An impact evaluation of the School of Specialisation program at Curtis Nkondo Secondary school for the period 2016-2020

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A research report submitted to the Faculty of Law, Commerce and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Management (in the field of Public Sector Monitoring and Evaluation).

March, 2023.

Abstract

This study investigates the impact of the School of Specialisation program at Curtis Nkondo Secondary School in Soweto. It explores the nature of STEM education, identifies the pillars underpinning a STEM curriculum then compares outcomes from a STEM school with those of an ordinary school. This mixed methods study collects data from both the experimental group and the control group. Quantitative data is in the form of test scores over the period 2016 to 2020. Qualitative data obtained from key informant in-depth interviews is used to gain contextual understanding of the study. This report presents result based on the learners at Curtis Nkondo and Freedom Park Secondary Schools. Mathematics and Science results of the 2016 Cohorts before and after the intervention were captured and documented.

The intervention was mainly through the School of Specialisation program offered at Curtis Nkondo secondary school. This is based on content delivery focused on the eight pillars of a STEM school namely interactive content, design pedagogy, authentic experiences, student engagement, creative problem solving, innovation and communication and collaboration. Baseline assessment was conducted to show that both Curtis Nkondo and Freedom Park Secondary schools were similar and that the only significant difference being the intervention. Analysis of results obtained showed that there was a significant difference between educational outcomes in Mathematics and Science for learners who went to the School of Specialisation program at Curtis Nkondo.

The Implication here being that using the STEM education framework for teaching mathematics and Science works to improve the outcomes in the subjects. Some investigations for further study were suggested.

Acknowledgements

I would like to thank the Lord Almighty for His abundant grace, favour, surprises and wonderful people and opportunities He placed along my path.
I would like to express my sincere appreciation to my supervisor, Mr Chikane who helped me through this journey.

I am grateful to all members of the Wits school of Governance who helped shape me into the insightful person I am today both academically and socially. Also, to Mbuso Jama, a friend and brother for not only the patience to listen but also the
kindness to help whenever he could.

Thank you, Charles Magaiza, a brother, friend, mentor, and spiritual father. Thank you for being a practical example of a disciplined Christian life. I have learnt from you that joy, fulfilment and happiness come from striving to be like Christ.

To my tribe, Zanele, Michelle, Dylan and Nyasha you no idea how you inspired me to go on with the writing of this report.

Finally, to my late parents, Leonard, and Idah Zambara, I feel blessed that God gave me parents who put love above every other thing. Whose inheritance of a sound education I will pass to my children. You are dearly missed and till today, I strongly feel your love. It’s better to have loved and lost than never to have loved at all.

Declaration

I declare that this project is my own work and no part of it has been copied from another source (unless indicated as a quote). All phrases, sentences and paragraphs taken directly from other works have been cited and the reference recorded in full in the reference list.

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Signature

Abbreviations used in the study.

SOS	School of specialisation
STEM	Science, Technology, Engineering and Mathematics
KIIs	Key Informant Interviews
RP	Research participant

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1. *The letter would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. ***Because of the relaxation of COVID 19 regulations researchers can collect data online, telephonically, physically access schools, or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate.***
4. ***The Researchers are advised to wear a mask at all times, Social distance at all times, Provide a vaccination certificate or negative COVID-19 test, not older than 72 hours, and Sanitise frequently.***
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10. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
11. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
12. *The researcher is responsible for supplying and utilising his/her research resources, such as stationery, photocopies, transport, faxes, and telephones, and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
13. *The names of the GDE officials, schools, principals, parents, teachers, and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
14. *On completion of the study, the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
15. *The researcher may be expected to provide short presentations on the purpose, findings, and recommendations of his/her research to both GDE officials and the schools concerned.*
16. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a summary of the purpose, findings, and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

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Mr. Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: ...12/08/2022.......................

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Making education a societal priority

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Chapter 1 Introduction

This study seeks to investigate the impact of the School of Specialization (SOS) program at Curtis Nkondo secondary school in Soweto against the targeted outputs and outcomes. Central to this study is the quality of passes in Mathematics and Physical Science. It is anticipated that the knock-on effects of this intervention would work to increase the Science, Technology, Engineering and Mathematics (STEM) labour force, reduce poverty and revitalise the township economy by equipping the targeted pupils with entrepreneurial skills to venture into science-related careers or businesses (Bybee, 2010a). The difference-in-difference method was used as a quantitative analytical tool to assess the program's impact. Further, stakeholder interviews were used to gain more insight into the qualitative impact of the intervention.

In 2016, the department of basic education introduced a School of Specialization program envisaged to revolutionize skills development in line with the government's program of "transformation, modernisation and re-industrialisation" (Motshekga, 2016). It was anticipated that "The schools of Specialisation program would have an enormous positive impact on Gauteng's economy…tackle poverty and promote short- and long-term economic growth" (Motshekga, 2016). Put briefly, the School of Specialisation program at Curtis Nkondo involves a tailored government funding model, a modified curriculum with a strong bias towards maths, science and entrepreneurship, and greater stakeholder involvement, particularly big business and local industry. These will be discussed in greater detail in chapter two.

South Africa adopted education as one of the tools it can use to change the trajectory of its citizens, moving from conditions of severe poverty to more affluent livelihoods. It is well documented (UNICEF, 2020; Ponelis & Holmner, 2015; Mandela, 1997) that the level of education affects economic growth, the extent of citizen dependence on the state and generally the living conditions of the people in a country. From this ideology, South Africa has seen a transformation in educational curricula and policy post-1994.

South Africa is a democratic state (Corder, 1994); therefore, inclusive growth occurs within a political environment steered by a democratically elected government. Coming from a history of colonisation and an apartheid regime, the agreed way forward after independence was that of inclusive transformation(Dugard, 1997; Roux, 2009). This would be achieved through social policies whose aim is educational reform, job creation and poverty reduction (Titmus, 1974). Educational programs and curricula are part of transformative social policies and are relevant to South Africa. Social policy is meant all the legislative frameworks that are enforced to stir the direction in which society can secure livelihoods, resources as well as access to the national cake by right of citizenship (Alcock & May 2014; Titmus, 1974).

This study sees the Schools of Specialisation program as an attempt at transformative social policy, as championed by Mkandawire (2001). The transformative social policy encompasses the economy, social relations and social institutions and uses various instruments to raise human well-being. Inclusive development and economic growth can thus become a reality through transformative social policy. It is further argued by Mkandawire (2011) that social policy for a developmental state has critical components: ideology structure and democracy. These aspects are pivotal for national building, which is a product of resolving social and national issues: inequality, racism, and national questions such as the current education challenges in South Africa.

Mkandawire (2001) views development from a developmental state point of view, in which a sovereign country can move on a developmental path and create healthy policies that take care of its institutions for socioeconomic development. It is further argued that development is a 'liberatory human aspiration to attain freedom from political, economic, ideological, epistemological, and social domination...' Ndlovu-Gatsheni (2012:51). From this it is noteworthy that a developmental state's performance is not solely measured by the performance of the economy but also the social well-being of all its citizens. Education, whose bedrock is the educational curriculum, plays a central role (Hallinen, 2015). Schools of specialisation, in this case, STEM schools, aim to be the microcosm of society in which the future generation is prepared to move the country forward.

Stem schools target embedded social inequality (Apple, 1992a; Gabbard, 2000; Wolfmeyer, 2017). It is argued that STEM is a social construct and discourse developed in response to issues that need a solution. As with all discourses, Mathematics and science education are deeply embedded in historical, cultural, and philosophical perspectives. A myriad of scholarship (Charalambous & Philippou, 2010; DeJarnette, 2012; Schmidt et al., 2012) exist regarding policy reform associated with STEM, and these generally are grouped into two agendas, namely social justice pursuit and pragmatic orientation. This research seeks to explore the two agendas mentioned above. It is noted though, that only a little research exists on understanding the meta-level of analysis seeking explicit and implicit messages embedded within policy documents. These are important if we are to provide a critique of the overall objectives of educational policy. Policy is a dynamic, strongly mediated and contested issue among stakeholders at all levels, from formulation to implementation. It is argued by Chesky & Wolfmeyer (2015) that STEM as discourse is embedded in philosophical underpinnings that have axiological, ontological and epistemological implications. Research into these allows for reflexivity enabling researchers to explore complex questions about the purposes of education, thus protecting the fragile democratic state by increasing public awareness of government activities.

