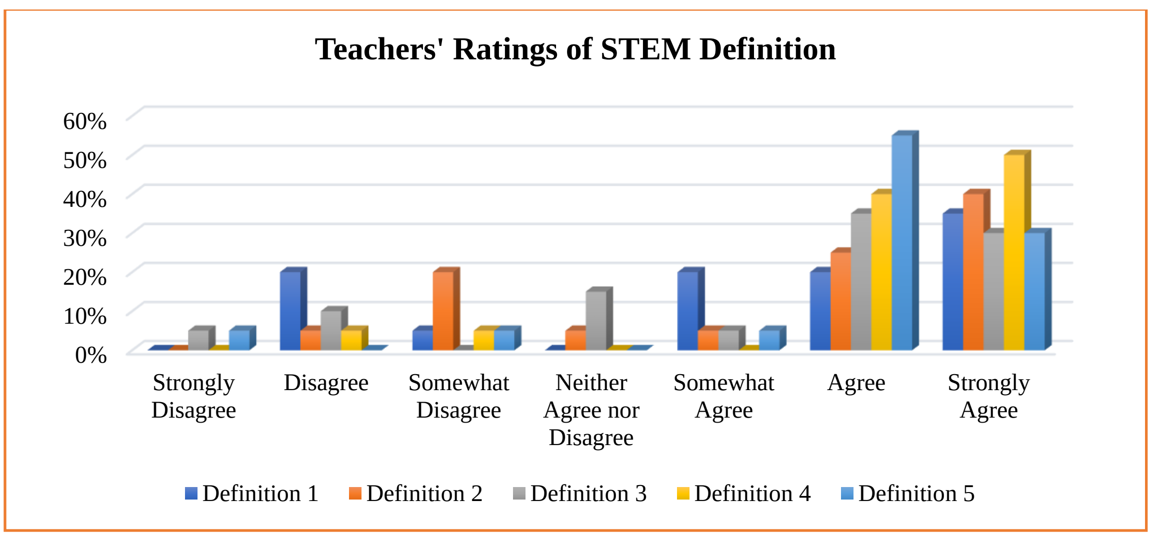

Figure 2. Teachers' Ratings of STEM Definitions

Administrators' Quantitative Results on STEM Definition

Table 5 presents full details of descriptives results of administrators' definition of STEM education.

Table 5

Statistics for STEM Definition for Administrators

		Definition 1	Definition 2	Definition 3	Definition 4	Definition 5
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		5.80	4.90	4.20	5.80	6.00
Median		6.00	5.50	4.50	7.00	7.00
Mode		7	6	6	7	7
Std. Deviation		1.398	2.025	1.814	2.300	1.886
Range		4	6	4	6	6

Just like teachers, administrators had some disagreements among themselves about the definition of STEM. For the first three definitions, there was a wide range of understanding of STEM education among the administrators. For definition 1, 80% of administrators agreed that STEM education is the purposeful and meaningful teaching of each STEM subject separately, 10% disagreed, and 10% neither agreed nor disagreed. Definition 2 received a wide range of perceptions among administrators. About 50% agreed that STEM education is the purposeful and meaningful integration of two or more STEM subjects, while 20% disagreed, 20% somewhat agreed, and 10% neither agreed nor disagreed. Definition 3 has two extremes. About 40% were on the disagreement side that STEM education is the purposeful and meaningful combination of all FOUR STEM subjects, and another 50% were on the agreeing side, while 10% neither agreed nor disagreed.

Concerning definitions 4 and 5, 80% of administrators agreed that STEM education entails an applied knowledge and skills approach to teaching, while 20% disagreed. Similarly, 90% of administrators agreed that STEM education entails an interdisciplinary approach to teaching and learning, while 10% disagreed. Figure 3 presents administrators' ratings of STEM definitions.

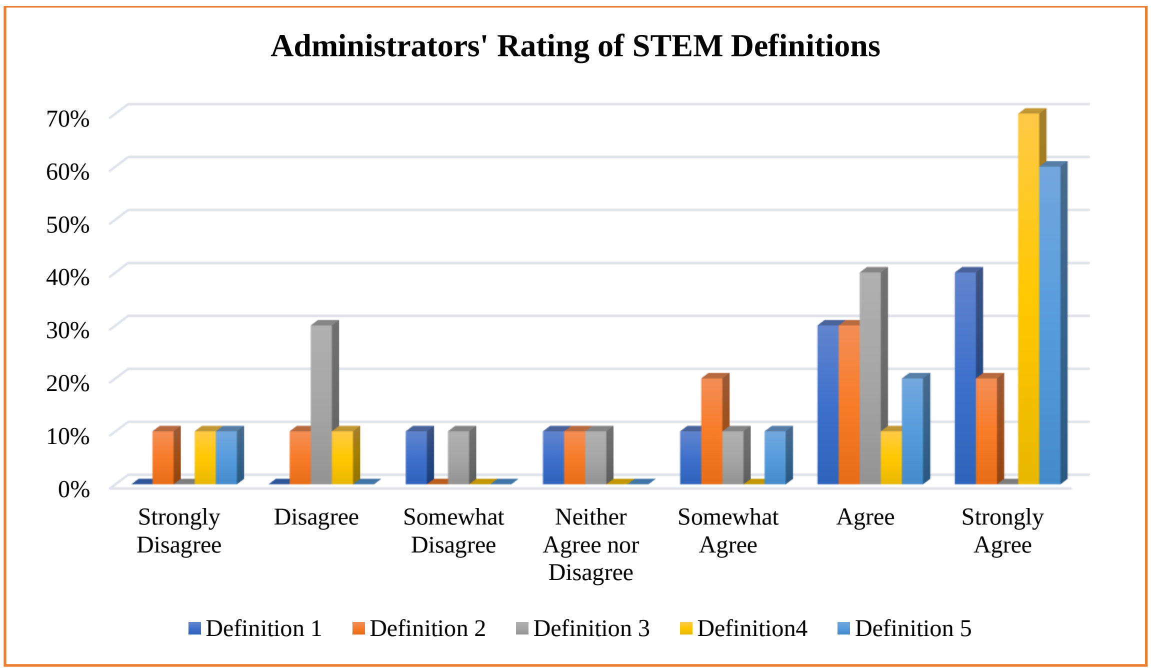

Figure 3. Administrators' Rating of STEM Definitions

Policymakers' Quantitative Results on STEM Definition

Table 6 presents full details of descriptives results of policymakers' definition of STEM education.

Table 6

Statistics for STEM Definition for Policymakers

		Definition 1	Definition 2	Definition 3	Definition 4	Definition 5
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		3.20	5.20	4.70	5.80	5.70
Median		2.00	6.00	5.00	6.50	7.00
Mode		1	7	2	7	7
Std. Deviation		2.486	2.201	2.111	1.932	1.947
Range		6	6	5	6	5

Taking a similar path and like teachers and administrators, policymakers showed some disagreements among themselves about the definition of STEM. Although policymakers took a different path concerning definition 1. Unlike teachers and administrators, 60% of policymakers disagreed with definition 1 that STEM education is the purposeful and meaningful teaching of each STEM subject separately, while 40% were on the agreement side. Policymakers were also torn apart on definitions 2 and 3. About 60% agreed that STEM education is the purposeful and meaningful integration of two or more STEM subjects, while the other 30% disagreed, and 10% remained neutral. Similarly, 60% agreed that STEM education is the purposeful and meaningful combination of all FOUR STEM subjects, while 30% disagreed, and 10% remained neutral. Like teachers and administrators, most policymakers agreed about definitions 4 and 5. About 80% agreed that STEM education is an applied knowledge and skills approach to teaching and learning, 10% disagreed, and 10% remained neutral. Similarly, 70% agreed that STEM education entails an interdisciplinary approach to teaching and learning, while 20% disagreed and 10% remained neutral. Figure 4 gives policymakers' ratings of STEM definitions.

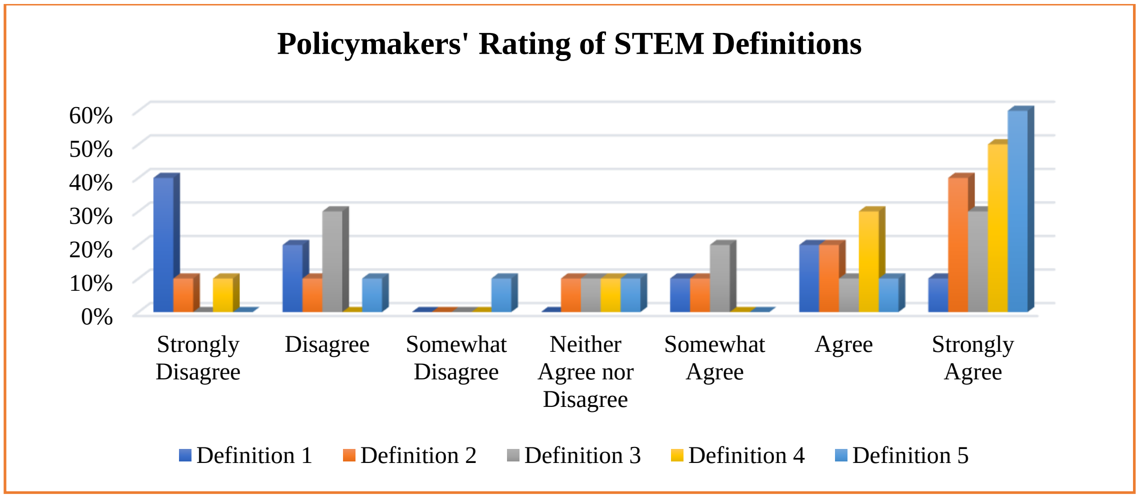

Figure 4. Policymakers' Rating of STEM Definitions

Comparing the Definition Means of all Groups

Table 7 presents a comparison of the definition means of the stakeholder groups. Teachers had high mean on definitions 2, 3, and 4. While Administrators had high mean on definitions 1 and 5. Policymakers had the least mean on definitions 1 and 5. Further, policymakers' mean for definition is the lowest.

Table 7

Comparisons of Mean Scores for STEM Definition

	Definition 1	**Definition 2**	**Definition 3**	**Definition 4**	**Definition 5**
Teacher *(M)*	5.20	5.45	5.30	6.15	5.85
Administrators *(M)*	5.80	4.90	4.20	5.80	6.00
Policymakers *(M)*	3.20	5.20	4.70	5.80	5.70

Qualitative STEM Definition Results

A closer look at the qualitative data reveals that there is some coherence between qualitative results and quantitative results. Just like quantitative data, qualitative data revealed some minor disagreement among STEM stakeholders on the definition of STEM education. These disagreements are not only between groups but also within groups. However, overall, STEM stakeholders define STEM education almost in the same way. STEM stakeholders might disagree about the definition of STEM in a few instances, but generally, their definitions of STEM are closely related. This is evident in the common qualitative themes that cut across all the groups. Table 8 lists the common codes that were used to sum up the themes of STEM definitions that came out across all groups.

Table 8

STEM Definition Qualitative Codes

Definition Codes		
Teachers	**Administrators**	**Policymakers**
❖ Integration of STEM subjects	❖ Integration of STEM subjects	❖ Integration of STEM subjects
❖ Teaching STEM subjects	❖ Interdisciplinary approach	❖ Acronym of the 4 STEM subjects
❖ Skill development for future success	❖ Creative/critical thinking,	❖ Interdisciplinary approach
❖ Problem-solving	❖ Analytical thinking	❖ Teaching STEM
❖ Hands-on	❖ Problem-solving	
❖ Imparting 21st century skills	❖ Constructivist thinking	
❖ Life serving skills	❖ Applied knowledge	

Teachers were strong on STEM definition being a kind of education that imparts to learners life-serving skills and 21st century skills such as critical/creative/analytical thinking, problem-solving, and innovation. This agrees with the quantitative data where about 90% of teachers agreed that STEM education entails an applied knowledge and skills approach to teaching and learning. All the teachers that were interviewed mentioned either 21st century skills, skill development, problem-solving, innovation, critical thinkers, and creative thinking.

In reference to applied knowledge, most teachers mentioned either survival skills, learning by doing, or hands-on activities. For instance, Teacher 001 said that “I would define STEM education as a custom-made form of education that makes learners innovators, and critical thinkers, and always able to be up to speed with the 21st century educational demands and standards.” Teacher 003 added that:

> STEM education is a way of teaching in a strategy that can be employed in teaching which enables learners to be creative, innovative, and problem solvers. It gives learners skills that are life-long and can save many economies. In hospitality and tourism, for instance, it can improve those industries tremendously.

Teacher 005 concluded that,

> STEM education is a way of teaching that enables learners to think in a way that they can develop skills and enable them to apply these skills in real-life activities. STEM education teaches survival, critical thinking and focuses on skills. It is the type of education that leads to the production of a critical, analytical, and creative learner who can survive in the 21st century.

Another perspective that dominated teachers’ definition of STEM is the integration and teaching of science, technology, engineering, and mathematics. This agrees with quantitative data where about 70% of teachers agreed that STEM education is the purposeful and meaningful integration of two or more STEM subjects. Similarly, 70% of teachers agreed that STEM education is the purposeful and meaningful combination of all STEM subjects. Hence, it is understandable for most teachers to bring out the integration and combination aspects of STEM in their definition. Teacher 003, for instance, said that:

> In STEM education there is a need to integrate the STEM domains. This means that STEM education is the integration of STEM subjects. The type of education that promotes the teaching and learning of science, technology, engineering, and mathematics in schools.

Teacher 004 also said that "STEM education is an approach to teaching and learning which integrates STEM disciplines. STEM education is the teaching and learning of the four STEM subjects using hands-on activities."

Administrators' definition of STEM education was very scanty. They were not comprehensive and concise as teachers. Administrators came out strongly on STEM education as promoting 21st century and survival skills such as critical/creative thinking, innovation, analytical, and problem-solving. This agrees with quantitative data where about 80% of administrators agreed that STEM education entails an applied knowledge and skills approach to teaching and learning. For instance, Administrator 006 defined STEM education as "an education that creates or makes learners to be creative, imaginative, analytical, and critical thinkers, hence, becoming problem solvers. It is a kind of education that brings out critical thinking, problem-solving, and creativity in a child."

Another view of STEM emphasized by one administrator is the integration approach to STEM education. Administrator 004 said that "STEM education is the approach of learning and teaching that integrates the STEM domains." This agrees with quantitative data where about 70% of administrators agreed that STEM education is the purposeful and meaningful integration of two or more STEM subjects. Another aspect that was emphasized by administrators and agrees with the quantitative data is the interdisciplinary approach to STEM education. Administrator 005 defined STEM as “an interdisciplinary approach to teaching and learning that requires a learner to be analytical, creative, and a critical thinker.” This is in line with the quantitative data where 90% of administrators agreed that STEM education entails an interdisciplinary approach to teaching and learning.

Of the three stakeholder groups, the policymakers had a formidable, comprehensive, and concise definition of STEM education. For instance, Policymaker 008 defined STEM education as “the acronym for science, technology, engineering, and mathematics.” One theme that over 90% of policymakers brought up was that of the integration and teaching of STEM domains. This agrees with the quantitative data where 70% of policymakers agreed that STEM education is the purposeful and meaningful integration of two or more STEM subjects. According to Policymaker 007,

> STEM education is the deliberate integration of STEM subjects in the teaching and learning process to make learning more meaningful. It is an education system that integrates science, technology, engineering, and mathematics as core areas. It is when you educate pupils in science, technology, engineering, and mathematics.

For Policymaker 010, “STEM education is teaching and learning STEM subjects. It is an integrated approach to teaching and learning STEM subjects focusing on hands-on learning with real-world applications to help develop a variety of skill sets.”

Another perspective of STEM that came up among policymakers, although not that strong, was the interdisciplinary approach to teaching and learning. Policymaker 010, for instance, defined STEM education as “an intradisciplinary approach to teaching and learning STEM subjects.” This agrees with the quantitative data where 70% of policymakers agreed that STEM education entails an interdisciplinary approach to teaching and learning.

Table 9 presents a summary of qualitative perceptions of STEM definition that came within and across stakeholder groups. These perceptions were not only emphasized but also common between groups.

Table 9

All Stakeholders’ Perceptions of STEM Definition

Perceptions of STEM Definition
➢ STEM education is the type of education that promotes the teaching and learning of science, technology, engineering, and mathematics in schools.
➢ STEM education is an approach to teaching and learning which integrates STEM disciplines.
➢ STEM education is the teaching and learning of the four STEM subjects using hands-on activities which lead to critical and analytical thinking of learners.
➢ STEM education is the deliberate integration of STEM subjects in the learning process to make learning fully meaningful.
➢ My definition of STEM education is that it is the acronym for the four STEM subjects.
➢ STEM education is an interdisciplinary approach to teaching and learning that requires a learner to be analytical, creative, and a critical thinker.

STEM Purpose Domain Results

Quantitative STEM Purpose Results

In Table 10 are the items representing the purpose of STEM education that participants were asked to rate how much they agree or disagree with each statement. The scale ranged from strongly disagree (1) to strongly agree (7).