An impact evaluation of Curtis Nkondo School of Specialisation is paramount because it presents a trial that government would use to evolve education in South Africa on a much larger scale. However, if research is not done on these schools' effectiveness, efficiency, and sustainability, rolling out such models may lead to wasteful expenditure due to program failure. On the same note, it is essential to identify the strengths and weaknesses of such initiatives and how they are affected by shocks like covid-19 and seek to find ways of making them applicable to different contexts within South Africa.

Schools of specialisation are run on a best practice model that shows certain degrees of freedom compared to the current practice in ordinary government schools. This model consists of multi-faceted stakeholders, including the public service, non-governmental organisations, corporate South Africa, and the community. This program renders itself applicable to a Blue Marble evaluation premised on a worldview perspective to program intervention.

A plethora of scholarship (Daugherty, 2013a; Spaull, 2013a; Spaull & Kotze, 2015; Van der Berg et al., 2011) surrounds educational research aimed at positively moving the needle regarding educational outcomes. These include school governance, teacher qualifications and years of experience, consistency in educational policy, and a curriculum based on the needs of the labour force. Elmore (1996, 2008) further identifies what he calls the core, consisting of three elements, the teacher, the student and the content. He further alludes that the combination of all three determines educational outcomes and not a single contribution of one element alone. Central to the core, is the instructional task, what the student is asked to do in the classroom.

Educational psychologists are concerned about how pupils acquire capabilities through formal instruction within a classroom setting (Bandura, 1965; Chomsky, 1986; Mwamwenda, 2009; Piaget & Buey, 1983; Vygotsky, 1935). This, coupled with contextual micro, meso, and macro factors, plays a role in achieving learning outcomes (Patton, 2019). The above being said, it is important to investigate the School of Specialisation program, taking into consideration the factors highlighted thus far.

1.1 Problem statement

The problem this study seeks to investigate relates to the decline in the performance of learners in Mathematics and Physical Science. The Matric class of 2021 saw a decline in learners' performance in South Africa. This decline is a blow to government efforts to increase the number and quality of Mathematics and Physical Science passes. The government has adopted the idea of strengthening STEM subjects, believing that this would be an important driver for development (Motshekga, 2017; Spaull, 2013b; Spaull & Kotze, 2015). A decline in Mathematics and Science outcomes is symptomatic of policy and educational failure.

1.2 Purpose statement

The purpose of this research is to investigate the impact of the School of Specialization program at Curtis Nkondo school in Soweto. This was done by comparing mathematics and physical science outcomes at Curtis Nkondo to those of an ordinary government school (Freedom Park Secondary School). A difference in difference (DID) method to measure the impact of the intervention because it allows for the identification of the causal effect of the intervention. It does this by comparing the changes in outcomes for a treatment group that receives the intervention with the changes in outcomes for a control group that does not receive the intervention. By comparing these changes, the method aims to isolate the effect of the intervention from other factors that may influence the outcome. The DID method was used because it is a powerful tool for evaluating the impact of interventions, especially when random assignment is not possible and external factors may influence the outcome.

The Impact of the School of Specialisation program must be understood so that government has research-based evidence, which is then filtered through for executive decision-making regarding educational practice. The rising unemployment figures are a severe cause for concern and place a great demand that education is relevant and can place pupils on the right trajectory to economic freedom after completing high school.

1.3 Research questions

This research seeks to answer *following research questions*:

> ***RQ 1:*** *Did the School of specialisation program at Curtis Nkondo cause a change in Mathematics and Physical Science outcomes?*
>
> ***RQ 2:*** *What are the factors that contributed to outcomes obtained at Curtis Nkondo School of Specialisation program?*
>
> ***RQ 3:*** *What features of the program could be improved to strengthen program effectiveness, efficiency, and sustainability?*

The research questions were chosen for the following reasons. Firstly, RQ1 addresses the primary objective of the study, which is to determine whether the School of Specialisation program at Curtis Nkondo had a significant impact on Mathematics and Physical Science outcomes. This question aims to evaluate the effectiveness of the program and is crucial in determining whether the program should be scaled up or replicated elsewhere.

RQ2 aims to identify the underlying factors that contributed to the outcomes obtained at Curtis Nkondo. This question seeks to explore the contextual factors that may have influenced the program's effectiveness, such as economic, institutional, social, and learner factors. Understanding these factors can provide valuable insights into how to implement similar programs in different contexts.

Finally, RQ3 aims to identify specific features of the program that could be improved to enhance its effectiveness, efficiency, and sustainability. By addressing this question, the researcher can provide recommendations on how to modify the program to ensure that it remains effective and efficient over time, as well as how to ensure its long-term sustainability.

To further provide a structured and rigorous framework for making informed decisions about the school of Specialisation program based on the sample data and to effectively answer RQ1, this study will conduct a significance test to establish if there is a significant difference between the Mathematics and Physical Science outcomes at Curtis Nkondo and Freedom Park High school. This study formulates the following hypothesis:

Null hypothesis (H_0):

The mean mathematics and science outcomes of Curtis Nkondo students are not significantly different from the mean mathematics and science outcomes of Freedom Park high school students.

Alternative hypothesis (H_A):

The mean mathematics and science outcomes of Curtis Nkondo students are significantly greater than the mean mathematics and science outcomes of Freedom Park high school students.

Chapter 2 Literature Review

2.1 Introduction

According to Denney & Tewksbury(2013) and Randolph (2009), the purpose of a literature review is to provide an overview of the current knowledge, theories, concepts, and findings related to a particular research question. This chapter aims to provide an extensive and analytical evaluation of the literature on STEM education. This was done to identify and understand the fundamental concepts, theories, and models related to STEM education. Randolph (2009) argues that a literature review helps identify gaps in the existing literature and areas where further research is needed. Exploring the literature enabled this study to identify gaps in knowledge that the study can attempt to fill. Furthermore, a literature review helps in synthesising and summarising existing research to develop a comprehensive understanding of the current state of knowledge and provides context for the research topic, demonstrating the relevance and importance of the study (Knopf, 2006).

An initial exploration of the definition of STEM will lead to the deliberation of the history of STEM and how it evolved its philosophical underpinnings and the need for STEM education. It is crucial to come up with a working definition that will be used for this study because the concept of STEM could be understood differently by different people and in different contexts. This will be followed by an international investigation of STEM from a global perspective, starting with the US, Western and Asian Countries. For this study by western countries, we refer to European countries that share the same political, economic, or cultural characteristics, such as the UK, Canada, and Germany. Subsequent paragraphs narrow the investigation to Africa and, more specifically, to South Africa, which is the research site of this study.

We look at STEM education's philosophical underpinning and critical attributes and the discourses surrounding them. Furthermore, this chapter will explore factors affecting educational outcomes and critique STEM as a paradigm followed by thoughts on the value of education in a South African context. The above was used to identify a gap in knowledge in which this study will then be located and to come up with a theoretical and conceptual framework to guide this study in answering research questions.

2.2 The value of education

A plethora of scholarship (Lange & Topel, 2006; Ledden et al., 2007) shares strong views on the value of education to the individual, one's country, and humanity in general. Firstly, education plays a pivotal role in fostering personal development. It equips individuals with knowledge, skills, and a comprehensive understanding of the world. This, in turn, becomes a catalyst for personal growth and self-discovery. As individuals acquire the tools to navigate and comprehend the complexities of their environment, they are better positioned to contribute meaningfully to society.

Moreover, education serves as a gateway to a spectrum of career opportunities. It has the transformative power to open doors to new horizons, paving the way for increased earning potential and professional advancement. In essence, education is not merely an end in itself but a means to empower individuals economically and provide avenues for personal fulfillment.

The significance of education transcends the individual realm to shape responsible and informed citizens. Through education, individuals gain an understanding of their rights and responsibilities as members of a community and participants in a democracy. This knowledge forms the bedrock of active civic engagement, fostering a society where citizens are not only aware of their rights but also committed to fulfilling their civic duties.

Furthermore, education serves as a guardian of cultural heritage and history. By imparting essential traditions, values, and knowledge from one generation to the next, education becomes a custodian of the collective identity of a society. It ensures that cultural richness is preserved, preventing the erosion of traditions that define a community.

From an economic standpoint, a well-educated population is a driving force for growth and development. A skilled workforce, a product of quality education, is essential for innovation and entrepreneurship. This, in turn, propels economic progress as individuals contribute to the creation of new ideas, technologies, and businesses. Thus, education emerges not only as an individual pursuit but as a collective asset that fuels the engine of societal advancement.

Overall, education is seen as an essential investment in the future of individuals and society, providing both personal and collective benefits (Formunyam, 2020).

South African education is built on a framework developed on the bedrock of 'Knowing, doing, and being' (Morrow, 1989). The curriculum documents translate this as 'knowledge, skills, and values'(CAPS, 2010). Based on these, the value of education can further mean that matriculants must understand government structures and constitutional processes, actively participate in the community, and possess those values that make them compassionate citizens.

The current challenge is that most high school graduates need access to what the curriculum promises. There need to be more economic opportunities, which points to a bleak picture of the relevance of education. There is a link between the prosperity of a country and, indeed, individuals and science and technology. It is noteworthy that if a country's economy is not performing well, this will affect the educational opportunities available, prompting a need to relook at the curriculum.

One of the functions of education lies in putting members of society into social strata based on educational qualifications. It is used by many as a tool to move up the economic ladder and access better living conditions. Education can be used as a tool to foster societal values and norms. This brings order and a sense of well-being and belonging within communities.

2.3 Why STEM schools?

STEM education is vital for several reasons, including economic development, improving the STEM workforce, and equipping learners to be innovative problem solvers (Blustein et al., 2020; Daugherty, 2013; El Nagdi et al., 2018). STEM fields are at the forefront of innovation. As such, they can be used as a tool for economic growth. Badmus & Omosewo (2020) argue that this matters because the nonchalance of STEM education poses a danger on the continent in that Stem provides a catalytic push needed for Africa to be conversant with its global counterparts in the 4^{th} Industrial revolution. For example, integrating robotics at the primary school level will enable learners to create computing programs that boost their creative and innovative capacity. Badmus & Omosewo (2020) further argue that the amount of money spent by African students seeking education overseas can be used to develop STEM in Africa using indigenous knowledge systems. Badmus & Omosewo (2020) further posit that education and work will determine the livelihoods of most people in Africa. If the education system fails to equip them with the necessary skills, the continent is headed toward the catastrophic effects of unemployment and poverty.

Blustein et al.(2020) argue that STEM careers are a tool to break the cycle of poverty because STEM careers are among the fastest growing, offer higher salaries, and provide a range of opportunities for professional development. In addition, Formunyam (2020) argues that STEM subjects improve students' capability to innovate as they better understand their environment. Exposing more students to STEM subjects earlier, students will engage more with science, math, and technology and enrol in higher STEM literacy. The need for STEM subjects lies in the thinking that it is seen as a panacea to depressed economies and lack of innovation (Zakaria & Iksan,2007)

According to Badmus & Omosewo (2020) a STEM education equips learners to be problem solvers, a skill in demand across many careers. Khumbah (2018) further argues that the continent currently lags in innovation and technology. This is on the realisation that there are more than a billion people in Africa (World Economic Forum, 2018). There is an urgent need for Africa to 'rise above the gathering storm' to catch up and keep abreast of global trends (World Economic Forum, 2016). To change Africa's trajectory, it is argued that there is a need to massify STEM education if Africa (Swaniker, 2013).
Several African countries need more skills (World Development Report, 2016). STEM education helps beef up the STEM workforce reducing reliance on expatriate labour. It is argued (Connell et al., 2019; Tikly et al., 2018) that the stock of African graduates needs to be more balanced towards humanities and social sciences, which is a drawback in Africa's ability to compete today and in the future. These issues have led to 'the inadequacy of domestic STEM workforce, adversely affecting Arica's position as a competitor' (Addaney, 2018; Knight, 2014; Union, 2015).

2.4 STEM and it’s comparative examples.

STEM is an acronym for Science, Technology, Engineering, and Mathematics that seeks to show how the disciplines are related and integrated (Widya & Rahmi, 2019). Breiner et al. (2012) argue that Stem as a discourse is a social construct whose evolution came about because of particular events. According to Merrill & Daugherty (2009), STEM is 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. Central to these definitions is the breaking down of silos between Science, Technology, Engineering, and Mathematics subjects into one seamless entity. STEM is understood as an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply knowledge gained in contexts that make connections between school, community, work, and the global experience enabling the ability to compete in a changing global economy. STEM teaching involves educational activities across all grade levels from primary through to post-doctoral levels in both formal and informal settings (Çalışkan, 2008; Suggate, 2009).

According to Catterall (2017), the seed of STEM education began in the 1950s with the US's reaction to the launch of Sputnik by the then-Soviet Union. They proceed to assert that Sputnik marked the beginning of the space age. This was viewed not as a Russian success in the development of humanity but the US's failure which they needed to do something about. Sputnik meant the US was threatened and vulnerable to Russian attack. In 1958, the US congress passed the National Defense Education Act, emphasising STEM education and STEM careers (Dugger, 2010). As such, it can be argued that STEM education was born out of a need for military dominance.

Apollo 2 marked a giant leap in space exploration with the Apollo lunar landing on the moon with eleven Astronauts (Dugger, 2010). This made the US regain its position as the leader in technological advancement.

There was a shift from a militaristic approach to the quest for economic dominance in the 1980s (Katzenmeyer & Lawrenz,2006). This occurred when Germany and Japan emerged as economic superpowers. At around the same era, the Program of International Student Assessment (PISA) published Mathematics and Science scores among 15-year-olds, revealing that the US was lagging behind China and other Asian countries (Catterall, 2017). This resulted in the publication by the US of ‘A Nation at Risk’. A document meant to improve the STEM workforce in the US. STEM was since then been viewed as a key component of US economic security (*Tucker,2012*). According to Dugger(2010), STEM in the late 80s and early 90s was a state-led economic imperative and it is in these years that the term STEM was coined. The idea was that STEM literacy would increase a workforce that could sustain economic growth and innovation within a country.

In the US, the concept of STEM education was introduced by the United States Administrators National Science Foundation (NSF) in 2001 (Hallinen,2015). It was driven by the need to create an innovative workforce that can solve local problems and empower the United States to compete in the global economy. There was a general fear that if the United States did not take STEM subjects seriously, this would have dire consequences in maintaining the United States as a world frontier in development (Hallinen, 2015). The STEM-focused curriculum then spread to Australia, China, France, South Korea, Taiwan, and the United Kingdom in the mid-2000s and to African countries, Like Kenya, Nigeria, Angola, and South Africa post-2010. The above section on the history of STEM education provided insight into the global evolution of STEM education. This spans military domination, rivalry, competition, and the inherent challenge for humankind to explore its environment. Understanding the evolution of STEM is vital for this study because it helps comprehend the pioneers' identity, patterns, and contributions. Learning from this leads to better policy design and implementation.

The implementation of STEM education in different regions will now follow. This is to gain more insight into STEM as it is understood and implemented in different countries, its success, failures, and reasons thereof. This is important because the success of any intervention is highly contextual and depends on complex factors. It is imperative to understand these in providing a critical report on STEM in South Africa and how it compares to other countries.