Table 10

Items Representing the Purpose of STEM Education

Below are items that represent the purpose of STEM Education. Please rate how much you agree or disagree with each statement. Strongly Disagree (1) to Strongly Agree (7)	
Purpose 1	The purpose of STEM education is to promote 21^{st} century skills.
Purpose 2	The purpose of STEM Education is to solve real-world problems, (e.g., climate change, economic issues, health issues, etc.).
Purpose 3	The purpose of STEM education is to prepare future generations to be innovators.
Purpose 4	The purpose of STEM education is to give people skills that make them employable and successful in their careers.
Purpose 5	The purpose of STEM education is to make a nation economically competitive on a global level.

Teachers' Quantitative Results on STEM Purpose

Table 11 presents full details of descriptives results of teachers' understanding of STEM purpose.

Table 11

Statistics for STEM Purpose for Teachers

		Purpose 1	Purpose 2	Purpose 3	Purpose 4	Purpose 5
N	Valid	20	20	20	20	20
	Missing	0	0	0	0	0
Mean		6.20	6.50	6.25	6.05	6.35
Median		6.00	7.00	6.00	6.00	6.00
Mode		6	7	6	6[a]	6
Std. Deviation		.523	.607	.786	.826	.587
Range		2	2	3	2	2

If there is one domain that most teachers agree upon is the purpose of STEM education. They may have disagreed on how STEM education must be defined, but they generally agreed on the purpose of STEM education. The only difference that exists is how much they agree. Of the five purposes of STEM, the responses range from somewhat agree to strongly agree. Only in one instance that one teacher indicated neither agree nor disagree. Concerning purpose 1, 5% of teachers somewhat agreed that the purpose of STEM education is to promote 21st century skills, 70% agreed, and 25% strongly agreed. Concerning purpose 2, 5% somewhat agreed that the purpose of STEM education is to solve real-world problems, 40% agreed, and 55% strongly agreed. Concerning purpose 3, 5% somewhat agreed that the purpose of STEM education is to prepare future generations to be innovators, 50% agreed, and 40% strongly agreed. About purpose 4, 30% somewhat agreed that the purpose of STEM education is to give people skills that make them employable and successful in their careers, 35% agreed, and another 35% strongly agreed. About purpose 5, 5% somewhat agreed that the purpose of STEM education is to make a nation economically competitive on a global level, 55%

agreed, while another 40% strongly agreed. Figure 5 gives full details about teachers' rating of STEM purposes.

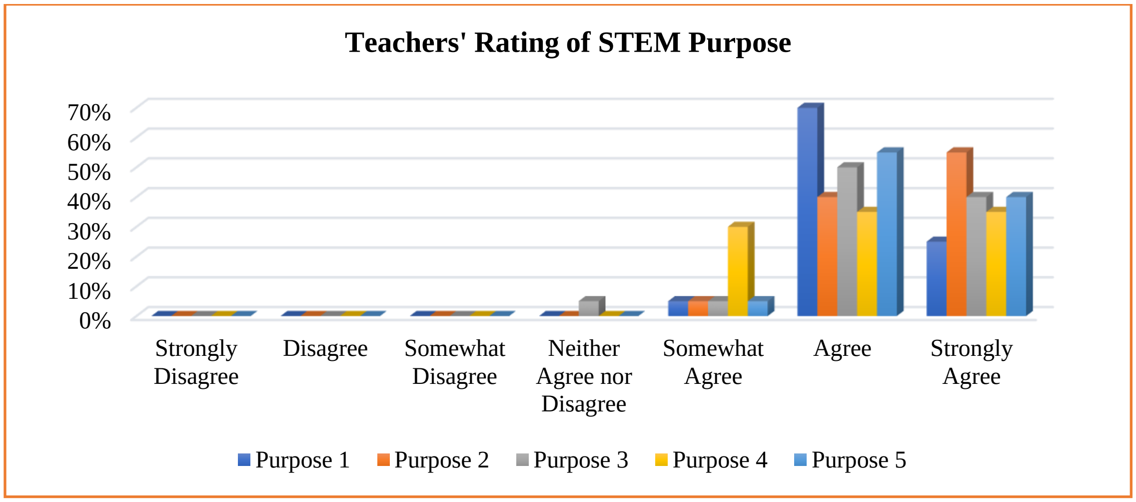

Figure 5. Teachers' Rating of STEM Purpose

Administrators' Quantitative Results on STEM Purpose

Table 12 presents full details of descriptives results of administrators' understanding of STEM purpose.

Table 12

Statistics for STEM Purpose for Administrators

		Purpose 1	Purpose 2	Purpose 3	Purpose 4	Purpose 5
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		5.50	6.60	6.70	5.80	6.20
Median		6.50	7.00	7.00	6.00	7.00
Mode		7	7	7	6[a]	7
Std. Deviation		2.068	.699	.483	1.619	1.619
Range		5	2	1	5	5

These results revealed that administrators took a slightly different stance from the teachers about the purpose of STEM. Although most of them agreed about the purpose of

STEM, a few did not agree and a few still took a neutral stance. For instance, concerning purposes 1 and 4, 10% took a neutral stance about the purpose of STEM. Regarding purpose 1, 20% of administrators disagreed that the purpose of STEM education is to promote 21st century skills, 70% agreed, and 10% remained neutral. Concerning purpose 2, all administrators agreed that the purpose of STEM education is to solve real-world problems, although 10% somewhat agreed.

If there was one purpose that all administrators agreed upon is purpose 3 “the purpose of STEM education is to prepare future generations to be innovators”, 30% agreed, and 70% strongly agreed. On purpose 4, 80% agreed that the purpose of STEM education is to give people skills that make them employable and successful in their careers, 10% disagreed, and 10% remained neutral. Similarly, 90% agreed that the purpose of STEM education is to make a nation economically competitive on a global level, and 10% disagreed. Figure 6 gives full details about administrators’ ratings of STEM purposes.

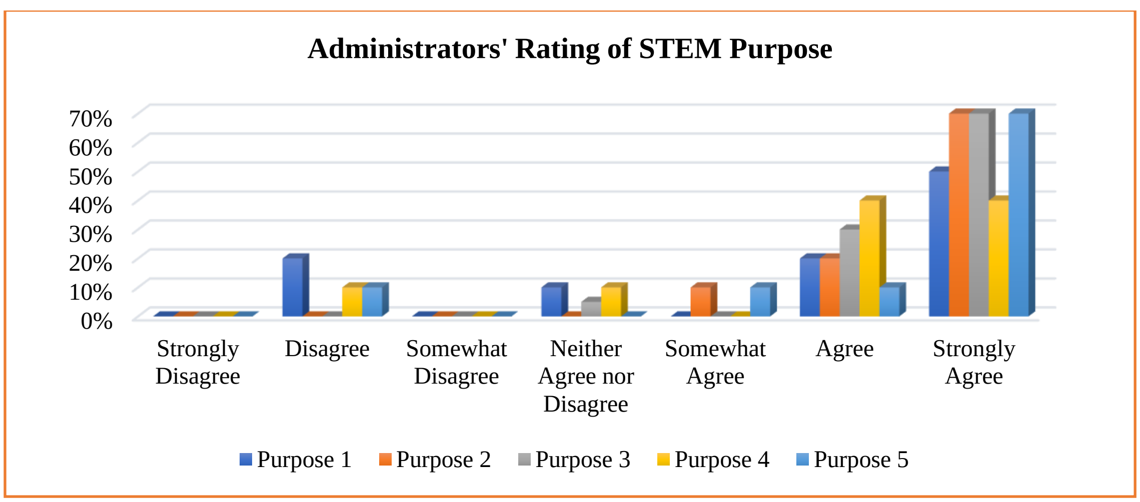

Figure 6. Administrators’ Rating of STEM Purpose

Policymakers' Quantitative Results on STEM Purpose

Table 13 presents full details of descriptives results of policymakers' understanding of STEM purpose.

Table 13

Statistics for STEM Purpose for Policymakers

		Purpose 1	Purpose 2	Purpose 3	Purpose 4	Purpose 5
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		6.20	6.50	6.00	4.50	5.80
Median		6.00	6.50	6.00	4.50	6.00
Mode		6	6[a]	6	2[a]	6[a]
Std. Deviation		.919	.527	1.491	1.958	1.619
Range		3	1	5	5	5

The policymakers differed more widely among themselves about the purpose of STEM education than teachers and administrators. Concerning purpose 1, 90% of policymakers agreed that the purpose of STEM education is to promote 21st century skills, while 10% remain neutral. If there was one purpose of STEM that policymakers agreed upon is purpose 2. All policymakers agreed that the purpose of STEM education is to solve real-world problems. Concerning purpose 3, 10% disagreed that the purpose of STEM education is to prepare future generations to be innovators, while 90% agreed. If there was one purpose of STEM that policymakers had divergent views is purpose 4. About 50% of policymakers agreed that the purpose of STEM education is to give people skills that make them employable and successful in their careers, while the other 40% disagreed, and the remaining 10% neither agreed nor disagreed. Concerning purpose 5, 80% agreed that the purpose of STEM education is to make a nation economically competitive at a global level, 10% disagreed, and the remaining 10% neither agreed nor disagreed. Figure 7 gives full details about policymakers' ratings of STEM purposes.

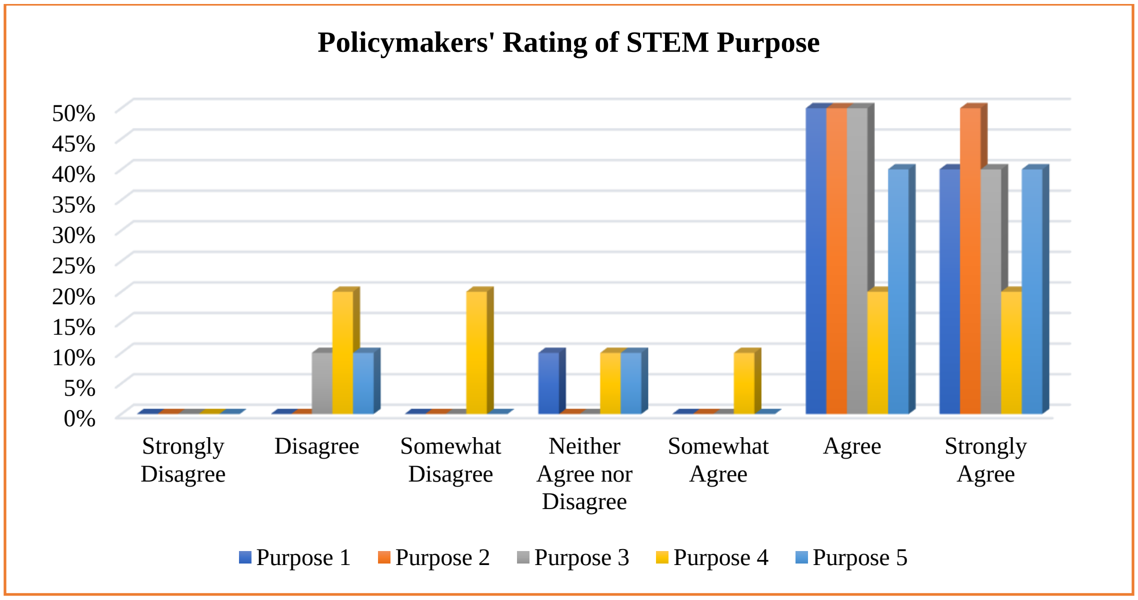

Figure 7. Policymakers' Rating of STEM Purposes

Comparing the Purpose Means of all Groups

Table 14 presents a comparison of STEM purpose means of the stakeholder groups. Teachers mean was high on purposes 1, 4, and 5. Administrators mean was high on purposes 2 and 3. While policymakers and teachers had the same means on purposes 1 and 2. Like STEM definition, policymakers had the least mean on purpose 4.

Table 14

Comparisons of Mean Scores for STEM Purpose

	Purpose 1	**Purpose 2**	**Purpose 3**	**Purpose 4**	**Purpose 5**
Teacher (*M*)	6.20	6.50	6.25	6.05	6.35
Administrators (*M*)	5.50	6.60	6.70	5.80	6.20
Policymakers (*M*)	6.20	6.50	6.00	4.50	5.80

Qualitative STEM Purpose Results

A general look at qualitative data under the purpose of STEM education shows that qualitative findings overly support the quantitative findings. Qualitative data has revealed that there is general agreement among all stakeholders about the purpose of STEM education. This is evident from the qualitative overarching themes that cut across all the stakeholder groups. Table 15 lists key codes that were used to sum up themes of STEM purpose that cut across groups.

Table 15

STEM Purpose Qualitative Codes

Purpose Codes		
Teachers	**Administrators**	**Policymakers**
❖ Imparting 21st century and life skills ❖ Promote innovation ❖ Self-employable ❖ Thinking outside the box ❖ Solve problems	❖ Imparting 21st century and life skills ❖ Produce artifacts ❖ Solve problems ❖ The country's global competitiveness ❖ Promoting innovation	❖ Preparing future generations ❖ Solve problems ❖ Promote innovation ❖ Imparting 21st century and life skills

Teachers were strong on the purpose of STEM as being that which imparts 21st century and life skills among learners. All the teachers that were interviewed acknowledged that the purpose of STEM education is to promote 21st century life skills such as critical, creative, and analytical thinking. This idea was mentioned more than 10 times across the interview transcript. This idea is reflected in quantitative results where 100% of the teachers agreed that the purpose of STEM education is to promote 21st century skills. According to Teacher 001, "The purpose of STEM education is to empower learners with real-life skills, competencies, and knowledge in the 21st century.

It responds to the needs of people – to alleviate poverty through critical thinking. It produces creative, innovative, and critical learners." For Teacher 003, "the purpose of STEM education is to produce learners who are critical, creative, and analytical in their thinking and can solve problems. It enhances creativity, innovativeness, problem-solving, and critical thinking in the learner."

The other perspective of STEM purpose that came up so strongly among the teachers is innovation. This perspective was mentioned more than eight times among the teachers. This agrees with the quantitative data where 95% of the teachers agreed that the purpose of STEM education is to prepare future generations to be innovators. According to Teacher 005:

> The purpose of STEM is to produce innovative learners who can in turn contribute to improving the economies of nations as well as the livelihood of the people at large. It is there to create a learner that is innovative and can use science, technology, engineering, and mathematics to solve problems.

Problem-solving was another perspective that kept on coming up among the teachers. The idea was coded at least seven times in the interview transcripts. This agrees with the quantitative findings where 100% of the teachers agreed that the purpose of STEM education is to solve real-world problems. According to Teacher 002, "The purpose of STEM education is to produce learners who are problem solvers and empowers them with real-life problem-solving skills in the 21st century."

Another point of view that kind of strayed and was mentioned a few times among teachers was that the purpose of STEM education is making people employable. Two teachers emphasized that the purpose of STEM education is to empower learners so that they can be creative and innovative and be able to use STEM knowledge to employ themselves. This agrees with quantitative findings where 100% of teachers agreed that the purpose of STEM education is to give people skills that make them employable. For Teacher 004, “the purpose of STEM education is to make citizens self-employable not only waiting for formal jobs and employment from the government.”

Administrators had similar perceptions as teachers. About 90% of the codes under administrators were also found among teachers. Although it is worth noting that administrators’ perceptions of STEM purpose did not coalesce around a similar theme. What this means is that not many administrators mentioned the same theme. The highest theme to be mentioned was only mentioned three times, as opposed to teachers where some themes were mentioned more than eight times. Administrators were scattered in their mention of themes. This confirms what quantitative data revealed. Under the quantitative data, administrators did not overwhelmingly agree about the purpose of STEM education.

The point of view that received a high mention among administrators is that “the purpose of STEM education is to impart 21st century and life skills to learners.” This view was the highest to be mentioned and it was only mentioned three times. In quantitative data, administrators were also somewhat divided about the purpose of STEM education. About 70% agreed that the purpose of STEM education is to promote 21st century skills, while 30% disagreed. According to Administrator 006, “the purpose of STEM education is to make individuals contribute to the global world through creativity, imagination, analytical and critical thinking who solve global challenges. It enables learners to acquire skills and knowledge which can make them survive real-world situations."

Administrators were also strong on the idea of STEM purpose as a tool for problem-solving. Administrators felt that the purpose of STEM education is to train young people to be able to solve real-world problems. This conforms with quantitative findings where 100% of administrators agreed that the purpose of STEM education is to solve real-world problems. According to Administrators 004:

> The purpose of STEM education is to help learners to generate solutions by using available resources and any other facility available to them. The purpose think that the purpose of STEM education is to make individuals contribute to the global world through solving global challenges.

One perspective which was mentioned by administrators and did not appear among teachers and policymakers is the country's global competitiveness. Two administrators emphasized that the purpose of STEM education is to raise the country's economic status to global levels. This agrees with the quantitative findings where although 10% of administrators disagreed, about 90% agreed that the purpose of STEM education is to make a nation economically competitive on a global level. According to Administrator 005, "The purpose of STEM education is to make the country relevant in the global village and also to be relevant to itself. It makes the country competitive in the global village/market."

The policymakers were not only strong about the purpose of STEM education, but they also showed passion and enthusiasm for STEM. Unlike administrators, policymakers' understanding of STEM purpose coalesced around certain themes. This is similar to the teachers' standpoint. Surprisingly though, quantitative data revealed some elements of disagreement among policymakers regarding some purposes of STEM. However, in qualitative data, policymakers showed some unanimity and spoke with one voice about their understanding of the purpose of STEM.