2.4.1 *The US and STEM Education*

Tucker (2012) argues that the US has a strong tradition of investment and innovation in STEM education. This has consequently led to it being a leader in developing cutting-edge technology and scientific research. The investment comes as a deliberate result of federal investments, strong university systems, entrepreneur culture, diverse and inclusive STEM community, and public-private partnerships (Blackley & Howell, 2015).

Through NASA and the National Science Foundation(NSF), the US federal government increased emphasis on STEM (Dugger, 2010). According to Katzenmeyer & Lawrenz (2006), this was through policy intervention that resulted in changes in curricula and educational evaluation. Gallant (2010) further argued that there was horizontal coordination of STEM education among states in which the US government created a non-federal STEM council to coordinate and facilitate STEM programs and initiatives. The US has a robust University system that plays a central role in promoting STEM education and research (Ferrini-Mundy & Gucler, 2009). Since the early nineties, US universities have developed several approaches through the National Research Foundation (NRF), National Research Council (NRC), and Kaleidoscope (PKAL) to promote undergraduate reforms that stimulate STEM education (Ferrini-Mundy & Gucler, 2009).

Bybee (2010) posits that the prevalence of a strong entrepreneurial culture that encourages innovation and supports the growth of technology and STEM-based companies provides a conducive environment for developing new technologies and fosters growth. Bybee (2010) further argues that this, coupled with the efforts made in creating diverse and inclusive communities, including programs to encourage underrepresented groups, for example, minorities and women, to pursue STEM careers, fosters inclusive development.

According to Gallant (2010), government, universities, and the private sector collaborate to support STEM education and provide students with real-world experiences and exposure to STEM careers. There have been many reports published in the last 30 years in the US that have resulted in calls to action, such as A Framework for K-12 Science Education (NRC, 2011) and Next Generation Science Standards (NGSS Lead States, 2013) (Mohr-Schroeder et al., 2015). These have helped change the educational landscape in favour of the development of STEM in the US (Burke & McNeill, 2011).

From the above, it is noted that the US implemented STEM education through a variety of programs. In summary, these include federal funding, professional development of teachers, a partnership between industry and education, STEM-focused schools, and STEM outreach programs to encourage participation from diverse groups. Overall, the implementation of STEM education in the US has been a collaborative effort involving government, education, industry, and the wider community, with a focus on providing students with the skills and knowledge they need to succeed in a rapidly changing global economy. Blustein et al. (2020) state that despite these strengths, the US faces challenges that may negatively impact its competitiveness in the global economy. These challenges emerge from unrepresentativeness, disadvantaged communities, and poor-quality STEM education associated with unequal societies. There are also challenges from STEM antagonists whose voices come from civic organisations and academics.

2.4.2 *Western countries and stem education*

As in the US, western countries have a strong tradition of investment and innovation in STEM education. According to DeJarnette (2012), they achieve this through government investments, robust university systems, entrepreneur cultures that foster innovation and support the growth of technology and STEM-based companies, and global collaboration with international companies including universities and research institutions. In addition, there is ongoing competition among western countries for the best talent and resources in the STEM field which may impact the quality of STEM education. Based on the information above, Western countries share a similar understanding and implementation strategy of STEM education as the US.

2.4.3 *Asian countries and STEM education*

Similar factors have influenced the implementation of STEM education in Asian countries, as in the United States and western countries, such as the need to produce a workforce with advanced technical skills and to maintain competitiveness in a rapidly changing global economy. However, the specific approaches to implementing STEM education have varied among different Asian countries. According to Teo et al. (2021), Singapore, South Korea, China, Malaysia, and Japan have strongly emphasised STEM education through several initiatives. These include funding for research and development, scholarships for students, and establishment of science and technology parks in South Korea(Teo et al., 2021).

Wahono et al.(2020) elaborate that Singapore which now has a strong reputation for its successful education system, established centres of excellence for STEM fields and provides students with opportunities for hands-on learning through internships and project work. Significant investments have been made in establishing research institutes that are STEM inclined. Apart from offering incentives for teachers to specialise in STEM, China has legislated and implemented several policies to boost STEM education and increase funding in the field (Kim et al., 2015; Teo et al., 2021; Wahono et al., 2020). Japan has a long-standing STEM investment history and has produced several world-renowned technology companies and researchers (Blackley & Howell, 2015). The government has implemented programs to encourage students to study STEM and provided funding for research and development.

These initiatives reflect a recognition by Asian governments of the importance of STEM education for driving economic and technological advancement. It is a commitment to providing students with the necessary resources and opportunities to succeed in these fields. Consequently, these countries have and continue to grow a strong talent pool of individuals with STEM skills. Asian countries thus have implemented STEM through the development of STEM centres and offered scholarships and incentives for teachers. What they have in common with Western countries and the US is the use of the private sector and the need to be inclusive of who has access to STEM education. The active involvement of the government is a common threat in all cases.

2.4.4 *Africa's stance on the STEM concept*

The African Union's (AU) agenda for 2063 aspires that Africa shall be a continent where 'well-educated and skilled citizens underpinned by science, technology, and innovation is the norm' (Addaney, 2018:14). As a regional body, the AU under the Science and Technology Consolidated Plan of Action encourages its member states to spend one per cent of its gross domestic product on research and development to enhance STEM education (Addaney, 2018). This report believes that more than one per cent is needed for a program intended to bring impactful change. Furthermore, only a handful of African countries have taken up the notion of STEM education.

Africa's stance on STEM is generally positive and supportive in countries that see it as an option (Spaull, 2013a). These leaders realise the importance of STEM and its potential for socio-economic development and competitiveness in the global economy. However, Spaull (2013) explains that challenges still need to be addressed, such as a lack of funding and infrastructure and the accessibility to quality STEM education in rural areas. South Africa, Kenya, Rwanda, Nigeria, and Egypt have implemented initiatives to promote STEM education (Formunyam, 2020). These countries have invested in improving STEM education, particularly at the primary and secondary levels, to increase the number of students who pursue STEM careers.

South Africa has a strong belief in STEM and has made significant investments in research and development, particularly in fields such as astronomy, biotechnology, and information technology. In 2016, South Africa commissioned a school of specialisation program aimed at pioneering STEM education at the high school level Formunyam (2020).
Kenya has been actively promoting STEM education and entrepreneurship and has launched initiatives such as the "Silicon Savannah" program to develop the country's technology sector (Lydia & Joash, 2015:4).

Gillet et al. (2019) argue that Rwanda has been implementing several initiatives to promote STEM education and innovation, including the "Rwanda Innovation Fund" and the "Kigali Institute of Science and Technology". These initiatives are aimed at promoting entrepreneurship and innovation in STEM fields, such as incubators, accelerators, and innovation hubs, to support the growth of startups and small to medium enterprises (SMEs). Nigeria is one of the largest economies in Africa and has a large pool of tech-savvy talent (Abina & Maria, 2019). The government has launched initiatives such as the "National Information Technology Development Agency" and "Nigerian Software Development Initiative" to promote the development of the country's technology sector (Corneille et al., 2020; El Nagdi et al., 2018).Tikly et al.(2018) argue that Egypt has a long scientific and technological advancement history and has been actively promoting STEM education and research in recent years, including establishing technology parks and research centres.

STEM in Africa is a government initiative still being implemented through clinical trials of curriculum change via intervention programs. Very little is mentioned regarding other stakeholders such as communities, big businesses, and technology companies. This may be because only a few African-initiated companies exist in these fields. Consequently, unlike in the US, learners in African counties are likely to have limited access to work-related experiences as they study STEM subjects.

2.4.5 *South Africa and STEM*

South Africa has made a concerted effort to promote STEM education (Kahn, 2013). These efforts span policy intervention from a political level, educational reforms, resource allocation, teacher development, and curriculum changes (Spaull, 2013b). Currently, South Africa is running clinical trials at the high school level. Regarding curriculum reform, the South African Department of Basic Education has made efforts to integrate STEM subjects into the primary and secondary school curriculum, focusing on hands-on, project-based learning (South Africa Flying Labs, 2021).