One viewpoint that dominated policymakers' interviews is imparting 21st century and life skills among learners. All policymakers mentioned this idea more than once. They felt that the purpose of STEM in the 21st century is to impart to citizens the 21st century and survival and life skills. Policymakers felt that to traverse the terrain of the 21st century, citizens require skills such as critical thinking, creative thinking, analytical thinking, innovation, and problem-solving. This position is heavily supported by quantitative findings where 90% of policymakers agreed that the purpose of STEM is to promote 21st century skills, although 10% remained neutral. According to Policymaker 009, the purpose of STEM education is to promote learners to be critical, creative, and analytical thinkers through the acquisition of scientific skills.

> I think that the purpose of STEM education is to make learners acquire the skills of critical thinking, and creative minds to solve problems in the community. In other words, the purpose of STEM education is to produce critical and creative thinkers (Policymaker 009).

The other idea of STEM purpose that dominated policymakers' interviews was promoting innovation. All policymakers indicated more than once the importance of innovation during our time. They acknowledged the complexity of current economies. To manage these economies on individual and national levels, policymakers felt that STEM should be able to produce innovators. Policymaker 007 emphasized that "the economy of today requires intensive innovation, therefore, the purpose of STEM is to promote innovation." This view conforms with the quantitative data where 90% of policymakers agreed that the purpose of STEM education is to prepare future generations to be innovators. According to Policymaker 010:

> The purpose of STEM education is to cultivate human resources that are able to work in the most innovative ways to bring development through innovation and invention. STEM should create innovative mindsets that can provide solutions to scientific, technological, engineering, and mathematical challenges in life.

Problem-solving was another perspective that was highly mentioned by policymakers. Policymakers felt that given the challenges the universe is facing at this time, it requires a citizenry capable of solving these problems. Policymaker 008 emphasized that "STEM education prepares the type of human resource which will be equipped with different skill sets and be able to work on their own to solve real-life challenges." This view is supported by quantitative findings where 100% of policymakers agreed that the purpose of STEM education is to solve real-world problems. According to Policymaker 009, the purpose of STEM education is to produce learners (21st century learners) with skills to solve real-world problems. "I think that STEM education should cultivate human resources so that they can work in the most innovative ways to bring development through problem-solving" (Policymaker 009).

Table 16 presents a summary of qualitative perceptions of STEM purpose that came within and across stakeholder groups. These perceptions were not only emphasized but also common between groups.

Table 16

All Stakeholders' Perceptions of STEM Purpose

Perceptions of STEM Purpose
➢ The purpose of STEM is to prepare a learner who is endowed with 21st century and life skills and competencies such as creativity, innovativeness, critical thinking, problem-solving, analytical reasoning, teamwork, communication, collaboration, and decision-making.
➢ The purpose of STEM education is to raise a nation to the level of global economic, scientific, and technological competitiveness.
➢ The purpose of STEM is to produce learners that can work towards improving the economy of the nation.
➢ The purpose of STEM education is to produce learners who can relate what they are thinking with real-world situations, learners who can translate theory and abstract concepts into real-world scenarios.
➢ The purpose of STEM education is to empower learners with real-life problem-solving skills, competencies, and knowledge in the 21st century.
➢ The purpose of STEM education is to cultivate human resources that can work in the most innovative ways to bring development through problem-solving, innovation, and invention.
➢ The purpose of STEM education is to make individuals contribute to the global world through creativity, imagination, analytical and critical thinking who solve global challenges.

STEM Learning Domain Results

Quantitative STEM Learning Results

In Table 17 are the items representing STEM learning that participants were asked to rate how much they agree or disagree with each statement. The scale ranged from strongly disagree (1) to strongly agree (7).

Table 17

Items Representing STEM Learning

Below are items that represent STEM Learning. Please rate how much you agree or disagree with each statement. Strongly Disagree (1) to Strongly Agree (7)	
Learning 1	STEM learning requires students to think in new ways.
Learning 2	STEM learning requires students to integrate concepts across different disciplines.
Learning 3	STEM learning requires students to question their understanding of the world.
Learning 4	STEM Learning requires students to actively engage in problem-solving thinking.
Learning 5	STEM learning requires students to actively construct knowledge.

Teachers' Quantitative Results on STEM Learning

Table 18 presents full details of descriptives results of teachers' understanding of STEM learning.

Table 18

Statistics for STEM Learning for Teachers

		Learning 1	Learning 2	Learning 3	Learning 4	Learning 5
N	Valid	20	20	20	20	20
	Missing	0	0	0	0	0
Mean		5.70	6.10	6.10	6.60	6.40
Median		6.00	6.00	6.00	7.00	6.50
Mode		6	6	6	7	7
Std. Deviation		1.593	.641	.641	.598	.681
Range		5	2	2	2	2

Teachers’ understanding of STEM learning tended to lean toward the same direction. The findings revealed that teachers overly agreed about STEM learning. Only in one instance that three teachers did not agree about STEM learning. In the other remaining instances, all teachers agreed about STEM learning. They only differ on how much they agreed about STEM learning. Mostly, their responses ranged from somewhat agree to strongly agree. About learning 1, 85% of teachers agreed that STEM learning requires students to think in new ways, while 15% disagreed. This is the only instance where teachers disagreed among themselves about STEM learning. Concerning learning 2 and 3, all teachers agreed that STEM learning requires students to integrate concepts across different disciplines and that STEM learning requires students to question their understanding of the world. Concerning learning 4, 65% strongly agreed that STEM learning requires students to actively engage in problem-solving thinking, 30% agreed, and 5% somewhat agreed. Concerning learning 5, 50% strongly agreed that STEM learning requires students to actively construct knowledge, 40% agreed, and 10%

somewhat agreed. Figure 8 gives full details about the teachers' ratings of STEM learning.

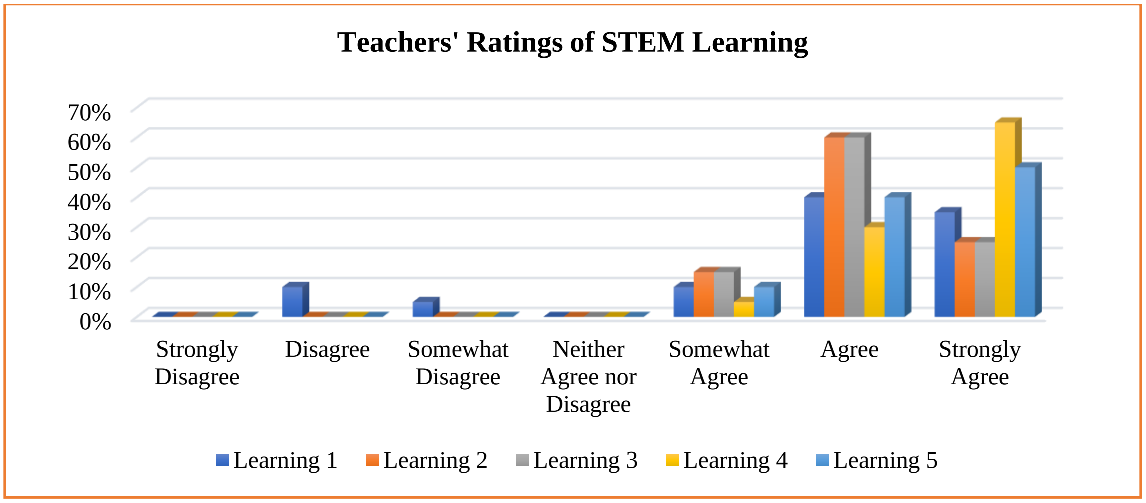

Figure 8. Teachers' Rating of STEM Learning

Administrators' Quantitative Results on STEM Learning

Table 19 presents full details of descriptives results of administrators' understanding of STEM learning.

Table 19

Statistics for STEM Learning for Administrators

		Learning 1	Learning 2	Learning 3	Learning 4	Learning 5
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		6.70	6.70	6.60	6.70	6.30
Median		7.00	7.00	7.00	7.00	6.50
Mode		7	7	7	7	7
Std. Deviation		.483	.483	.516	.483	.949
Range		1	1	1	1	3

These results revealed that administrators were on the agreeing side of how STEM learning should look like. Only on learning 5 that one administrator neither agreed nor disagreed. In all other instances, administrators' responses ranged from agree to strongly agree. Figure 9 gives full details about administrators' ratings of STEM learning.

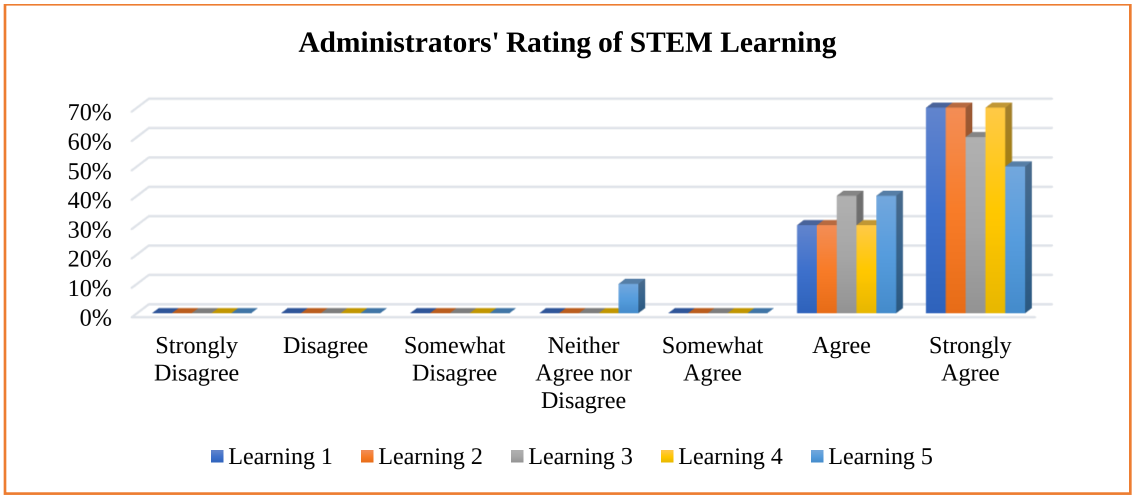

Figure 9. Administrators' Rating of STEM learning

Policymakers' Quantitative Results on STEM Learning

Table 20 presents full details of descriptives results of policymakers' understanding of STEM learning.

Table 20

Statistics for STEM Learning for Policymakers

		Learning 1	Learning 2	Learning 3	Learning 4	Learning 5
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		5.80	6.40	6.40	6.80	6.80
Median		6.00	6.50	6.00	7.00	7.00
Mode		6[a]	7	6	7	7
Std. Deviation		1.619	.699	.516	.422	.422
Range		5	2	1	1	1

The policymakers' understanding of STEM learning was not much different from the administrators. Just like the administrators, policymakers had similar opinions about how STEM learning should look like. They only disagreed on learning 1 where only one policymaker disagreed and another neither agreed nor disagreed about STEM learning 1.

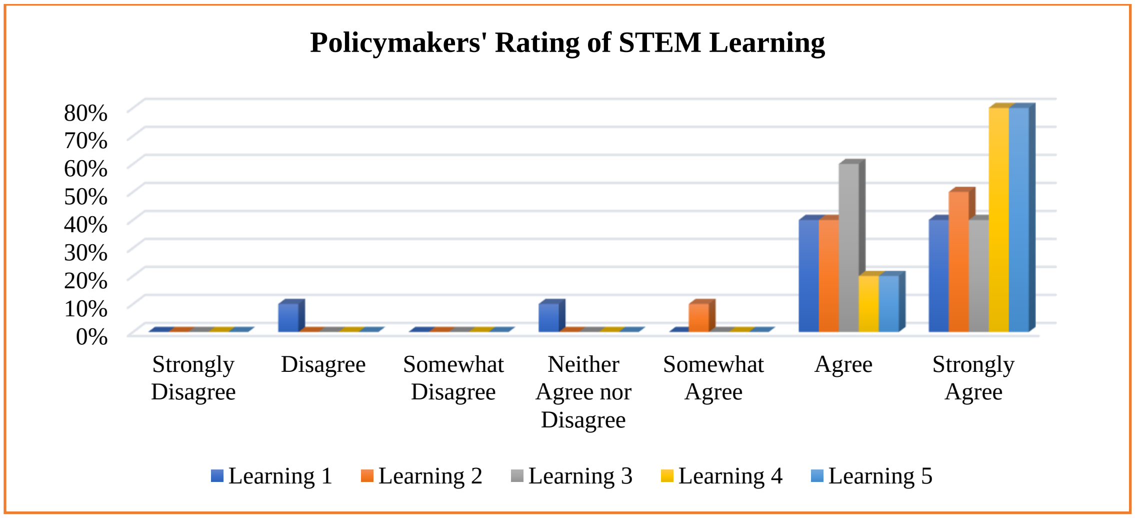

Figure 10. Policymakers' Rating of STEM Learning

In all other STEM learning perceptions, policymakers agreed on how STEM learning should look like. Their responses ranged from agree to strongly agree. Figure 10 gives full details about policymakers' ratings of STEM learning.

Comparing the Learning Means of all Groups

Table 21 presents a comparison of STEM Learning means of the stakeholder groups. Administrators had high means on Learning 1 through 3. Policymakers had high means on learning 4 and 5. Teachers in this case had the least means.

Table 21

Comparisons of Mean Scores for STEM Learning

	Learning 1	**Learning 2**	**Learning 3**	**Learning 4**	**Learning 5**
Teacher (*M*)	5.70	6.10	6.10	6.60	6.40
Administrators (*M*)	6.70	6.70	6.60	6.70	6.30
Policymakers (*M*)	5.80	6.40	6.40	6.80	6.80

Qualitative STEM Learning Results

The analysis of qualitative data concerning STEM learning revealed that all stakeholder groups had a lot to say about how STEM learning should look like. In a manner of comparison, between STEM definition, purpose, and learning, more themes came out of STEM learning as can be observed in Table 22 that presents codes that were summed up to form STEM learning themes. Similar themes came across all stakeholder groups. However, and surprisingly enough, most themes that came out of the qualitative data did not explicitly reflect the themes in the quantitative data. The qualitative themes were more of a stand-alone and did not speak much to the quantitative findings.

Table 22

STEM Learning Qualitative Codes

Learning Codes		
Teachers	**Administrators**	**Policymakers**
❖ Oriented toward problem-solving	❖ Move away from the traditional approach	❖ Solution-based
❖ Project-based	❖ Constructivist approach	❖ Constructivist approach
❖ Research-based	❖ Hands-on	❖ Empowering
❖ Learners centered	❖ Practice-oriented	❖ Evidence-based
❖ Inquiry-based	❖ Inquiry-based	❖ Lifelong project
❖ Engaging	❖ Empowering	❖ Artifacts
❖ Wholistic	❖ Discovery-based	❖ Problem-solving
❖ Integrative	❖ Research-based	❖ Integrative
❖ Constructivist approach	❖ Learner-centered	❖ Hands-on
❖ Practice-oriented		❖ Project-based
❖ Promoting life skills		❖ Promote life skills

Many codes were derived from teachers' understanding of STEM learning, but the common ones were problem-solving, promoting life skills, learner-centered, and practice (research, project, inquiry) based learning. About 90% of teachers mentioned problem-solving-based kind of learning. The teachers felt that STEM came about because of the challenges that the world is facing today. Hence, if we are to fully attend to these challenges, we need a kind of education oriented toward problem-solving, where learners are taught from an early age how to solve problems. Teacher 003, for instance, emphasized that "I think STEM learning should engage learners in more research work concerning problems faced by the world and I feel facilities should be made available for learners to engage in such with fewer difficulties." According to Teacher 005:

> In STEM learning, there must be a key question to probe student learning and then learners must be empowered to find answers to the key question. STEM learning should encourage learners to come up with solutions to the problems of our time.

Another idea that kept recurring among teachers was that STEM learning must be practical – that is project-, research-, and inquiry-based learning. Most teachers felt that traditionally, education is filled with theory and less practice. Therefore, teachers felt that if STEM learning is to be meaningful and relevant, it must bring in the aspect of practice. Several teachers gave a scenario where Zambia has a lot of graduates who cannot practice or apply what they learned in school to real-life situations. This is because to this day education prioritizes theory over practice. Therefore, if STEM learning is to remain true to its essence, it has to embrace practice-based learning. In explaining this point most teachers linked practice-oriented to project-based learning, inquiry-based learning, and research-based learning. Teacher 004 emphasized that "I think STEM education can be best learned through research. It should be practice-oriented where you allow learners to research solutions to the problem presented to them. In this way, STEM is learned by inquiring, discovering, and researching."

Teachers also felt that STEM learning must be learner-centered. Several teachers acknowledged that teacher and content-centered learning is still at large in schools. However, they felt that the true nature of STEM must be learner-centered – putting learners at the center of learning.

The other point of view highlighted by several teachers was promoting life skills. Several teachers felt that STEM learning must be skills oriented. If learners are to fit and survive in the world, they will need skills. One teacher emphasized that "STEM learning should produce learners who are creative, analytical, and innovative with what they do – to promote critical thinking and innovation" (Teacher 005).