It has been argued that curriculum plays a central role in shaping society's socio-economic and political spheres (UNICEF, 2021; Gumede, 2008, 2013; Jansen, 2007). It can be insinuated that the living conditions of people are a product of the curriculum, which in turn manifests in their economic conditions and social strata. It is against this backdrop that the African National Congress (ANC) and South African government changed both curricula and policy to improve access, quality, and relevance of education to meet personal, national, and global targets as set up in the United Nations sustainable development goals (SDG) (Bloch, 2009).

Spaull (2013b) states that the South African government has also invested in teacher training programs to improve the quality of STEM education and increase the number of teachers qualified to teach STEM subjects. The government has established partnerships with private sector companies, such as tech companies and universities, to support STEM education and provide students with real-world experiences and exposure to STEM careers.

South Africa has established several STEM centres and institutes, such as the "South African National Research Foundation" and the "South African National Space Agency", to promote research and development in STEM fields (South Africa Flying Labs, 2021). The government has also launched several outreach programs to encourage students from underrepresented groups, such as girls and rural students, to pursue STEM careers. According to the South African National Planning Commission (2012), the government now requires organisations to spend 1.5 per cent of their payroll on training their workforce. In addition, in the Science and Technology Consolidated Plan of Action, the African Union urges members to spend 1 per cent of its GDP on research and development to enhance STEM innovations Addaney (2018).

Despite all this effort, South Africa faces several challenges in effectively implementing STEM. These include inadequate funding, teacher shortages, inadequate infrastructure, disadvantaged communities, stereotyping, and gender bias. The South African government has in the past come under criticism (The University of Johannesburg's Education Policy Consortium (EPC), South African Democratic Teachers' Union (SADTU, Centre for Education Policy Development (CEPD), The National Education Evaluation and Development Unit

(NEEDU)), for adopting foreign educational policies that have failed to produce intended outcomes within the South African context. These gave resulted in wasteful expenditure. STEM critics view it as another futile exercise if it is to be rolled out in South Africa.

STEM education often requires significant investment in infrastructure, technology, and teacher training, and many schools in South Africa lack the resources to provide high-quality STEM programs. There is a shortage of qualified teachers in South Africa, particularly in STEM subjects, and many schools struggle to attract and retain teachers with the necessary skills and expertise. Many schools in South Africa lack the necessary infrastructure and technology to provide high-quality STEM education, including access to computers, the internet, and laboratory equipment. Many students in disadvantaged communities, particularly those in rural and low-income areas, lack access to quality STEM education and may struggle to pursue STEM careers. There is still a gender bias and stereotyping of STEM subjects in South Africa, which may discourage girls and women from pursuing STEM careers.

It is argued that the strengthening of high school education in Mathematics and Science poses a significant challenge for south Africa, yet it is one of the essential drivers for development (Motshekga,2015; Spaull, 2013; Spaull & Kotze, 2015). Participation and progression in Mathematics and Science education in South Africa is problematic and below those of other countries at comparable levels of economic development. National Department of Education (NDoE), in 2004, argues that it was half that of Chile, Brazil, and Cuba. According to Spaull (2013b), slightly more than one-third of pupils who pass the Matric exam achieve sufficiently high grades to be admitted to the university, and of those obtaining bachelor passes, not all end up being accepted,19.4 per cent in 2014. Spaull (2016) further asserts that it is concerning because even then, close to 50 per cent of those initially enrolled drop out.

According to Botha (2010), black pupils in South Africa suffer double jeopardy of marginalisation because of racial inequality and poverty. This, together with the downward trajectory of economic development in South Africa, continues to increase the plight of black pupils. It can be argued that racial inequality cannot be ignored in determining educational attainment (Chikane, 2018; Jansen, 2019). Lessons from the student Fees Must Fall movement that plagued tertiary institutions in South Africa in 2016 show that highly talented and bright black pupils have been losing their right to education because of poverty, Chikane (2018).

Statistics show a gloomy reality in that "only 44 per cent of black and coloured youth aged 23-24 attained… (upper-secondary education) compared to 83 per cent of Indian youth and 88 per cent of white youth" Spaull (2013a:7). According to Spaull (2015: 3), "race is closely related to poverty, and as of 2011, blacks took up 90 per cent of the poverty share in South Africa". Against this backdrop, it is imperative to assess the impact of Schools of specialisation so that their effectiveness, efficiency, and sustainability are established.

Formunyam (2020) argues that SA has challenges in producing a STEM workforce. These include determining the most strategic expenditure of funds that will result in the most significant impact on the preparation of students to have success in STEM fields. Educators are still determining the implications and significance of STEM. Furthermore, there is a Lack of in-depth knowledge of STEM careers for both students and teachers. These challenges pose significant barriers to implementing effective STEM education in South Africa and must be addressed to support the country's competitiveness in a rapidly changing global economy.

This section explored STEM from a South African perspective. The following section will provide a global analysis of STEM education to identify similarities and differences regarding the formulation and implementation of STEM. These observations were used to assess and inform the impact of the school of Specialisation program as implemented at Curtis Nkondo Secondary School.

2.5 A Global analysis of STEM education

From the above literature, it is conclusive to say that STEM fields are some of the most important and rapidly growing fields in the world. These fields play a critical role in driving economic growth and innovation and improving the quality of life for people across the globe. The development of STEM education and research varies significantly between regions, the above exploration of literature enables one to gain more significant insights into how these countries understand and implement STEM.

Similarities exist between STEM in the United States, Asia, and Africa. Despite differences in the level of development, all three regions recognise the significance of STEM fields for their respective economies and societies. Governments in the United States, Asia, and Africa have invested in STEM education and research to support the development of these fields. All three regions strongly focus on innovation and aim to create new technologies and products to improve people's lives. This drive for innovation is especially evident in the technology sector, where companies in the United States, Asia, and Africa compete to create the latest and most excellent devices and software.

In all three regions, STEM fields rely heavily on collaboration between researchers, universities, and private industry. Collaboration is essential for solving complex problems and advancing knowledge in these fields. Furthermore, STEM fields are seen as highly relevant to modern society's needs and challenges. For example, issues such as energy, climate change, and healthcare are global concerns that require the development of new technologies and approaches in STEM fields to address.

The implementation of STEM education varies among different countries, including the United States, Western countries, and Asian countries, although there are some similarities in the approaches taken. Each country has unique needs, cultural context, and resources, which have shaped how STEM education is implemented. The specific approaches taken in each country may differ in terms of the level of government support, the focus on STEM subjects, the methods used for teacher training, and how real-world applications are incorporated into the curriculum. Additionally, cultural attitudes towards STEM education and the value placed on these subjects vary widely between countries.

The United States, western, Asia, and Africa differ in the level of investment they make in STEM fields. In the United States, investment in STEM is high, with significant funding for research and development from the government and private sector. The technology sector is a major driver of innovation and economic growth, with companies like Apple, Google, and Facebook leading the way. In Asia, investment in STEM is snowballing, especially in countries like China and India, where government investment has been significant in recent years. Technology is also a primary industry, with companies like Huawei, Samsung, and Tencent leading the way. On the other hand, Africa has lower levels of investment in STEM, but there has been recent growth in government support for STEM education and research.

The quality of STEM education is different in Asia and Africa compared to the US and western countries. In the United States, STEM education is highly developed, with well-established universities and research institutions. Asia also has a strong STEM education system, with many leading universities. However, STEM education needs to be developed in Africa, with fewer resources and fewer opportunities for students to pursue STEM careers.

The United States, Asia, and Africa also differ in diversity in STEM fields. In the United States, there has been a push to increase diversity in STEM fields, with initiatives aimed at increasing the participation of underrepresented groups, such as women and minorities. In Asia, there is a lack of diversity in STEM fields, with a relatively small number of women and minorities participating in these fields. In Africa, diversity in STEM fields is also a challenge, but there have been efforts to increase representation in recent years.