Another perspective that was mentioned by a few teachers and surprisingly this theme cut across all stakeholder groups is the constructivist approach to learning. Teachers felt that in STEM learning, learners must be able to construct their own knowledge. This view conforms with the quantitative data where all teachers agreed that STEM learning requires students to actively construct knowledge. According to Teacher 002:

> For too long now, educators have felt that students are like empty tins that need to be filled with content. This is a kind of traditional education where learners are

fed with information. It was perceived that learners come to school without prior knowledge and experience. However, STEM learning takes a different approach. It is a learning that not only encourages knowledge construction but also fosters the construction of new knowledge among learners. STEM approaches acknowledge that learning must be constructivist in philosophy.

Just like teachers, the themes that came up among the administrators did not reflect much of the themes in quantitative data except for one. One theme that almost all administrators mentioned is that STEM learning must be practice oriented. In reference to practice-oriented, some administrators used phrases such as discovery-based, research-based, inquiry-based, or hands-on. Like teachers, administrators felt that for STEM to be meaningful and relevant in the Zambian context, it has to embrace the practice approach. For instance, Administrator 007 emphasized that "STEM learning should encourage more of research – collaborative learning, practice of what they think should be done."

Another idea that administrators frequently mentioned was that STEM learning must be learner centered. Administrator 005 for instance, emphasized that "STEM learning should be learner-centered where teachers are mere facilitators and consolidate the teaching and learning process." Administrator 004 said that "STEM learning should be learner-centered as opposed to teacher-centered and content-centered."

Another idea that was mentioned by administrators was that STEM learning must move away from traditional approaches to constructivist approaches. Several administrators felt that there is a lot of recitation, memorizing, and repetition in learning. Hence, advocating for new approaches to learning. One administrator emphasized that

“STEM learning must move away from memorization and recitation. STEM learning should be a kind of learning which enables learners to create their own knowledge by formulating hypotheses and sorting the hypotheses” (Administrator 007). Administrator 006 concluded that “STEM learning must move away from positivism to constructivism.” This agrees with quantitative data where 90% of administrators agreed that STEM learning requires students to actively construct knowledge.

Policymakers’ understanding of STEM learning was very scanty. This is surprising because policymakers had the most comprehensive definitions and purposes of STEM understanding. To find out that they are scattered about STEM learning is surprising. However, one idea that dominated policymakers’ understanding of STEM learning is the constructivist approach to learning. This theme cuts across the other stakeholder groups but it was the most emphasized among policymakers. This finding agrees with the quantitative data where 100% of policymakers agreed that STEM learning requires students to actively construct knowledge. Policymaker 010 emphatically said that “STEM learning should be constructivist in approach so that learners construct their own knowledge and become co-creators of knowledge.”

Policymakers also emphasized the development of skills among learners. They felt that STEM learning should promote life skills among learners so that they can survive the hostile world. This idea conforms to the quantitative findings where 100% of policymakers agreed that STEM learning requires students to actively engage in problem-solving thinking. One policymaker emphasized that “STEM learning must promote learners' thinking so as to be innovative and creative in solving problems in their communities" (Policymaker 010). Another policymaker maintained that "STEM learning should be designed to produce a learner who is a critical, creative, and analytical thinker" (Policymaker 009). It was clear among policymakers that in STEM learning,

> Learners must be able to think about problems and be able to come up with solutions, learners must be exposed to the challenges of the day and allowed to devise their own solutions to the problems of the world. Empowering learners to be able to solve problems (Policymaker 010).

Another idea that came out strongly among policymakers is hands-on. Unlike teachers and administrators, who used the term practice, policymakers unanimously and overwhelmingly used the phrase hands-on. Policymakers feel that STEM learning must be hands-on where learners are given the opportunity to do and make things. Policymakers 009, for instance, emphasized that "STEM learning must be hands-on, that is, projects and activities involving modern technology with a strong balance between the classroom and the communities pupils live." Another policymaker pointed out that "STEM learning must produce artifacts – produce a product that will make them earn a living. Use STEM subjects to produce products" (Policymaker 008).

Table 23 presents a summary of qualitative perceptions of STEM learning that came within and across stakeholder groups. These perceptions were not only emphasized but also common between groups.

Table 23

All Stakeholders' Perceptions of STEM Learning

Perception of STEM learning
➢ STEM education can be best learnt through research. You allow learners to research solutions to the problem presented to them. They this way STEM is learnt by inquiring, discovering, and researching.
➢ STEM learning must take into account the full or holistic and integrated approach of both knowledge acquisition and skills development.
➢ STEM learning should be learner-centered where teachers are mere facilitators and consolidate the teaching and learning process.
➢ STEM learning should be constructivist in approach so that learners construct their own knowledge and become co-creator of knowledge.
➢ STEM teaching should allow learners to collaborate with their friends so as to encourage teamwork, critical thinking, and innovation among learners.
➢ STEM learning must be able to actively engage learners such that they become full and active participants in their own learning.

STEM Teaching Domain Results

Quantitative STEM Teaching Results

In Table 24 are items representing STEM teaching that participants were asked to rate how much they agree or disagree with each statement.

Table 24

Items Representing STEM Teaching

Below are items that represent STEM Teaching. Please rate how much you agree or disagree with each statement. Strongly Disagree (1) to Strongly Agree (7)	
Teaching 1	STEM teaching requires project-based teaching methods.
Teaching 2	STEM teaching requires using inquiry-based methods.
Teaching 3	STEM teaching requires artifacts to assess student learning and mastery of content.
Teaching 4	STEM teaching requires presenting real-life problems to learners.
Teaching 5	STEM teaching must involve teaching that enhances teamwork, communication, critical thinking, and innovation.

Teachers' Quantitative Results on STEM Teaching

Table 25 presents full details of descriptives results of teachers' understanding of STEM teaching.

Table 25

Statistics for STEM Teaching for Teachers

		Teaching 1	**Teaching 2**	**Teaching 3**	**Teaching 4**	**Teaching 5**
N	Valid	20	20	20	20	20
	Missing	0	0	0	0	0
Mean		6.15	6.30	5.70	6.50	6.75
Median		6.00	6.00	6.00	7.00	7.00
Mode		6	6	6	7	7
Std. Deviation		.671	.470	1.455	.607	.444
Range		2	1	5	2	1

The teachers' understanding of STEM teaching did not vary much except on teaching 3 where two teachers disagreed and one neither agreed nor disagreed. The overall findings of teachers' understanding of STEM teaching revealed that teachers mostly agreed about how STEM teaching should look like. Their responses ranged from somewhat agree to strongly agree. Concerning teaching 1, 15% of teachers somewhat agreed that STEM teaching requires project-based teaching methods, 55% agreed, and 30% strongly agreed. Concerning teaching 2, 100% agreed that STEM teaching requires using inquiry-based methods. Of the 100%, 70% agreed while 30% strongly agreed. It was about teaching 3 where teachers had divergent views about STEM teaching. About 85% agreed that STEM teaching requires artifacts to assess student learning and mastery of content, while 10% disagree, and 5% neither agreed nor disagreed. Concerning teaching 4, 5% somewhat agreed that STEM teaching requires presenting real-life problems to learners, 40% agreed, and 55% strongly agreed. Concerning teaching 5, all teachers agreed that STEM teaching must involve teaching that enhances teamwork, communication, critical thinking, and innovation. Figure 11 gives full details about teachers' ratings of STEM teaching.

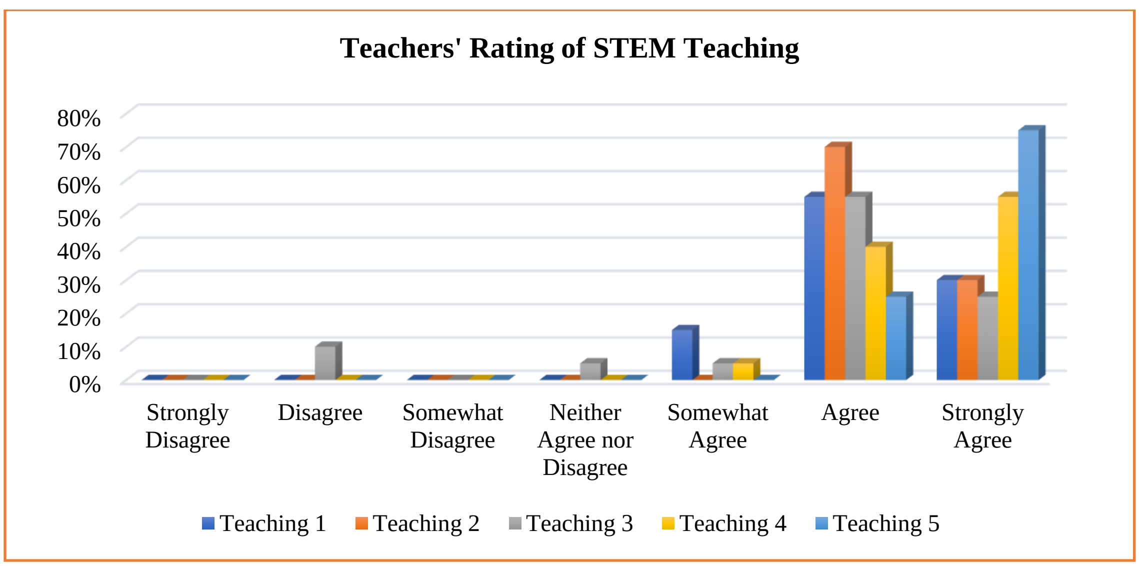

Figure 11. Teachers' Rating of STEM Teaching

Administrators' Quantitative Results on STEM Teaching

Table 26 presents full details of descriptives results of administrators' understanding of STEM teaching.

Table 26

Statistics for STEM Teaching for Administrators

		Teaching 1	Teaching 2	Teaching 3	Teaching 4	Teaching 5
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		6.50	6.20	6.30	6.50	6.70
Median		6.50	6.50	6.50	7.00	7.00
Mode		6[a]	7	7	7	7
Std. Deviation		.527	1.033	.823	.707	.483
Range		1	3	2	2	1

The administrators' understanding of STEM teaching just like teachers, did not differ much. Their understanding of STEM teaching coalesces around agreeing except on teaching 2 where one administrator neither agreed nor disagreed. Their responses ranged from somewhat agree to strongly agree. Concerning teaching 1, 50% agreed that STEM teaching requires project-based teaching methods, while the other 50% strongly agreed. Concerning teaching 2, 10% neither agreed nor disagreed that STEM teaching requires using inquiry-based methods, 10% somewhat agreed, 30% agreed, and 50% strongly agreed. About teaching 3, 20% somewhat agreed that STEM teaching requires artifacts to assess student learning and mastery of content, 30% agreed, and 50% strongly agreed. Concerning teaching 4, 10% somewhat agreed that STEM teaching requires presenting real-life problems to learners, 30% agreed, and 60% strongly agreed. Concerning teaching 5, all administrators agreed that STEM teaching must involve teaching that enhances teamwork, communication, critical thinking, and innovation. Figure 12 gives full details about administrators' ratings of STEM teaching.

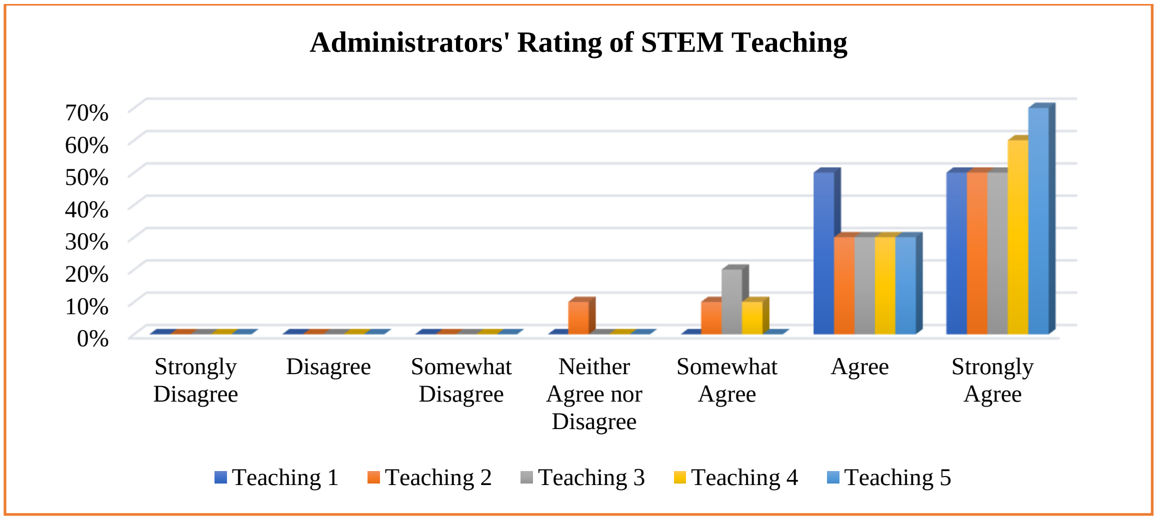

Figure 12. Administrators' Rating of STEM Teaching

Policymakers' Quantitative Results on STEM Teaching

Table 27 presents full details of descriptives results of policymakers' understanding of STEM teaching.

Table 27

Statistics for STEM Teaching for Policymakers

		Teacher 1	Teacher 2	Teacher 3	Teacher 4	Teacher 5
N	Valid	10	10	10	10	10
	Missing	0	0	0	0	0
Mean		6.40	6.70	5.30	6.30	6.80
Median		6.50	7.00	5.50	6.50	7.00
Mode		7	7	7	7	7
Std. Deviation		.699	.483	1.636	.949	.422
Range		2	1	5	3	1

Policymakers' understanding of STEM teaching also did not differ much except in two instances where one policymaker disagreed and three neither agreed nor disagreed about some aspects of STEM teaching. Generally, policymakers' understanding of STEM teaching leaned toward agreeing. Concerning teaching 1, 10% of policymakers somewhat agreed that STEM teaching requires project-based teaching methods, 40% agreed, and 50% strongly agreed. Concerning teaching 2, 30% agreed that STEM teaching requires using inquiry-based methods, while 70% strongly agreed. It was about teaching 3 that policymakers' opinions varied. About 10% disagreed that STEM teaching requires artifacts to assess student learning and mastery of content, 20% neither agreed nor disagreed, 20% somewhat agreed, 20% agreed, and 30% strongly agreed. Concerning teaching 4, 10% neither agreed nor disagreed that STEM teaching requires presenting real-life problems to learners, 40% agreed, and 50% strongly agreed. Concerning teaching 5, all policymakers agreed that STEM teaching must involve teaching that enhances teamwork, communication, critical thinking, and innovation. Figure 13 gives full details about policymakers' ratings of STEM teaching.

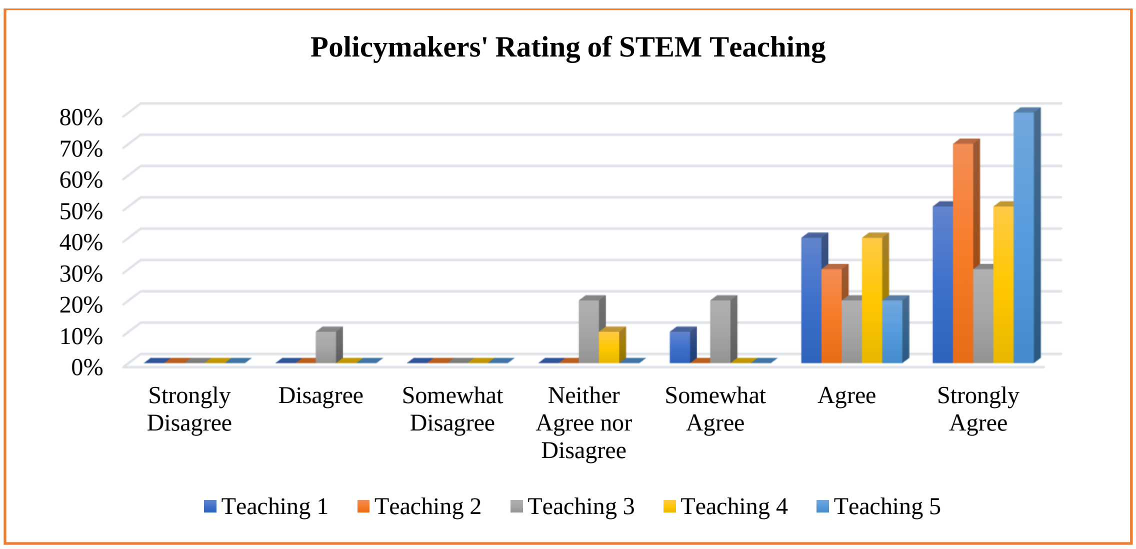

Figure 13. Policymakers' Rating of STEM Teaching

Comparing the Teaching Means of all Groups

Table 28 presents a comparison of STEM teaching means of the stakeholder groups.

Table 28

Comparisons of Mean Scores for STEM Teaching

	Teaching 1	**Teaching 2**	**Teaching 3**	**Teaching 4**	**Teaching 5**
Teacher (*M*)	6.15	6.30	5.70	6.50	6.75
Administrators (*M*)	6.50	6.20	6.30	6.50	6.70
Policymakers (*M*)	6.40	6.70	5.30	6.30	6.80

Qualitative STEM Teaching Results

Table 29

STEM Teaching Qualitative Codes

STEM Teaching Codes		
Teachers	**Administrators**	**Policymakers**
❖ Problem-based teaching	❖ Integrative	❖ Problem-Based
❖ Teacher facilitator	❖ Practical	❖ Progressive teaching
❖ Learner-centered	❖ Hands-on	❖ Constructivist
❖ Move away from traditional methods of teaching	❖ Learner-centered	❖ Move away from traditional methods
❖ Interdisciplinary	❖ Problem-based	❖ Artifacts
❖ Provoking	❖ Research-based	❖ Teamwork
❖ Foster curiosity	❖ Inquiry-based	❖ Integrative
❖ Research-based	❖ Discovery-based	❖ Practical
❖ Hand-on	❖ Teamwork	❖ Teacher facilitator
❖ Discovery-based	❖ Teacher facilitator	❖ Project-based
❖ Practical	❖ Promoting life-skills	❖ Inquiry-based
❖ Promote creativity		❖ Real-time meaning
❖ Inquiry-based		❖ Promoting life skills

Analysis of STEM teaching qualitative data revealed a close association between qualitative findings and quantitative findings. Almost all the themes that came out of qualitative data were reflected in quantitative data. Of all the STEM domains studied in this study, STEM teaching qualitative results and quantitative results have the closest relationship. Table 29 lists the common qualitative codes that were used to sum up the STEM purpose themes.

Almost all the teachers' qualitative themes are reflected in quantitative data. This shows how teachers' understanding of STEM teaching does not differ much. These themes were mentioned by almost all those interviewed. Teachers felt that the point of departure for STEM teaching should be learner centered. Most teachers emphasized that the focal point for STEM teaching should be the learner. Teachers felt that in most cases, teachers take the center stage in the teaching and learning processes. Hence, they urged that if STEM must succeed it has to center the learning process on the learners themselves. Teacher 003 pointed out that:

> STEM teaching should be pupil centered. It should be structured in such a way that the teacher is a facilitator and learners do most of the work on their own. The teacher is just there to guide and supervise and not to take the center stage.

Teacher 003 went on to say that:

> STEM teaching should depart from the conventional methods of memorization, dictation, and recitation. Rather, STEM teaching must embrace learner-centered approaches where learners are empowered and become the center stage of

> learning. STEM teaching must present a problem to learners and then learners must go and research or find solutions to the problem.

The teachers were also strong on STEM teaching as being inquiry-based. In reference to inquiry-based, other teachers used terms such as research-based, discovery teaching, provoking, and fostering curiosity. This idea agrees with quantitative data where 100% of teachers agreed that STEM teaching requires using inquiry-based methods. The teachers felt that if STEM is to take root on Zambian soil, it must embrace an inquiry aspect of teaching. Teacher 005, for instance, emphasized that:

> STEM teaching must develop a different approach to asking questions – questions must not be asked in such a way that they are not leading to answers – these questions must be open-ended to allow learners to explore and not closed-ended questions that only provide YES or NO answers. Questions must be thought-provoking and must foster curiosity. In short, STEM teaching must be inquiry-based and discovery learning.

The other perspective that dominated qualitative data among the teachers was project- or problem-based teaching. Teachers felt that given that the nature of STEM education is confronting real-life problems or challenges, STEM teaching must use problem-based teaching methods. This conforms with the quantitative data where 100% of teachers agreed that STEM teaching requires project-based teaching methods. It also conforms with the other quantitative theme where 100% of teachers agreed that STEM teaching requires presenting real-life problems to learners.

Another idea that is worth noting was promoting creativity and life skills. Teachers felt that since the true nature of STEM is to give people skills and to prepare them to be innovators, STEM teaching has to be skills oriented. This means that teachers must bear in mind that learners need skills that will make them relevant and useful to themselves and the nation at large. This agrees with quantitative data where all teachers agreed that STEM teaching must involve teaching that enhances teamwork, communication, critical thinking, and innovation. Teacher 002 emphasized that “STEM teaching must be structured in a way that learners can come up with different creative and innovative ideas and projects.”

Another fascinating code that came out of teachers' qualitative data was the interdisciplinary aspect of STEM. Teachers felt that genuine STEM teaching must be interdisciplinary in approach. Given that STEM education entails an interdisciplinary approach to teaching and learning, STEM teaching must embrace the interdisciplinary approach. According to Teacher 004, “STEM teaching must be interdisciplinary in nature and must capture knowledge and skills needed for survival.”

All the points raised by administrators were also raised by teachers. This indicates how teachers and administrators have a similar understanding of STEM teaching. Although administrators did not raise many ideas as teachers did. Administrators were strong on STEM teaching being research-based. In reference to research-based, some administrators used phrases such as inquiry-based and discovery-based. This finding agrees with the quantitative data where 90% of administrators agreed that STEM teaching requires using inquiry-based methods. Administrators felt that STEM would not be

STEM if it did not embrace discovery-based approaches to teaching. Administrator 006, for instance, emphasized that:

> STEM teaching should be discovery and inquiry-oriented and should promote research on real-life problems to offer solutions. STEM teaching must use research-based methods where learners are encouraged to research other than being spoon-fed by teachers – they should research to be able to find knowledge themselves. Because I think that STEM teaching must also use inquiry-based methods where learners are empowered to inquire about answers for themselves.

The other point of view that dominated administrators was that STEM teaching must be learner-centered and that teachers must be mere facilitators. Administrators felt that there would be no point in introducing STEM if STEM teaching is not centered on the learner. That is, there would be no difference between STEM teaching and other forms of teaching if STEM teachers did not take the role of facilitation. Administrator 007 emphasized that "in STEM teaching, the learner must take the center stage – the teacher becomes a facilitator to challenge learners — that is, STEM teaching should be structured in such a way that it is centered on the learner."

The other perspective that almost every administrator could not resist mentioning was that STEM teaching must be practical, hands-on, and problem-based. This idea agrees with quantitative data where all administrators agreed that STEM teaching requires project-based teaching methods. Administrators felt that the introduction of STEM education in the country is to encourage hands-on kind of learning. Therefore, if STEM teaching does not embrace this approach, it will lose its essence. Like teachers, administrators were also keen to indicate that STEM teaching must promote life skills among learners. This agrees with quantitative findings where all administrators agreed that STEM teaching must involve teaching that enhances teamwork, communication, critical thinking, and innovation. Administrators felt that anyone who graduates in STEM must at least have life skills to be useful to themselves and the nation at large. Life skills are very critical, such that STEM teaching must endeavor to promote them. According to Administrator 006, “STEM teaching should involve creativity, resourcefulness, collaboration, the ability to guide and relate learning experiences to real societal issues. It should emphasize teamwork, imagination, creativity, and analytical and critical thinking.”

Just like teachers and administrators, policymakers raise similar points as can be observed in Table 29. Over 95% of codes that came out of policymakers’ transcripts were also mentioned among teachers and administrators. This indicates how all stakeholder groups had similar views about STEM teaching. Policymakers were strong on life skills and teamwork. Policymakers felt that the true meaning of STEM teaching requires that it promotes life skills and teamwork. This idea is highly reflected in quantitative data where 100% of policymakers agreed that STEM teaching involves teaching that enhances teamwork, critical thinking, and innovation. Policymakers felt that STEM education will only become relevant if it can promote life skills among learners and at the same time encourage teamwork among learners. Reflecting on some cultural aspects of Zambia, one policymaker argued that culturally, we are not individuals, rather, we are a unity, and we much work as such. STEM education can facilitate bringing about this cultural value.

Therefore, STEM teaching must endeavor to promote these life skills, especially teamwork (Policymaker 008). Policymaker 009 pointed out that:

> STEM teaching should allow learners to collaborate with their friends so as to encourage teamwork among them. STEM teaching must enhance teamwork, critical thinking, communication, and innovation. Facilitation in STEM should promote critical, creative, and analytical thinking in learning by exposing learners to real-life problems where they are required to design real-time solutions.

Another point that policymakers were strong about was integration. Most policymakers in trying to expound on how STEM teaching must look like, they referred to their definition of STEM. About 70% of policymakers agreed that STEM education is the purposeful and meaningful integration of two or more STEM subjects. Policymakers felt that STEM education is integrative in nature. Therefore, if STEM education is to return its true meaning, STEM teaching must be integrative. Policymakers felt that STEM teaching must be able to integrate STEM domains. One policymaker emphasized that "STEM teaching must integrate STEM subjects. STEM education can only become STEM when there is an aspect of integration. It must be an integration of STEM subject areas with problem-solving approaches" (Policymaker 005).

Like teachers and administrators, policymakers believe that STEM teaching must be practical, inquiry-, and project-based. This conforms with quantitative data where all policymakers agreed that STEM teaching requires project-based teaching methods. Similarly, 100% of policymakers agreed that STEM teaching requires using inquiry-based teaching methods. Most policymakers called for STEM teaching to embrace inquiry- and project-based teaching methods. Policymaker 010 pointed out that:

> Teachers must use projects and inquiry-based methods. STEM teaching must produce a prototype – come up with projects whereby learners can apply what they learn in class to a real-life situation. In the traditional kind of teaching, the application component is missing. However, STEM teaching must incorporate the application aspect of teaching by encouraging the production of artifacts.

Table 30 presents a summary of qualitative perceptions of STEM teaching that came within and across stakeholder groups.

Table 30

All Stakeholders' Perceptions of STEM Teaching

Perceptions of STEM Teaching
➢ STEM teaching should be centered on learners, should be discovery- and inquiry-oriented, and should promote research on real-life problems to offer solutions.
➢ STEM teaching must use research-based methods where learners are encouraged to research their own answers other than being spoon-fed by teachers – they should research to be able to find knowledge themselves.
➢ STEM teaching must combine/integrate the four domains of STEM so that learners see the science aspect, math aspect, technology aspect, and engineering aspect.
➢ STEM teaching must embrace a paradigm shift, to shift from positivist to constructivist approaches to teaching.
➢ STEM teaching should allow learners to collaborate with their friends so as to encourage teamwork, critical thinking, and innovation among learners.
➢ STEM teaching must embrace learner-centered approaches where learners are empowered and become the center stage of learning.

STEM Vision and Relevance Domains Results

On top of the four STEM domains (STEM definition, purpose, learning, and teaching), more qualitative data were collected on two additional domains – STEM vision and relevance. The researcher wanted to have a glimpse of stakeholders' vision of STEM and what they thought the relevance of STEM was. Several themes came out of this data as shown in Table 31 that presents codes that were used to sum up STEM vision and relevance themes that cut across groups.

Table 31

STEM Vision and Relevance Codes

STEM Vision and Relevance Codes			
	Teachers	**Administrators**	**Policymakers**
Vision of STEM	❖ Way to go in 21st century ❖ A good approach to education ❖ Zambianized ❖ Fundamental to the economy	❖ Way to go in 21st century ❖ Good program ❖ Re-imagined ❖ Recommended	❖ Way to go in 21st century ❖ Desirable approach ❖ Re-organized ❖ Zambianized
Relevance of STEM	❖ For economic growth ❖ Problem-solving ❖ Artifacts	❖ Applicable to real-life ❖ Attend to present challenges	❖ Empowerment ❖ Future generations ❖ Improve lives ❖ Applicable to real-life

If there was any area in this study that all stakeholders spoke unanimously, confidently, and passionately, was about STEM vision. All stakeholders were very clear about their vision of STEM education. They spoke about the vision of STEM in terms of where they wanted STEM to be, progress, and what must be done. Stakeholders may have differed about STEM definition or purpose, but they remained united about the vision of STEM. This is evident from the themes that cut across all stakeholder groups.

Pertaining to the vision of STEM, teachers, administrators, and policymakers, all mentioned that the point of departure for STEM education in Zambia is that it must be tailored to the Zambian context before rolling it out. The stakeholder groups used different phrases for this theme but meant the same thing. The teachers for instance said that STEM must be Zambianized if it must take root on Zambian soil. Teacher 004, for instance, said that “when STEM started in the country, it was rushed such that there was no preparedness on the part of the key and grassroots stakeholders. If STEM is to continue and take root on Zambian soil, it must be revised, adjusted, and reintroduced. In short, it must be Zambianized.” Administrators said that STEM education must be re-imagined. While policymakers said that it must be changed to suit the Zambian context. Policymaker 008, for instance, said that:

> My vision for STEM education is that there is hope and it is the way to go. However, there is a need to change the curriculum and adapt it to the Zambian context other than the way it is borrowed from other countries. If adapted and taught properly, STEM education has the potential to bring about the change that the country is seeking.

Demonstrating their passion for STEM education, all stakeholders pointed out that STEM is the way to go and that it is a good approach to teaching and learning. Teacher 003, for instance, said that:

STEM is a viable and good concept. STEM is the way to go if the country is to develop and attain sustainable development goals. As things stand in the country, there are no formidable industries to talk about. If the country is to develop industries that produce things, there is a need to produce learners who can think critically and those who can participate in the development of industries and the country's economy. I would love to see a scenario where Zambia as a country embraces STEM, in this way, the country would not depend on other countries for technological innovations given that STEM education enhances technological innovations. STEM education is the way to go in this 21st century, especially for underdeveloped countries.

According to Teacher 004:

STEM is a good approach to teaching and learning in this 21st century. It is a good idea that only needs to be redefined so as to fit and reflect the Zambian context. It is a positive way of teaching and learning.

Administrators were also emphatic about STEM being the 'way to go'.

Administrator 005 said that:

My vision of STEM education is that it is the way to go because it makes education relevant and contextual. If our nation is to develop and reach the level of other developed countries, we need STEM education because it produces learners who are critical, creative, and analytical to foster national development.

Administrator 004 concluded that, “my vision of STEM education is that it is the way to go, and it is achievable if well planned and coordinated. It is a good approach that challenges learners in a manner that brings out critical thinking.”

Policymakers took their vision of STEM education to another level. They strongly believe that STEM education is the answer to the questions and challenges of the 21st century and that it is a desirable approach to teaching and learning. Policymaker 009, for instance, pointed out that:

> My vision of STEM education is that it is the way to go. Given the world that we live in, and the technological and scientific advancement that we witness, Zambia as a nation needs STEM education to be at the same level as other countries. We live in a changing world that requires different ways of doing things. Thus, STEM education is that one component that can make Zambia be at par with other developed countries.

About the relevance of STEM education, all stakeholder groups spoke with one voice about the importance of STEM education to the economic growth of the country. They also believe that STEM is not only relevant to the nation but also to individual learners. Teacher 003 said that:

> One of the reasons that STEM education emerged is because of the problems faced by the country. And one way that these problems especially, economically, scientifically, and technologically can be solved is by turning to STEM education. STEM education can provide life-long skills to learners who in turn can attend to the problems of our time. STEM education becomes relevant in the sense that it

> becomes a goal between raw materials and finished products. Through STEM education, citizens will be able to develop skills, knowledge, and competencies to be able to make finished products out of raw materials. STEM education is very relevant because Zambia is lagging when it comes to solving its problems, and innovations. If STEM is realized, it will sort out our problems as a country.

Similarly, Administrator 007 said that:

> STEM education is very relevant to dealing with the challenges of our country – because it produces learners who can attend to the challenges of our country. STEM education is relevant because it helps learners to bring out their potential and to come up with tangible artifacts. It makes education at large applicable in real life.

In a similar vein, policymakers acknowledged the importance of STEM education to the nation. One policymaker argued that:

> STEM education is very relevant to Zambia because it provides necessary skills to learners that make them self-employable. Meaning that graduating learners will not have to wait for formal employment, rather with STEM skills they will be able to employ themselves" (Policymaker 009).

Policymaker 010 concluded that:

> The relevance of STEM education cannot be over emphasized in the Zambian context. STEM education provides learners with application skills that they can use even when they drop out of school. Those who pass through STEM education can appropriate skills that they can use in their lives.

CHAPTER V

DISCUSSION

This chapter begins with a reminder of the main purpose of this study and its research questions. Next, the key findings of the study will be briefly summarized here. The main body of the chapter will discuss and interpret the key findings of the study. These key findings will be discussed and interpreted by answering each research question. After the main body, the implications and limitations of the study will also be discussed. The chapter will conclude with the recommendation section.

Discussion

The primary aim of this study was to explore key STEM stakeholders' perceptions of STEM education in Zambia. STEM education has become a buzz phrase in the education arena in Zambia, and yet, we know little about what those involved in STEM think or know about STEM education. In order to better understand perceptions of STEM from a holistic perspective, it was crucial to investigate the perceptions of STEM held by key stakeholders (teachers, administrators, and policymakers) in the domains of STEM vision, STEM definition, STEM purpose, STEM relevance, and STEM learning and teaching. The study compared the perceptions of STEM among STEM teachers, administrators, and policymakers. The following research questions guided the study:

1. How do STEM teachers, STEM administrators, and STEM policymakers perceive STEM education?

(a) How do they define STEM education?

(b) How do they perceive the purpose of STEM education?