2.6 Critique of the STEM educational system

The STEM discourse is rampant, with few voices questioning its claims. It has gained so much momentum and is arguably the most influential, most oppressive, and most revolutionary education policy of our time' (South Africa & National Planning Commission, 2012). It is therefore imperative that its calls be investigated. Chesky & Wolfmeyer (2015) look for loopholes in STEM education's efficiencies, possibly fallible foundational principles used to justify policy decisions, and covert agendas affecting minor groups.

Chesky & Wolfmeyer (2015) argue the following against STEM schools:

- STEM schools focus too heavily on technical subjects and need to provide more exposure to other subjects such as arts, humanities, and social sciences.
- STEM schools are often criticised for lacking diversity, particularly regarding gender and race, which can limit students' perspectives and opportunities.
- Some argue that the strict focus on STEM subjects can stifle creativity and critical thinking skills.
- While STEM jobs are in high demand, there is concern that the skills taught in STEM schools may not prepare students for the job market, as technology and industries change rapidly.

However, it is also argued that STEM schools provide unique and valuable opportunities for students, including hands-on learning experiences, exposure to cutting-edge technologies, and a strong foundation in essential and in-demand skills(Gillet et al., 2019; Tikly et al., 2018).

The aspect of educational reform is familiar to South Africa. The post-colonial era has seen both institutional and curriculum changes (Gumede, 2008; Gumede, 2013; Mouton et al., 2012). At the institutional level, nineteen educational departments were reduced to one national and nine provincial departments (Gumede,2008). In terms of curriculum, there was a shift from apartheid education to Outcome-based education (OBE), which was followed shortly in 2002 with the National Curriculum Statement (NCS). According to Spaull & Kotze (2015), these reforms did not seem to solve South Africa's challenges and were meddled with problems of applicability within the South African context. NCS was revised soon after its implementation in 2005 and in 2012, Curriculum and Assessment Policy Statement (CAPS) was introduced (Curriculum Assessment Policy Statements, 2011).

To exercise due diligence in this research, it is imperative to allude to the fact that there is a need for sound reason when adopting a foreign educational framework. The above examples of education reform represent the notion of Africa catching up with the western world. There is a need to guard against STEM being an addition to this list of adopted curricula which ends up a fruitless exercise. The origins of STEM are based on dominance and the need for global superiority Badmus & Omosewo (2020). If this is allowed to filter into education, it may not address social issues. Carnoy (2016) argues that STEM education is divisive in its epistemology and creates a 'hard split' between itself and humanities. Stem education requires teachers who can deliver the curriculum objectives. Implementation of Stem in South African schools is envisaged to be a challenge considering that teacher training in Mathematics and Science still needs to be improved (Bybee, 2010a; Charalambous & Philippou, 2010; Pool et al., 2013). Furthermore, there have yet to be documented cases of STEM success within the African context over a considerable period to give attribution to the STEM model.

2.7 The philosophical underpinning of a STEM school

Chesky & Wolfmeyer (2015) argue that global educational practices are understood through themes. These themes constitute world views that are embedded in philosophy. As such, STEM presents a lens through which the world sees and understands education. It is therefore essential to critically enquire about the claims made by STEM and how they inform us. According to Chesky & Wolfmeyer (2015), philosophical arguments made by STEM can be viewed from axiological, epistemological, and ontological domains embedded in STEM policies. This study is anchored in the pillars adopted by the Centre for Excellence in Stem education and summarised in **Error! Reference source not found.**.

According to the Centre for Excellence in STEM Education (2022), the philosophy of a STEM school is built on eight pillars of design pedagogy, interactive content, authentic experiences, student engagement, creative problem solving, global and social awareness, innovation and optimism, and collaboration and communication. These pillars are explored in the paragraphs below. The eight pillars of the philosophy of a STEM school can be classified into different branches of philosophy. From an axiological standpoint, STEM education values the acquisition of scientific and technical knowledge and skills and the application of that knowledge to real-world problems (Anderson, 2020; Breiner et al., 2012b). The goal is to produce individuals who can think critically and creatively and who can make informed decisions based on scientific evidence (Burke & McNeill, 2011). Innovation and optimism fall within the axiology philosophical aspect of STEM. This pillar is concerned with values and ethics, highlighting the importance of being optimistic and innovative in the face of challenges.

According to Burke & McNeill (2011), interactive content, authentic experiences, and global awareness are all epistemological. Interactive content focuses on how knowledge is acquired and processed, stressing the importance of interactive content to help students develop their critical thinking skills. *Authentic Experiences* relate to knowledge acquisition, but it emphasises the importance of real-world experiences for students to understand the relevance and application of their learning.

Global and Social Awareness pertains to how students understand the world and their place in it, highlighting the importance of developing a global and socially conscious mindset. From an epistemological lens, Chesky & Wolfmeyer (2015) argue that STEM education is based on the idea that knowledge is acquired through systematic observation and experimentation and that this knowledge is subject to revision in light of new evidence. It values empirical evidence and

the scientific method as the most reliable means of acquiring knowledge about the natural world.
STEM education views the world as having a physical and empirical basis that can be studied and understood through scientific inquiry (Chesky & Wolfmeyer, 2015). It assumes that the natural world operates according to consistent and discoverable laws and that these laws can be used to explain and predict natural phenomena.

Ontology is about design pedagogy, student experiences, creative problem-solving, collaboration, and communication. Design Pedagogy is concerned with the nature of reality and the existence of things, emphasising the importance of design thinking in the educational process. Student Engagement relates to the nature of reality, as it focuses on the student experience and the need for them to be actively engaged in their learning.

Creative Problem Solving relates to the nature of reality and the existence of things, as it highlights the importance of creativity and problem-solving skills in real-world situations.
Collaboration and communication are concerned with the relationship between things and how they interact, emphasising the importance of collaboration and communication skills in the modern world. **Error! Reference source not found.** shows a summary of the philosophical classification of STEM pillars.

CLASSIFICATION	PILLARS
Axiology	Innovation and Optimism
Epistemology	Interactive Content, Authentic Experiences, Global and Social Awareness
Ontology	Design Pedagogy, Student Engagement, Creative Problem Solving, Collaboration, and Communication

Table 1 The philosophical underpinnings of a STEM school

2.8 Key attributes of a STEM school

From the philosophical underpinning of a STEM education, we narrow down to the key attributes of a STEM school. These will act as indicators in this study and be used in qualitative data collection and analysis. They will also help answer research question three on STEM practice at Curtis Nkondo Secondary school and how it compares to ordinary government schools like Freedom Park High School. These attributes will also inform this study on how to practice at Curtis Nkondo is aligned with the government's policies on STEM in South Africa and how this compares to that of other countries.

Stem schools have a strong focus on STEM subjects, with a curriculum that integrates and emphasises science, technology, engineering, and mathematics. It is project-based and hands-on learning with a focus on real-world problem-solving and experimentation. Learners in a STEM classroom use technology such as computers and engineering software as a tool to explore and apply STEM concepts.

It is argued (Breiner et al., 2012b; Bybee, 2010) that STEM schools foster a collaborative and interdisciplinary learning environment, with students working in teams on projects and exploring STEM subjects from multiple perspectives. The curriculum in a Stem school is tailored to prepare learners for the work environment within the context of STEM careers (Blustein et al., 2020). The focus is mainly on developing knowledge, skills, and experiences in demand in these fields.The goal of a STEM education is to produce innovative critical thinkers in developing new products to make the country competitive in the global market (Mohr-Schroeder et al., 2015). As such, learners in a STEM classroom are encouraged to ask questions, make observations, and engage in creative problem-solving.

According to Blackley & Howell (2015), STEM schools partner with businesses and industries to give learners hands-on experience and exposure to the careers they look forward to taking. These key attributes are designed to create an engaging and effective learning environment that prepares learners for success in STEM fields and to foster the skills and knowledge essential for success in STEM fields, the skills and knowledge that are paramount in taking up 21st-century careers and citizenship.