(c) How do they perceive STEM teaching and learning?

2. How do the perceptions of STEM: STEM vision, STEM definition, STEM purpose, STEM relevance, and STEM teaching and learning compare among STEM teachers, STEM administrators, and STEM policymakers?

The results of the study indicate that there is a general passion among stakeholders to see a successful implementation story of STEM in the country. The results show that the stakeholders expressed their interest in STEM and pointed out that STEM is the way to go if Zambia must traverse the economic, scientific, environmental, technological, and the social cultural terrains of the 21st century. The results further indicate that there were overall themes that were peculiar to a stakeholder group and those that were common across all stakeholder groups for each of the STEM perception domains. However, it must be noted that, in as much as stakeholders showed interest in STEM and that there were common themes across stakeholder groups, the results also suggest minor degrees of disagreement among stakeholders pertaining to some perceptions of STEM. The general conclusion of the findings reveals minor differences within and between stakeholder groups. However, there is general agreement within and between groups about STEM education. The results reveal coherence and/or collaboration within and between groups about STEM education in the country. Most stakeholders think the same about STEM in the country.

How do STEM teachers, STEM administrators, and STEM policymakers perceive STEM education?

When the idea of this study was conceived it was all for the reason that very little was known about STEM in the country – its meaning, purpose, relevance, and practices let alone what key stakeholders thought and knew about STEM in the country. This study wanted to investigate what stakeholders thought and knew about STEM so that the public would be informed about the happenings around STEM education in the country. Hence the question, *how do STEM teachers, STEM administrators, and STEM policymakers perceive STEM education?* To answer this question, stakeholders were asked about their vision of STEM in the country and what they thought the relevance of STEM was. The findings suggest that stakeholders had strong opinions about STEM education and its relevance to the nation. All three stakeholder groups pointed out that in this 21st century with scientific and technological innovations, STEM is the ideal approach to teaching and learning and that it is the way to go if Zambia must meet the demands of our time.

What these results demonstrate is that there is a strong desire among key stakeholders to have fully functional STEM programs in schools. The results are in accord with the government of Zambia's efforts to implement STEM in schools. According to Mwale et al. (2020), in recent years, the Zambian school system has experienced increased attention and prioritization of STEM in public schools. This is observed in growing attention to STEM in the areas of policy and legal framework formulation, curriculum reforms, and other STEM-related activities and initiatives across the country. The government of Zambia has put in place policy and legal frameworks and instituted some statutory bodies to guide and oversee the implementation of STEM in the country. These results supplement the government's vision in the implementation process of STEM in the country.

The findings further indicate that Zambia has joined other countries on the globe in pursuit of STEM. World literature shows that since its introduction, STEM has drawn attention from all over the world (Asanda, 2014; Baldi et al., 2019; Ciftci et al., 2020; English, 2016; Falloon et al., 2020; Kanadli, 2019; Mohr-Schroeder et al., 2020; Roehrig, 2021). Almost all countries in the world today are in one way or another involved with STEM education (English, 2016). These results align with what has been happening globally where STEM has become a global consciousness. Literature has shown that:

> International concerns for advancing STEM education have escalated in recent years and show no signs of abating. Educators, policy developers, and business and industry organizations, to name a few, are highlighting the urgency for improving STEM skills to meet current and future social and economic challenges. The almost universal preoccupation with STEM education in shaping innovation and development is evident in numerous reports (English, 2016, p. 1).

The results of this study support world literature that most countries and governments have taken STEM to be a major educational priority and that STEM programs, policies, and activities are active in almost all countries (Freedman, 2015).

The stakeholders' perceptions of STEM were also investigated from their understanding of the relevance of STEM to the nation. The results indicate that all stakeholder groups spoke with one voice about the importance of STEM to the nation, especially in the 21st century. The results demonstrate that one way that Zambia can face head-on the economic, technological, scientific, and socio-cultural challenges of our time and the future is to embrace or turn to STEM. The findings further indicate that the stakeholders strongly acknowledged that STEM is very important because it provides the learner with the necessary and much-needed life and 21st century skills such as critical thinking, innovation, problem-solving, analytical, communication, teamwork, collaboration, decision-making, and creativity.

These findings align with existing literature. Numerous studies conducted in different countries indicate the significance of STEM to the development of human capital (Kayan-Fadlelmula, et al., 2022). STEM skills of creativity, innovation, analytical, problem-solving, and critical thinking have been identified to be imperative to navigating or responding to the demands of the 21st century and the forces of 4IR. Therefore, STEM education is very important in imparting 21st century skills to learners. Speaking about the relevance of STEM to the 21st century, Mpofu (2020) argues that in the 21st century, scientific and technological innovations have become increasingly important as we face the benefits and challenges of both globalization and a knowledge-based economy. To succeed in this new information-based and highly technological society, all students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past. Overall, STEM is important to the 21st century because it provides skills that make people employable today, enhances teamwork and communication, it provides sustainable solutions to today's challenges, and it teaches critical thinking and innovation.

These findings speak to what the government of Zambia is striving to achieve. The government's efforts to implement STEM are born out of the desire "to produce learners who are self-motivated, creative, confident and productive individuals, who are holistic, independent learners with values, skills, and knowledge to enable them to succeed in life" (Magusa, et al., 2022, p. 133). The findings of this study are important because they can inspire and guide the government of Zambia in its efforts to implement STEM in the country. They point the government in the right direction in its quest to formalize the implementation of STEM in the country.

How do STEM teachers, STEM administrators, and STEM policymakers define STEM education?

To enable us to understand key stakeholders' overall perceptions of STEM, it was imperative to know how they define STEM. Both qualitative and quantitative data brought up various ways that the stakeholders understand and define STEM.

The findings reveal some minor disagreement within and between stakeholder groups. Of all the STEM domains investigated in this study, STEM definition received the most divergent view about STEM within and between the groups. The quantitative data shows that across all proposed definitions of STEM, there is some degree of disagreement among stakeholders. These findings speak to what literature has long before demonstrated. Literature has shown that despite the increased STEM consciousness around the world, there is so much disagreement on the definition of STEM education. According to Ievers and McGeown (2020), despite the increased international investment in STEM education, there is still ambiguity around the exact meaning of STEM education, and confusion remains surrounding its effective implementation. With so many reports and studies that have gone into STEM research, there is still a lack of a coherent and unified definition of STEM education. Mpofu (2020), sums it up “in most nations, educators lack a cohesive understanding of STEM education and are also deprived of an easy-to-understand STEM education framework that informs classroom practices” (p. 1). In Sgro’s et al. (2020) words, “one issue surrounding contemporary STEM education is the ambiguity of what constitutes a “STEM” definition. This ambiguity is in part due to STEM being comprised of four related but distinct fields” (p. 185).

The findings of the study support the argument that depending on where one goes to seek an answer to the question, “what is STEM education?” answers may differ greatly. A study by Martin-Paez et al. (2018), for instance, reveals inconsistencies in STEM language and a lack of definition of STEM terms. Of the articles reviewed by Martin-Paez et al. (2018), 55% failed to explain a single STEM concept. Those that attempted to define STEM concepts used a variety of terms for clarifying the nature of STEM education. They found studies that used concepts such as STEM curriculum, STEM literacy, STEM subject, STEM identity, STEM learning, STEM teaching, and STEM integration to refer to and/or complement the concept of STEM education. Deniz et al. (2021) and Bybee (2013) share similar sentiments about the ambiguity in the definition of STEM. They point out that even STEM professionals do not have a clear understanding of STEM. They suggest that the meaning of STEM is somewhat ambiguous, and it may vary across different educational settings. It may mean different things to different people at different times. These findings have exposed this lack of a coherent and cohesive definition of STEM. The findings further call for all stakeholders to the same table and begin to develop an easy-to-understand definition of STEM. This will lessen the difficulties of trying to understand and define STEM. Furthermore, it will enable researchers and all those interested in STEM to move past the difficulties and ambiguity of STEM definition.

These findings are very important because they help stakeholders, especially those mandated to oversee the implementation of STEM in the country. The results are a wake-up call that it should not be taken for granted that STEM stakeholders and everyone else knows what STEM education is. The results have shown that even among STEM professionals there is still some disagreement as to what constitutes STEM definition. Therefore, these findings are a guide especially to policymakers to design a STEM conceptual framework to guide STEM understanding and any research in STEM. The results also call for STEM professionals to come together and develop a basic STEM conceptual framing to guide STEM definition and any STEM-related endeavors.

It must be emphasized, however, that despite the lack of consensus among stakeholders about the definition of STEM, the results also suggest that most stakeholders tended to lean towards certain definitions and understanding of STEM. The quantitative data revealed that three definitions dominated the quantitative data responses. What these findings show is that in as much as there is no consensus among stakeholders about the definition of STEM, the majority of them agree that STEM is (a) an integration of STEM subjects, (b) an applied knowledge and skills approach to teaching and learning, and (c) an interdisciplinary approach to teaching and learning. These findings are supported by qualitative findings. Qualitative results also suggest that in as much as there are a variety of STEM definitions and understandings, all three stakeholder groups agree about STEM being (a) the integration of STEM subjects, (b) the interdisciplinary approach to teaching and learning STEM domains, and (b) the application of skills and knowledge.

These results support the global literature on the definition of STEM. Amidst the lack of a cohesive definition of STEM, several pedagogical understandings about STEM have emerged in the literature. Pedagogically, STEM paradigms seek to eliminate the traditional barriers of separating the four domains of STEM by introducing approaches that encourage connectivity, inquiry, exploration, discovery, and experimentation among learners (Vasquez et al., 2013; Wang et al., 2011). These are integrative approaches that come in the form of interdisciplinary and a combination of STEM subjects, which is essential to the implementation of STEM as a “meta-discipline” (Vasquez, 2014). Of these integrative approaches, the interdisciplinary approach has been the most identified in the literature (Asunda, 2014; Ciftci et al., 2020; Falloon, et al., 2020; Mohr-Schroeder, 2020; Moore et al., 2020; Roehrig et al., 2021). Batdi (2019) could not have put it better when he argued that there are different approaches to STEM in the literature. However, the common ground of these approaches is that STEM is an interdisciplinary approach and is used in a real-life context. Srikoom et al. (2018) express this point even better when they point out that:

> While definitions vary, however, there are areas of commonality. For example, most definitions include descriptions of 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 and community (p. 313).

The findings of this study are in line with the common definitions of STEM in literature. For instance, Kelley and Knowles (2016) defined STEM as “the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning” (p. 3). Similarly, Sanders (2009), argues that “our notion of integrative STEM education includes approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects” (p. 21). The findings of this study reflect these definitions, especially in the areas of integration and interdisciplinary.

How do STEM teachers, STEM administrators, and STEM policymakers perceive the purpose of STEM education?

Just like STEM definition, to enable us to understand key stakeholders’ overall perceptions of STEM, it was imperative to know how they perceive the purpose of STEM. Both qualitative and quantitative data brought out various ways that stakeholders understand and perceive the purpose of STEM.

The results show that there are minor disagreements among stakeholders about the purpose of STEM. However, most stakeholders agree about the purpose of STEM education. These findings reveal that stakeholders were strong on the purpose of STEM as that which promotes innovation and economic growth of a nation. These findings support the theory that STEM advancement is a major driver of sustainable economic growth and has transformed numerous lives across the globe. According to Makgato (2019):

> STEM knowledge is associated with 75% of the fastest growing occupations, innovations, and wage premiums. A technology- and knowledge-driven economy needs workers trained in STEM. The majority (70%) of employers in developed countries (e.g., Australia) characterize employees with STEM skills as the most innovative. About 75% of the fastest growing occupations require STEM knowledge and skills. The digital revolution and increasing demand for design and manufacturing are driving the growth of the creative sector which extends from arts to science and technology, creativity and innovation. Designing and making objects in STEM as creative thinking is expected to become increasingly important as a contributor to the national economy and the job market. Existing and new jobs are likely to require a creative approach to perform nonroutine tasks and solve problems, while future workers are likely to appreciate an opportunity to act creatively. STEM skills and knowledge are required for work in a growing range of existing occupations in the future and will also contribute to the creation of new professions within the digital technology era (p. 5).

The findings of this study, further speak to what the government of Zambia has been trying to achieve. One of the reasons that the Zambia government is trying to introduce STEM in schools is that it enlightens and mitigates the transition process from a natural resource-based economy to a knowledge-based economy. It was felt that if the country must manage the current and future economic complexities, it requires STEM skill sets, knowledge, and competencies. The Ministry of Education acknowledged this when it noted that since time immemorial, Zambia's economic growth has been reliant on natural resources. However, due to overpopulation and subsequential depletion of natural resources, Zambia's natural resources can no longer effectively sustain the economy of the country, hence, the need to diversify. While the Zambian economy is fundamentally dependent on minerals, attempts to use this natural endowment to grow and diversify [the economy] have largely failed. Therefore, the government of Zambia identified STEM education among other areas as one of the tools that can assist in transitioning from a natural resource-based economy to a knowledge-and information-based one.

The findings of this study also speak to the international trend where countries and governments have turned to STEM as an important focus for renewed global competitiveness. STEM workforce is essential for countries to increase innovation and in return meet economic needs and reach global competitiveness (Breiner et al., 2012; de Melo Bezerra et al., 2018; Beede et al., 2011). As evidenced in our societies today, countries' economies are becoming more and more knowledge-based and multifaceted (Asanda, 2012; Ciftci et al., 2020). Therefore, STEM education has been identified as one of the forces that can contain knowledge-based and multifaceted economies. In qualifying this position, Thibaut et al. (2018), argue that "qualified STEM professionals are needed to remain economically competitive in the global market and to fill contemporary demands such as ensuring sufficient and sustainable energy, efficient healthcare, and well-considered technology development" (p. 1). Economic global competitiveness is one of the major driving forces that has compelled many countries, especially developed countries, to adopt STEM education. It is evident from many studies that STEM disciplines are strong drivers of competitive national economies (Breiner, 2012; Beede et al., 2011; de Melo Bezerra, 2018; Thibaut et al., 2018; Kelley et al., 2021). The findings of this study speak highly of the economic competitiveness of the country. This is important to note because the findings of this study can be a bedrock upon which Zambia can lay the foundation for economic growth and subsequential competitiveness with other nations.

One of the findings of this study is that the purpose of STEM is to prepare future generations to be innovators and solve real-world problems. This finding conforms to what most previous studies have found. In Zambia for instance, the Ministry of Education has identified STEM and its related disciplines as vital in preparing students to be innovators and solve complex problems. According to a report on education, science, and technology for the fourth session of the 12th national assembly of Zambia, “the industrialization and diversification priorities depend on improving science, technology, engineering, and mathematics knowledge, which is also critical for responding to the challenges caused by climate change” (National Assembly of Zambia, 2020, p. 5). It is envisaged that Zambian students with STEM skill sets, knowledge, and competencies will help drive innovation and fuel a knowledge-based economy; face head-on the challenges of our time; meet the demands of an ever-changing world; respond to the effects of the 4IR; and, at the same time meet the demands of the evolving and dynamic workforce.

The findings of the study further support the argument that one of the driving factors to the urgent emergency of STEM education is the need to train a qualified STEM future workforce. According to Holmlund (2018) and Kanadli (2019), one of the purposes of STEM education is to strengthen and expand a STEM-related workforce. This is because it is projected that future jobs, be they STEM-related or non-STEM-related, will require at least someone with STEM skills and knowledge. In the United States of America, for example, the 2013 report from the Committee on STEM Education stressed that "the jobs of the future are STEM jobs, with STEM competencies increasingly required not only within but also outside of specific STEM occupations" (English, 2016, p. 1). In the past decade alone, STEM jobs grew three times more than non-STEM jobs (Ciftci et al., 2020). This trajectory is poisoned to continue in the future. Therefore, the findings of this study are very important because they show that future jobs, whether STEM-related or not, will require STEM skill sets.

Another finding of this study which speaks to previous literature is that the purpose of STEM is to promote 21st century skills. Over 80% of the articles reviewed in this study acknowledge that the emergence of STEM on the education scene is to equip learners with 21st century. The literature agrees that one of the driving factors that led to the urgent emergence of STEM globally is the need to equip students with 21st century skills and competencies so as to meet the challenges of our time.

To begin with, the 21st century is faced with complex and multifaceted challenges be they economic, ecological, scientific, health-related, or sociocultural (OECD, 2018). "Climate change and the depletion of resources question our consumption habits, the development of artificial intelligence and new technologies challenge our traditional conception of work, and ongoing globalization entails migration, urbanization, and increasing diversity shaping countries and economies" (Gouedard, 2020, p. 7).

How do STEM teachers, STEM administrators, and STEM policymakers perceive STEM teaching and learning?

Just like STEM definition and purpose, to enable us to understand key stakeholders' overall perceptions of STEM, it was imperative to investigate how they perceive STEM teaching and learning. Both qualitative and quantitative data brought out various ways that the stakeholders understand and perceive STEM teaching and learning.

Compared to STEM definition and purpose, STEM learning and teaching shows even less disagreement among stakeholders. This shows that all stakeholders seem to be saying the same thing about STEM teaching and learning. These minor disagreements are somewhat understandable because they emanate from a lack of a consistent definition of STEM and a simplified STEM conceptual framework to inform and guide STEM teaching and learning. According to Mpofu (2020), "in most nations, educators lack a cohesive understanding of STEM education and are also deprived of an easy-to-understand STEM education framework that informs classroom practices" (p. 1). The findings of this study agree with the literature which argues that one of the gray areas in STEM education is classroom practice. Srikoom et al. (2018), qualify this gray area when they argue that "while there is widespread agreement about the importance of STEM, it remains an ambiguous term, particularly in classroom practices. We know little about what integrated STEM instruction looks like in the classroom, and how teachers conceptualize and implement integrated STEM" (p. 313). The question that begs the answer here is how a STEM lesson looks like in a classroom. Or, what constitutes a STEM unit lesson? These questions arise because there is no single answer or any agreement about how STEM education must be integrated into a classroom. According to Mpofu (2020):

> Despite the increasing attention to STEM education worldwide, its stakeholders in particular educational institution managers and classroom practitioners are still grappling to come to terms with what constitutes STEM [practice] and how it can move to classroom settings. No clear-cut answer to these issues can be discerned in the literature and discourses among STEM-related communities of practice (p. 2).

The minor disagreement about STEM teaching and learning reflects what world literature has always highlighted. For Thibaut (2018), the implementation of STEM education is proving to be difficult because of the lack of consensus about classroom practices in STEM. According to Ievers and McGeown (2020), despite the increased international investment in STEM, there is still ambiguity around what exactly constitutes STEM practice. Several authors agree that despite the increased attention to STEM in funding, policy, legislature, report, and research arenas, there remains some uncertainty about what constitutes a STEM lesson (Honey et al., 2014; Kelley & Knowles, 2016; Tippett & Milford, 2017).

It must be noted however that, despite these disagreements among stakeholders about STEM teaching and learning, the findings of this study also suggest that there is more cohesion among stakeholders about STEM learning and teaching than there is disagreement. The quantitative data shows that the agreement levels ranged from 85% to 100%. This means that more stakeholders agree about how STEM learning and teaching must look like. These quantitative results are supported by qualitative results. The qualitative finding also suggests that stakeholders' understanding of STEM learning and teaching coalesces around the same themes found in quantitative data, except for STEM learning in some instances.

These results support the most used approaches to teaching and learning of STEM as observed in world literature. There is overwhelming evidence from the literature that learner-centered, hands-on learning, inquiry-based, problem-based, and project-based pedagogies are regarded as appropriate approaches to teaching and learning of STEM education (Han, 2013). These approaches seek to eliminate conventional teacher and lecture-centered pedagogies. The findings of the study have brought out this point clearly. These findings support the theory that "within the best practice of STEM education, there has been a significant development of inquiry-based learning, which conflicts with traditional mechanisms of high-stakes testing to be found elsewhere" (Ievers et al., 2020; Kearney, 2016). Fomunyam (2020), observed that in recent years, research on STEM education has revealed that many pedagogical approaches and strategies are used by teachers when teaching STEM disciplines in schools. These approaches are largely inquiry-centered.

One interesting finding of this study is that STEM learning and teaching should be constructivist in approach. The quantitative data revealed that about 97.5% of all stakeholders agreed that STEM teaching and learning require students to actively construct knowledge. Similarly, the qualitative data shows that all stakeholder groups indicated that STEM learning and teaching should move away from positivist approaches to constructivist approaches where learners can construct their own knowledge. This finding is consistent with the theoretical framework used in this study – cognitive constructivism. A synthesis of STEM literature shows that STEM teaching and learning are coherently understood and grounded in cognitive constructivist perspectives. This means that the results of this study suggest that STEM teaching and learning should employ cognitive constructivist approaches. STEM instruction in this case helps support the construction of knowledge as learners are guided through their learning. Han (2013) once argued that teaching STEM education is grounded in the principles and theoretical background of cognitive constructivism where learners are actively engaged in different aspects of problem-solving and interactive activities. This is to argue that STEM policies, programs, initiatives, and implementation should be grounded in the principles of cognitive constructivism. This is because authentic STEM teaching and learning happens when (a) learning is seen as an active, constructive process, and not a receptive one (b) learning is presented as a process of active discovery (c) learners are actively engaged in constructing STEM knowledge, skills, and competencies, and (d) learners are allowed to take charge of their own learning. The findings of this study imply that any formulation of STEM policy, legal frame of reference, and initiative must take into account that authentic STEM teaching and learning is grounded in the tenets of constructivism supported by the findings of cognitive science.

How do the perceptions of STEM education: STEM definition, STEM purpose, and STEM teaching and learning compare among STEM teachers, STEM administrators, and STEM policymakers?

The final question of this study sought to investigate how the perceptions of STEM compared among key stakeholders. The results of the study have revealed both some similarities and differences in perceptions between and/or among the stakeholder groups. The results revealed overall themes that were unique to a stakeholder group and those common across all stakeholder groups for each of the STEM domains. The overall review of the qualitative data indicates that there are more similarities in themes and understanding across stakeholder groups than there are differences. It must be noted that the similarities in perceptions outweigh the differences. The differences pertain to focus, emphasis, and tone.

Of the six domains (vision, relevance, definition, purpose, teaching, and learning), STEM vision received the most similarities among the groups. As indicated in the results chapter, if there is any area in this study where all stakeholders spoke unanimously, confidently, and passionately, about STEM is on STEM vision. All stakeholders were very clear about their vision of STEM education. They spoke about the vision of STEM in terms of where they wanted STEM to be, progress, and what must be done. Stakeholders may have differed about STEM definition or purpose, but they remained united about the vision of STEM. All three groups had similar themes regarding their vision of STEM. They all felt that STEM is a good approach to teaching and learning and that it is the way to go in this 21st century for the country. They all stood on a firm ground that if STEM is to be effective and meaningful in the country, it must be Zambianized so as to reflect the Zambian terrain.

What these findings reveal is a deep yearning among key stakeholders to see STEM take root in the country. This is echoed in the Zambian government's efforts to implement STEM in the country. According to Mwale et al. (2020) in recent years, the Zambian education system has experienced widespread attention and prioritization of STEM education in public schools. There is a growing interest among government officials in implementing an authentic STEM curriculum in schools. This is witnessed in growing attention to STEM in the areas of policy and legal framework settings, curriculum reforms, and other STEM-related activities and initiatives across the country.

However, stakeholders were also quick to mention that STEM curriculum, policies, programs, and any STEM-related activities, must be born out of the Zambian womb so that it captures the local context, needs, values, and aspirations of the people. The findings suggest that in its original and unrevised format, STEM is foreign to the Zambian context. If it is to be meaningful and relevant to Zambian learners, there is a need to redefine and recontextualize it so that it speaks to and reflects the Zambian context. One government official who also happened to be a policymaker said that STEM education was conceived and born out of a different context, therefore, if it is to take root on Zambian soil, it must reincarnate to take the form of the Zambian context so that it reflects the local context, local content knowledge, and available local tools.

Comparing the perceptions of STEM definitions among stakeholder groups, qualitative results have shown that stakeholders slightly vary in their understanding of

STEM definition. However, there are common themes that cut across all groups. Common definitions that cut across groups include the integration of STEM subjects, the teaching of STEM subjects, and interdisciplinary approaches to teaching and learning. It should be mentioned that the findings suggest that policymakers had the most concise and formidable definition of STEM. One policymaker, for instance, defined STEM education as "the deliberate integration of STEM subjects in the learning process to make learning fully meaningful." Another policymaker said, "my definition of STEM education is that it is the acronym of the four STEM subjects." What this means is that policymakers understand STEM concisely more than the other two stakeholder groups. This is understandable because policymakers are close to the happenings of STEM in terms of STEM curriculum development, STEM policy and theory formulation, and STEM supervision. STEM policymakers in Zambia are responsible for STEM education in the country. Most policymakers interviewed came from the Zambia National Science Center and the National Science and Technological Council. These are two arms of government that were created under the Science and Technology Act and whose main function is to promote science, technology, and innovation in order to create wealth and contribute to the improvement of the quality of life in Zambia (Science and Technology Act, 1997). Under the Science and Technology Act of 1997, the government established these statutory bodies to oversee all the activities of STEM in schools and the country at large. As statutory bodies, these institutions' main function as enshrined in the Act is to promote science, technology, and innovation in the country as a driving factor of socio-economic development. Other functions include (a) promoting the development of an indigenous and environmentally friendly technological capacity; (b) regulating research in science and technology in Zambia; (c) advising the Government on science and technology policies and activities in Zambia; (d) liaising with Government, industries, and centers and institutes in science and technology; (e) mobilizing and distribute financial, human and other resources to management boards for science and technology research; (f) promoting the use of science and technology in the industry; (g) ensuring that gender concerns are integrated at all levels of science and technology development; (h) creating science and technology centers and institutes; (i) taking all measures that are necessary to popularize science and technology.

This explains why policymakers had the most concise, formidable, and cohesive definition of STEM because they have first-hand information and training about STEM. This applies to other domains studied in this study. Teachers' perceptions were also close to those of the policymakers. This is because teachers are the ones on the ground implementing STEM. Administrators, however, had the most scanty understanding of STEM definition and purpose. This is because, in terms of STEM implementation in Zambia, policymakers and teachers are the ones closely involved. Administrators are in most cases left out.

About STEM teaching and learning, the qualitative findings suggest that teachers had the most to say about STEM teaching and learning. They showed a clear path of what STEM practice should be. These findings are understandable because teachers are on the ground to implement STEM practice. They are in class to teach and therefore understand how STEM should be taught. The qualitative data also showed that policymakers' and administrators' understanding of STEM practices sounded more theoretical than practical. This is because they are not in the classroom to experience STEM practices.

The overall conclusion is that both qualitative and quantitative data reveal some cohesion in perceptions of STEM within and between all stakeholder groups. All the stakeholders seem to be saying the same thing about STEM in the country. The question that begs an answer is, why has there been difficulties in implementing STEM education in the country if all key stakeholders seem to be saying the same thing about STEM?

Implications

Practical Implications

In the problem statement of this study, it was noted that there has been back and forth from the MoGE in the implementation process of STEM education in Zambia. In 2019, the parliament of Zambia approved the establishment and construction of 52 STEM schools across the country. In January 2020, the official implementation of the STEM curriculum was launched in 15 pilot schools. However, before STEM was implemented in all 52 schools, the process was halted. In the meantime, schools are left to decide and implement STEM at their discretion.

One of the key findings of this study indicates that STEM is a good and desirable approach to teaching and learning and that it is the way to go in the 21st century. This finding suggests that if the country is to respond effectively to the demands and challenges of the 21st century, must embrace STEM. This finding can directly influence the MoGE in its decision to proceed with the implementation of STEM in the country. This study would be a great resource for the MoGE and the government given that it is the first of its kind to talk about the perceptions of STEM among stakeholders in the country. As indicated in the literature gap section, no study in Zambia has studied the perceptions of STEM education among key stakeholders. Therefore, the findings of this study will greatly contribute to and inspire any future endeavors in the implementation of STEM in the country. In short, this study will inform the government and the MoGE about how to proceed with STEM in the country. The study has shown that STEM is the ideal approach to teaching and learning and that it is the way to go in the 21st century. The study gives directions on how STEM must proceed. It has laid the foundation upon which future implementation can proceed.

Another practical implication of this study is that it will inform curriculum and policy development in the country. The challenge we have been having in the Zambian context is that curriculums and policies are borrowed from outside. There are few attempts to formulate local curriculums and policies. To begin with, STEM is a new phenomenon in Zambian. Therefore, before any effort to implement it, there is a need to redefine and recontextualize it so that it speaks to and reflects the Zambian context. One of the key findings of this study speaks to this challenge. It indicates that STEM must be Zambianized before it is rolled out. This finding suggests that STEM in its original format has a foreign dimension that needs to be tackled before implementing it in Zambia. STEM education was conceived and born out of a specific context and for a specific purpose which might be different from the Zambian context. Therefore, if STEM is to take root on Zambian soil, it must reincarnate, be localized, and take the form of the Zambian context so that it reflects the local context, local content knowledge, and available local tools. This process only happens during curriculum development and policy formulation. This study will guide these processes by inspiring and informing curriculum developers and policy formulators.

Another important implication of this study is that it will inform and inspire STEM practices in the country. As noted earlier, the most common challenges in STEM are STEM practices. According to Sgro's et al. (2020), "one issue surrounding contemporary STEM education is the ambiguity of what constitutes a "STEM" lesson" (p. 185). The results of this study suggest that STEM teaching and learning must be interdisciplinary, integrative, project/problem-based, research/inquiry-based, learner-centered, discovery teaching, hands-on, and constructivist approach. At the level of practice and implementation, this study will not only inform the general practice of STEM but also classroom practices, implementation, and conceptualization for teachers. The study has answered several unanswered STEM questions such as how does STEM education look like in the Zambian classroom context? Or, how do teachers implement STEM education in a lesson unit?

Another practical implication of this study is that it will help to shape the conception of STEM among STEM stakeholders and the general public. It is evident from the data and literature that there is no consensus on the conceptualization of STEM worldwide. According to Deniz et al. (2021) and Bybee (2013), even STEM professionals do not have a clear understanding of STEM. The findings of this study, however, have closed that gap by highlighting some common conceptions of STEM. Therefore, this study contributes to shaping STEM knowledge among people. The study highlighted several definitions of STEM that the stakeholders were in agreement with. This creates the platform upon which Zambia can begin to develop a unified and comprehensive STEM definition.

Theoretical Implications

This study has some theoretical implications that are worth noting. One of the major gaps identified in the literature was the lack of a unified and comprehensive theoretical perspective to ground STEM research. Of all the literature reviewed for this study, there was little mention of STEM theoretical framework. Bussey et al. (2020), also observed that "research published in various fields in STEM education utilizes a broad range of stated theoretical frameworks. However, there does not seem to be a single set of theoretical frameworks from which all STEM education research is conducted" (p. 52). In the context of America, Asunda (2014), observed that most school districts had not put in place standard frameworks to guide STEM teaching and learning. "Additionally, states had no consensus on what key STEM concepts students should master and whether those concepts should be included in the curriculum at a certain grade level or within a specific content area" (National Science Board, 2007, p. 5).

This study proposed a theoretical framework that could close this gap. The study employed cognitive constructivism, which is the closest framework that can guide STEM research. Although not many studies explicitly mention cognitive constructivism as a STEM theoretical framework, a review of STEM literature demonstrates that STEM content and pedagogies are coherently understood and grounded in the tenets of cognitive constructivism. For instance, Hans (2013) points out that:

> STEM education is grounded in the theoretical background of constructivism where students are engaged in the diverse components of problem solving, interdisciplinary curriculum, open-ended questions, hands-on activities, group work, and interactive group activities. For example, in STEM problem base learning classrooms, students are required to solve problems and engage in ill-defined tasks within the boundary of a well-defined outcome collaborating with other group members. Effective STEM education should be interdisciplinary and contain diverse content objectives within the context of hands-on activities to produce an artifact (p. 68).

Most of the studies reviewed do not present an explicit statement of their theoretical perspective. However, reading between the lines, the background literature provides the framing and backing for pedagogy and content that are constructivist. This is evident in the interdisciplinary and integrative nature of STEM content and pedagogies which tend to be constructivist. Cognitive constructivism approaches have a rich history in the teaching and learning of individual STEM disciplines. Therefore, if students are to obtain authentic, high-quality, and far-reaching STEM knowledge, skills, and competencies, STEM must be grounded in cognitive constructivism approaches.

The findings of this study support cognitive constructivism as an appropriate theoretical framing for STEM practice. The findings suggest that STEM learning and teaching require students to actively construct knowledge. The results further propose that STEM learning and teaching should be constructivist in approach so that learners can construct their own knowledge and become co-creators of knowledge.

Limitation

This study yielded many useful findings about STEM education – its vision, definition, relevance, purpose, and teaching and learning. However, some potential limitations should be acknowledged.

The first limitation is the sensitiveness surrounding STEM education. STEM education is still a sensitive topic in Zambia. Given the standoff in the implementation process, schools and all those involved in STEM are not sure about how to proceed. Those who have decided to continue implementing are not sure if they are doing the right thing and those who have abandoned it completely fear that the government may not financially support them. In short, stakeholders are not sure what to do. So, when they saw someone (a researcher) asking questions about STEM, they became uneasy. Some expressed concerns that maybe they were being investigated if they were doing the right thing or not. Others thought that the researcher was a journalist looking for good headlines in the tabloid. One administrator openly told me that “We cannot talk to you about STEM because we don’t know the government’s position on this issue.” In short, most participants were not comfortable talking about STEM because of the unresolved issues surrounding the topic. The study would have yielded different results if participants were comfortable and free enough to openly talk about STEM without fear of being investigated or reported.

The second limitation is the time of the year that the study was conducted. This study was conducted between November and December. First of all, this is the end of the year when people are exhausted and looking forward to a break. So, their minds would be somewhere else. Second and most importantly, this is the time of the year that schools have internal and national examinations. So, this is the time that teachers were busy and stressed with administering and grading exams. This study could be improved if conducted at a different time when stakeholders are not stressed and are free to answer questions. Perhaps if the study was conducted at a different time when people are relaxed, it could have yielded different results.