2.9 Factors affecting educational outcomes.

Literature (Ferguson et al., 2007; Koc & Celik, 2015; Pianta et al., 1990) alludes to different elements that influence educational outcomes. This study will look at family, school, political and economic factors.

2.9.1 *Family and its effects on educational outcomes*

Family background plays a significant role in learner achievement. Family income, parents' education level, and family structure are the most important and commonly researched attributes (Ferguson et al., 2007; Pianta et al., 1990; Spaull, 2013a). Family income determines what education parents can afford for their children (Ferguson et al., 2007). Affluent families tend to send their children to schools where they get more support, increasing their chances of success. Children of educated parents will tend to follow in their parent's footsteps. These parents are likely to help their children with homework and offer home environments conducive to positive educational outcomes.

Glanville et al. (2008) suggest that the family structure is also essential. Children from 'broken families' tend to fare less well than those where both parents are present and offer a supportive role to the child. Families play a significant role in the socio-emotional development of a child. Marschall (2006) further states that early childhood experiences can impact a child's social-emotional development, including their ability to form relationships, regulate their emotions, and develop resilience. Such children may struggle in a school environment where collaborative learning and the ability to deal with other children are necessary. It is however worth noting that this is only sometimes the case. From the writer's experience, some children from impoverished and 'broken families' perform better than those from affluent families where both parents are present. This may allude to genetics and the child's intrinsic motivation.

Piaget & Buey (1983) posit that the quality of early childhood care and education can have a lasting impact on educational outcomes. Early childhood development can affect brain architecture which affects learning. This can be linked to nutrition which has a knock-on effect on both mental a physical health (Çalışkan, 2008). It is argued (Ferguson et al., 2007; Spaull, 2013a) that a good educational base anchored in both mathematics and English literacy is a good predictor of academic success later in life. Children with positive early childhood experiences are likely to have strong language and communication skills critical for success in school.

2.9.2 *Institutional factors affecting educational outcomes.*

Teacher quality is argued to be the single most influential factor affecting educational outcomes (Aaronson et al., 2007). Well-prepared and effective teachers can better engage students in learning and provide high-quality instruction that meets their individual needs. The same teachers play a significant role in creating a positive, supportive learning environment which can impact student motivation and engagement. Good quality teachers monitor student progress by regularly assessing learners and giving constructive feedback, which can lead to improved learning. They also offer differentiated instruction to cater to learners with diverse learning needs. Literature (Çalışkan, 2008; Dinham, 2005; Koc & Celik, 2015) shows that better-qualified teachers with more experience tend to score high in these attributes.

Dinham (2005) asserts that effective school leadership can positively impact the learning environment and academic outcomes for students. By providing strong leadership and support, school leaders can help to ensure that all students have access to high-quality education and opportunities for success. Effective school leadership ensures a good school culture. They are custodians of instructional quality and student achievement. This they do by setting very high standards for themselves and the stuff they manage. In a school setup, high-quality teacher retention and proper resource allocation are characteristics of effective leadership. A school does not exist in isolation. As such, community engagement is essential. School leaders who engage with families and the community can build strong partnerships supporting student learning and academic achievement.

2.9.3 *Economic and political factors*

Hallinen (2015) argues that there is a strong relationship between a country's ability to solve its problems and its level of innovation. In other words, more innovative countries are better equipped to tackle the challenges they face, whether they be social, economic, or environmental. It is further argued by Cainelli et al.(2004) that innovation is an essential driver of economic growth and development. It allows countries to create new products, services, and technologies that can improve people's lives. For example, innovations in healthcare can lead to new treatments for diseases, innovations in transportation can improve the efficiency of travel, and innovations in energy can reduce dependence on non-renewable sources.

It is logical to deduce that when a country can solve its problems through innovation, it creates a virtuous cycle of economic growth and development. As the country becomes more innovative, it can tackle new challenges and create new solutions, which drives further innovation. This can lead to a positive feedback loop, where innovation drives economic growth, which leads to increased investment in innovation. Capello & Lenzi (2013) further argue that innovation is about more than just creating new products and services. It also involves the ability to adapt to change and to find new solutions to old problems. In this sense, innovation is not just about creating new technologies but also new approaches and ways of thinking.

The above arguments suggest that for countries struggling to solve their problems, innovation can provide a way out of their difficulties. By investing in innovation, these countries can create new industries, create jobs, and improve the quality of life for their citizens. This is particularly important for developing countries, where innovation can drive economic growth and reduce poverty.

Based on the above, it is plausible to assert that there is a relationship between a country's ability to solve its problems and its level of innovation. By investing in innovation, countries can drive economic growth, create new industries, and improve the quality of life for their citizens. This highlights the importance of investing in STEM education and research and fostering a culture of innovation and entrepreneurship for countries looking to drive economic growth and development.

It is further postulated that the core of innovation lies in knowledge of science and technology (Lemke, 2010). Failing to be innovative may result in a country failing to rise above its challenges, resulting in dire consequences if a country fails to compete in the global economy. The inability to compete globally is because of an inadequate STEM workforce. According to Formunyan (2020), STEM activists argue that the ability to compete globally is crucial for the prosperity of a nation. Hallinen (2021), alleges that our knowledge-based economy is driven by constant innovation and that the foundation of innovation lies in a dynamic, motivated, and well-educated workforce equipped with STEM skills. There is therefore an urgent need to pull resources together and build a strong STEM workforce.

Academic literature (Bandura, 1965; Piaget & Buey, 1983; Spaull, 2013a; Vygotsky, 1935) points to several factors affecting educational outcomes. According to Vygotsky (1935), pupils learn best under guidance provided by an adult scaffolding the pupil during the teaching-learning process. In this case, the teacher's role is that of guidance and facilitation. Bandura

(1965) adds to this and posits that learning also depends on the pupils' social environment and living conditions. Factors such as family social status, income, and standard of living play a significant role in pupil educational achievement. The level of cognitive development, as alluded to by Costley et al. (2013), is dependent on the pupil's age. Hussain (2006) argues that parental involvement and guidance indirectly influence educational outcomes. Family income, especially in the early years (0-6 years) of one's educational career, impacts educational outcomes later in life (Aakvik et al., 2005). The less the family income, the less likely the child will have educational resources provided for them.

Aaronson et al. (2007) argue that the teacher-pupil ratio plays a significant role in attaining positive educational outcomes. They further state that smaller class sizes result in more effective interaction, which leads to a better grasp of content (Aaronson et al., 2007). Teachers get to know their pupils better, enabling them to deliver lessons tailored to the specific needs of the class (Koc & Celik, 2015).

Studies in Nigeria show that the location of a school contributes to educational outcomes (Owoeye & Yara, 2011). They assert that schools in urban areas tend to attract better-qualified teachers and have more resources that the pupils can use to enhance their educational outcomes. Table 1 shows some of the factors that were held constant in this report to come up with comparable control and treatment groups. According to Jackson et al (2015), there is a causal relationship between spending and educational outcomes in general, however, there is a limit to spending and other factors also come into play. It is a top priority in STEM education and research to find out what kinds of spending matter the most and in what contexts school spending is likely to open the bottleneck and improve student outcomes (Hallinen, 2021).

Targeted School spending can impact educational outcomes. Targeted is meant research-based, context-specific spending geared to the specific need of the school (Jackson, 2018). The quality of spending is often more important than quantity. Investing in effective programs, high-quality teachers, and modern technology can significantly impact educational outcomes more than simply increasing overall spending.

Jackson (2018) goes on to explain that targeting spending to areas with the greatest need, such as low-performing schools or disadvantaged communities, can also positively impact educational outcomes. It is noteworthy that other factors, such as poverty, family background, and community resources, can also impact educational outcomes and may need to be addressed in addition to increased spending. Jackson (2018) emphasises that an evaluation of school spending may take a long time because the relationship between school spending and educational outcomes may become apparent for several years, as the effects of increased spending may take time to materialise.