The third potential limitation is the sample size especially for administrators and policymakers and for the qualitative method. The quantitative method engaged 40 participants. Of the 40 there were 20 teachers and10 administrators and policymakers for each. The sample size for administrators and policymakers was not representative. The study could be improved by increasing the sample size for these two groups. In addition to this, not all the 40 participants who took the survey participated in the interviews. Only five participants participated in interviews for each group. This interview sample size was also not representative. The study could be improved by increasing the interview sample size. Also, there was only one interview for each participant. Given the small sample size, the study could have been strengthened by conducting more than one interview for each participant.

The fourth potential limitation is that the data collection process began with the surveys (forced response questions) and was followed by open-ended questions and interviews. This may have been a limitation in the sense that respondents saw the options in the forced-response questions. This may have influenced their thinking. This is somewhat evident from interview transcripts. Some interview responses and open-ended question responses had exact descriptions from the forced response questions. This suggests that open-ended and interview responses were influenced by the survey options. The study could have been improved if respondents were asked the open-ended and interview questions before they could see the options in the forced response questions.

Recommendations

The recommendations for this study are twofold – recommendations for change and recommendations for further study.

In the statement of problem section, it was noted that there has been back and forth from the government of Zambia in the implementation process of STEM in school. Schools are left to implement STEM at their discretion. The findings of this study revealed that key stakeholders are passionate about STEM and feel that STEM is a desirable approach to teaching and learning and the way to go in our era. However, the findings also show that before STEM is rolled out in schools, it must be re-defined, re-imagined, and localized so that it speaks to and reflect the Zambian context. Based on this these findings, it is recommended that, STEM education should be adapted to the Zambian context so that it reflects the local context, local content knowledge, and available local tools.

Second, the overall conclusion of the findings of this study revealed that there is collaboration in STEM perceptions within and between all stakeholder groups. All the stakeholders seem to say that STEM is the way to go and that it is the ideal approach to teaching and learning STEM-related disciplines. They all seem to say the same thing about STEM in the country. The question that begs an answer is, why has there been difficulties in implementing STEM education in the country if all key stakeholders seem to be saying the same thing about STEM? Based on this question, it is recommended that more studies be conducted to investigate why there are difficulties in implementing STEM when key stakeholders seem to generally agree on STEM definition, vision, relevance, and practice.

The findings have shown that the problem with STEM education in Zambia is not so much about its definition, purpose, relevance, or practice. Rather, the problem is about something else. Therefore, more studies are required to investigate what *'this something else'* is. In other words, to investigate why the standoff in the implementation process of STEM when everyone involved seems to be for the idea that STEM is relevant to the Zambia context.

APPENDIX A

RECRUITMENT LETTER

Choobe Maambo, S.J., M.Ed.
6324 N. Kenmore Ave., Chicago, IL 60660, Cell +260963213715
Email: choobe2@yahoo.com

7th November 2022

Key STEM Stakeholder

Dear Sir/Madam,

RE. REQUESTING YOUR PARTICIPATION IN A RESEARCH STUDY

My name is Choobe Maambo, S.J. I am a student studying for a doctoral degree in education: curriculum and instruction in the School of Education at Loyola University in Chicago, USA. I am writing to let you know about the opportunity to participate in a research study I am conducting for my dissertation thesis about the *Key Stakeholders' Perceptions of STEM Education in Zambia.* You are being asked to participate in this study because of your direct involvement in STEM education at your institution.

The primary purpose of the study is to explore key STEM stakeholders' perceptions of STEM education in the country. To better understand STEM education from a holistic perspective, it is necessary to understand the perceptions of STEM education from key stakeholders. The study will compare the perceptions of STEM among STEM professionals, administrators, and teachers. This is important because it will not only help my academic journey, and other future researchers but also all those involved in STEM to understand the kind of information circulating about STEM and how those messages might foster the development of STEM education in the country.

I hope that you will accept to anonymously complete a 20 to 30 minutes survey and a 20 to 30 interview session. Your Participation is voluntary. You can withdraw your participation at any time during the research without any penalty. You will be asked to give written consent before the research begins. Your responses will be treated as confidential and anonymous. Your privacy will be maintained at all times during the study and after. There are no foreseeable risks in participating in this study.

If you would like additional information about this study, please contact me at +260963213715 or choobe2@yahoo.com. Thank you again for considering this research opportunity.

Sincerely

Choobe Maambo, S.J., M.Ed.

APPENDIX B

INFORMED CONSENT

STATEMENT OF CONSENT FORM

Title: Key Stakeholders' Perceptions of STEM Education in Zambia: A Mixed Methods Inquiry
Researcher: Choobe Maambo S.J.
Faculty Sponsor: Dr. Charles Tocci

Dear STEM Stakeholder

Introduction and Purpose of the Study
You are being asked to take part in a research study entitled *Key Stakeholders' Perceptions of STEM Education in Zambia: A Mixed Methods Inquiry*. Before you decide to participate in this study, it is important that you take time to understand what is involved in this study. This form will tell you about the study – the purpose, procedure, risks, and benefits that you should know before you decide if you would like to take part. Please take time to read this information carefully and ask the researcher if there is anything that is not clear and if you need more information.

The primary purpose of the study is to explore key STEM stakeholders' perceptions of STEM education in the country. To better understand STEM education from a holistic perspective, it is necessary to understand the perceptions of STEM education from key stakeholders. The study will compare the perceptions of STEM (STEM definition, purpose, and practice) among STEM professionals, administrators, and teachers.

Why you are being asked to participate
Your school/institution has been purposefully chosen for this study because it has been involved in STEM education. You too have been purposefully selected because you are a STEM stakeholder and have been directly involved in STEM education at your school/institution.

How long will it take
I expect your participation to last for about 45 to 60 minutes.

What you will be asked to do in the study
If you choose to participate in this study, you will:

- Complete a 20 to 30-minute survey.
- Participate in a one-on-one interview to discuss your perceptions of STEM education. The interview is expected to last for about 20 to 30 minutes at most.

Potential risks and discomfort
Potential risks and discomfort associated with participation in the study are unlikely and of low probability. While we do not foresee any risks or discomfort to you, some

questions asked pertain to your beliefs and perceptions. You are free to skip any question you do not want to answer or withdraw your participation at any time for any reason. If you feel upset or uncomfortable during the study for any reason, you can contact the investigator at +260963213715.

Benefits

Participants in this study cannot expect any benefits from involvement in this research study. However, we hope that the information obtained from this study may benefit participants hoping to continue to engage in STEM education.

Voluntary participation and right to withdraw

Your participation in this study is completely voluntary and you may choose to stop participating at any time. It is up to you to decide whether or not to take part in this study and you can refuse to answer any question you are not comfortable with. If you decide not to participate you are free to quit at any time and you will not lose any right to compensation. Even if you begin the study, you may quit at any time without any penalty. Withdrawing from this study will not affect the relationship you have, if any, with the researcher. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed.

Confidentiality and privacy

Your responses to this study will be kept confidential and anonymous. All information taken from the study will be coded to protect each subject's name. No names or other identifying information will be used when discussing or reporting data. The investigator will safely keep all files and data collected in a secure locked facility. Once the data has been fully analyzed it will be destroyed.

Contact information

If you have questions about the research study or your role in the study, please feel free to contact me either by cell phone at +260963213715 or by e-mail at choobe2@yahoo.com or Dr. Charles Tocci at ctocci@luc.edu.

If you have questions regarding your rights as a research participant, or if problems arise that you do not feel you can discuss with the researcher, please contact the Loyola University Office of Research Services at (773) 508-2689.

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Consent

I have read and I understand the provided information and have had the opportunity to ask questions. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost. I understand that I will be given a copy of this consent form. I voluntarily agree to take part in this study.

Participant's name ________________ signature ________________ Date ___________

Investigator's name _______________ signature _________________ Date ___________

APPENDIX C

SURVEY

SURVEY

1. Name: ___________________________________
2. What is your gender? □ Male □ Female
3. What is your age? ___________
4. What is the name of your school/institution?

   ____

5. What is your position/title:

   ____

6. How do you identify yourself? (Choose all that apply)

   (a) □ Teacher

   (b) □ Administrator (e.g., Headteacher, deputy head, Lab assistant, curriculum developers, etc.)

   (c) □ STEM professional (e.g., policymaker, advocate, activist, engineer, scientist, medical doctor, etc.)

   (d) □ Others (please specify):

   ____

7. If you chose (a) to question 6, what STEM subject(s) do you teach?

____

____

____

For the following, please indicate how much you agree or disagree with each of the statements. Please respond to each item as honestly as you can and independently, do not be influenced by your previous choices.

STEM stand for Science, Technology, Engineering, Mathematics

STEM definition Below are items that represent definitions of STEM Education. Please rate how much you agree or disagree with each statement.	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
STEM education entails the purposeful and meaningful teaching of each STEM subject separately							
STEM education is the purposeful and meaningful integration of two or more STEM subjects into a single STEM class unit.							
STEM education is the purposeful and meaningful combination of all **FOUR** STEM subjects in a single STEM class unit							
STEM education entails an applied knowledge and skills approach to teaching							
STEM education entails an interdisciplinary approach to teaching and learning							
Open-Ended response: *How do you define STEM Education?*							

STEM Purpose Below are items that represent the purpose of STEM Education. Please rate how much you agree or disagree with each statement**.**	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
The purpose of STEM education is to promote 21st century skills							
The purpose of STEM Education is to solve real-world problems, (e.g., climate change, economic issues, health issues, etc.)							
The purpose of STEM education is to prepare future generations to be innovators.							

The purpose of STEM education is to give people skills that make them employable and successful in their careers.							
The purpose of STEM education is to make a nation economically competitive on a global level.							
Open-Ended Response: *What do you think is the purpose of STEM education?*							
STEM Learning Below are items that represent STEM Learning. Please rate how much you agree or disagree with each statement.	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
STEM learning requires students to think in new ways.							
STEM learning requires students to integrate concepts across different disciplines.							
STEM learning requires students to question their understanding of the world.							
STEM Learning requires students to actively engage in problem-solving thinking.							
STEM learning requires students to actively construct knowledge							
Open-Ended Response: *What do you think STEM learning should look like?*							
STEM Teaching Below are items that represent STEM Teaching. Please rate how much you agree or disagree with each statement.	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
STEM teaching requires project-based teaching methods							

STEM teaching requires using inquiry-based methods							
STEM teaching requires artifacts to assess student learning and mastery of content.							
STEM teaching requires presenting real-life problems to learners							
STEM teaching must involve teaching that enhances teamwork, communication, critical thinking, and innovation							
Open-Ended Response: *What do you think STEM Teaching should look like?*							
THE END							
Please provide your contact details here if you would like to participate in a 20 – 30 minutes interview: ____ ______							

APPENDIX D

INTERVIEW PROTOCOL

INTERVIEW PROTOCOL

1. What is your vision of STEM education?

2. How would you define STEM education?

3. What do you think is the purpose of STEM education?

4. How do you think STEM is relevant in Zambia?

5. What should STEM learning look like in Zambia?

6. What should STEM teaching look like in Zambia?

APPENDIX E

LETTER TO THE PERMANENT SECRETARY OF EDUCATION

Choobe Maambo S.J., M.Ed
6324 N. Kenmore Ave., Chicago, IL 60660, Cell +260963213715
Email: choobe2@yahoo.com

12/10/2022

The Permanent Secretary

Ministry of General Education

Lusaka – Zambia

Dear Sir/Madam,

RE. PERMISSION TO CONDUCT RESEARCH IN STEM EDUCATION SCHOOLS AND INSTITUTIONS

My name is Choobe Maambo, S.J. I am a student studying for a doctoral degree in education: curriculum and instruction in the School of Education at Loyola University in Chicago, USA. I write to seek permission to conduct research for my dissertation study in some of the STEM schools and institutions in Zambia.

The topic of study is *Key Stakeholders' Perceptions of STEM Education* in Zambia. The primary purpose of the study is to explore key STEM stakeholders' (teachers, administrators, and STEM professionals) perceptions of STEM education in the country. This is important because it will not only help my academic journey and other future researchers in STEM but also all those involved in STEM to understand the kind of information circulating about STEM and how those messages might foster the development of STEM education in the country.

I, therefore, implore your humble office to permit me to visit some of the STEM Schools and Institutions for this study. Participants will be asked to anonymously complete a 20 to 30 minutes survey and a 20 to 30 minutes interview session. Participants who will volunteer to participate will be asked to give their written or verbal consent before the research begins. Their responses will be treated as confidential and anonymous. Individual privacy will be maintained in all published and written data resulting from the study. There are no foreseeable risks in participating in this study.

Upon completion of the study, I undertake to provide the Ministry of General Education with a copy of the full research report. Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Sincerely
Choobe Maambo, S.J., M.Ed.

APPENDIX F

LETTER TO THE DIRECTOR

Choobe Maambo, S.J., M.Ed
6324 N. Kenmore Ave., Chicago, IL 60660, Cell +260963213715
Email: choobe2@yahoo.com

7th November 2022

The Director General

STEM Institution

Dear Sir/Madam,

RE. PERMISSION TO CONDUCT RESEARCH AT YOUR INSTITUTION

My name is Choobe Maambo, S.J. I am a student studying for a doctoral degree in education: curriculum and instruction in the School of Education at Loyola University in Chicago, USA. I write to seek permission to conduct research for my dissertation study at your institution. Your institution has been purposefully chosen because it has been involved in STEM education.

The topic of study is *Key Stakeholders' Perceptions of STEM Education in Zambia.* The primary purpose of the study is to explore key STEM stakeholders' (teachers, administrators, and STEM professionals) perceptions of STEM education in the country. This is important because it will not only help my academic journey, and other future researchers but also all those involved in STEM to understand the kind of information circulating about STEM and how those messages might foster the development of STEM education in the country.

I hope that you will allow me to recruit a few STEM professionals to anonymously complete a 20 to 30 minutes survey and a 20 to 30 interview session. Participants who will volunteer to participate will be asked to give their written consent before the research begins. Their responses will be treated as confidential and anonymous. Individual privacy will be maintained in all published and written data resulting from the study. They will be reassured that they can withdraw their participation at any time during the research without any penalty. There are no foreseeable risks in participating in this study.

I, therefore, implore you to permit me to conduct this study at your institution. Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Sincerely

Choobe Maambo, S.J. M.Ed.

APPENDIX G

LETTER TO THE HEADTEACHER

Choobe Maambo, S.J., M.Ed
6324 N. Kenmore Ave., Chicago, IL 60660, Cell +260963213715
Email: choobe2@yahoo.com

7th November 2022

The Headteacher

Dear Sir/Madam,

RE. PERMISSION TO CONDUCT RESEARCH AT YOUR SCHOOL

My name is Choobe Maambo, S.J. I am a student studying for a doctoral degree in education: curriculum and instruction in the School of Education at Loyola University in Chicago, USA. I write to seek permission to conduct research for my dissertation study at your school. Your school has been purposefully chosen because it is a STEM school or has been involved in STEM education.

The topic of study is *Key Stakeholders' Perceptions of STEM Education in Zambia.* The primary purpose of the study is to explore key STEM stakeholders' (teachers, administrators, and STEM professionals) perceptions of STEM education in the country. This is important because it will not only help my academic journey, and other future researchers but also all those involved in STEM to understand the kind of information circulating about STEM and how those messages might foster the development of STEM education in the country.

I hope that you will allow me to recruit a few STEM teachers and other STEM professionals (e.g., Lab assistants and administrators) to anonymously complete a 20 to 30 minutes survey and a 20 to 30 interview session. Participants who will volunteer to participate will be asked to give their written consent before the research begins. Their responses will be treated as confidential and anonymous. Individual privacy will be maintained in all published and written data resulting from the study. They will be reassured that they can withdraw their participation at any time during the research without any penalty. There are no foreseeable risks in participating in this study.

I, therefore, implore you to permit me to conduct this study at your school. Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Sincerely
Choobe Maambo, S.J. M.Ed.

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VITA

Choobe Maambo is a Jesuit priest born and raised in Africa, Zambia. He started his primary education at Chikuni Primary School in 1988 in Monze district Zambia. In 1995, he entered his secondary education at St. Canisius Secondary School in Monze-Zambia. He graduated from secondary school in 2000. In 2002, Choobe joined the Society Jesus [The Jesuits] to begin his priestly formation at the Lusaka Jesuit Novitiate in Zambia. After two years of novitiate, in 2004, he went on to obtain his first degree in Philosophy and Humanities at Arrupe University in Harare Zimbabwe in 2008.

Between 2008 and 2010, Choobe taught Mathematics and Science in two secondary schools in Zambia. In 2010, he went on to obtain his second degree in Theology at Hekima University in Nairobi Kenya. After his Theology degree in 2013, Choobe began his master's degree program in Education: Curriculum and Instruction at Boston College: Lynch School of Education in Massachusetts United States of America. Between 2015 and 2019, Choobe became the associate novice director at the Lusaka Jesuit novitiate. During this same time, Choobe taught Mathematics at St. Ignatius College in Lusaka Zambia. Choobe is currently a doctoral student in Education: Curriculum and Instruction at Loyola University in Chicago U.S.A.

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