Furthermore, political decisions have implications for the resources available to schools and the quality of education they can provide (Apple, 1992; Blue, 2007; Chikane, 2018). Political ideology can influence the goals and priorities of education, with some parties and leaders emphasising certain subjects or values over others. This can either lead to a united country or one that is divided. A division in political ideologies can lead to civil unrest. Civil unrest affects school attendance, destroys school infrastructure, and hinders the attainment of good grades.
Political leaders formulate policies governing education, including standards for curriculum, assessment, and teacher training (Fischer, 1998; Giovannoni, 1977; Titmus, 1974). A pro-education government will stimulate development programs aimed at improving the education level of its citizens. Political decisions about resource allocation can significantly impact educational outcomes, especially for disadvantaged groups who may have less access to educational resources.

2.10 Theoretical and conceptual framework

Central arguments in this literature reveal that STEM schools are anchored in axiological, ontological, and epistemological principles that influence pedagogy (Chesky & Wolfmeyer, 2015). The overarching theoretical framework in this study is premised on the eight pillars of a STEM school, namely design pedagogy, interactive content, authentic experiences, student engagement, creative problem solving, global and social awareness, innovation, and optimism, as well as collaboration and communication (*Center for Excellence in STEM Education*, n.d.).

The Centre for Excellence uses this framework for STEM education in New Jersey and several STEM schools in the United Kingdom. Within the African context, the same framework has been adopted by The International School of Kenya, as well as by the Zambian and Ugandan government in 2020. Rwanda is pioneering STEM education in Africa because it managed to adopt a STEM curriculum in 2019 from pre-primary to upper secondary *NEPAD* (2021).

Elmore (1996, 2004) further argues that the instructional core is the most influential factor in improving educational outcomes. The instructional core is meant for teachers, content, and curriculum. This study sees the instructional core as embedded in the eight pillars proposed by the Center of Excellence in STEM Education. This is illustrated in Figure 1 below.

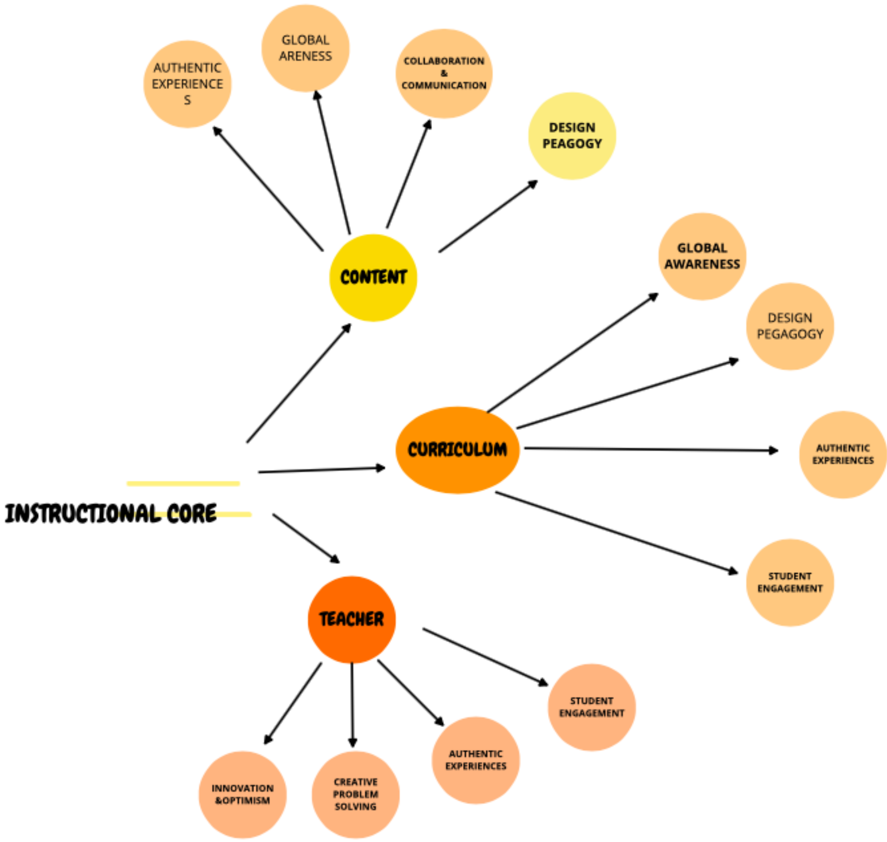

Figure 1 Integration of the eight pillars of STEM and the Instructional Core

The eight pillars overlap the instructional core. For example, the teacher must nurture creative problem solving but again this can be embedded in the curriculum depending on the tasks that need to be given to learners as part of the compulsory assessment.

It is important because the approach empowers learners to be drivers of their learning by applying constructivist approaches. Learners are put at the Centre of inquiry, and teachers act as facilitators. The aim is to produce independent thinkers. By seeing the world from a holistic perspective, are stimulated to be innovative. Innovation consequently leads to the development of new products and processes which are then able to sustain economies stimulating economic growth and international competitiveness. This research will use this framework to compare STEM education at Curtis Nkondo school of specialisation with that of the west and other African countries.

A theoretical framework is a statement or a group of statements upon which a study is underpinned. The exploration of the literature reveals that a variety of theoretical frameworks can inform STEM schools. This study adopts constructivism, STEM integration, problem, and project-based learning in creating a STEM identity. Constructivism posits that learning occurs when individuals construct their understanding through experience and interaction with their environment. STEM schools that use constructivist approaches focus on hands-on, project-based learning and encourage students to explore and experiment with new ideas and technologies. STEM Integration framework emphasises the integration of STEM subjects, recognising that real-world problems often involve multiple disciplines and that effective solutions require interdisciplinary thinking. STEM schools that use this approach aim to foster collaboration and integration between STEM subjects and other areas of study. Problem-Based Learning: This approach emphasises the use of real-world problems as a starting point for learning, with students working to identify and solve these problems through collaboration and applying STEM knowledge and skills. Project-Based Learning framework encourages students to learn by working on authentic, meaningful projects that involve the application of STEM knowledge and skills to real-world challenges.

STEM Identity recognises the importance of developing a positive identity and self-efficacy in STEM subjects and aims to create learning environments that support and encourage students to pursue careers and interests in STEM.

These frameworks can inform and guide the curriculum, teaching methods, and assessment practices used in STEM schools, to create engaging and effective learning experiences that prepare students for success in STEM fields.

Establishing the school of specialisation program's impact lies at this study's core. A logical Framework was used to assess the impact. According to McLean (1988), Gertler et al., 2016), and Khandker et al. (2009), a logical framework is a planning and monitoring tool that provides a structured approach to defining and analysing objectives, outcomes, and activities and helps to identify the causal relationships. Khandker et al., (2009) further state that the LogFrame matrix also provides activities with expected results and assesses the achievements of these results against defined indicators and targets.
In this study, the indicators and targets are defined in the literature review and are summarised in Table 2.

OBJECTIVE	OUTPUT	ACTIVITIES	INDICATORS	ASSUMPTIONS	RISKS
To provide students with a comprehensive STEM education	Curriculum developed and implemented that covers all areas of STEM	Develop a comprehensive STEM curriculum	% of curriculum that covers all areas of STEM	The government will provide funding for teacher training and resource acquisition.	Insufficient funding from the government
	Adequate number of qualified teachers trained in STEM education	Train teachers in STEM education	Number of teachers trained in STEM education	Teachers were receptive to training and willing to implement the new curriculum.	Resistance from teachers to change
	Sufficient resources, including laboratory equipment and technology, were made available for STEM instruction	Acquire and install laboratory equipment and technology	Availability of resources for STEM instruction	Students were interested in and motivated to learn about STEM	Lack of student interest in STEM
To increase student engagement and achievement in STEM	Increased student attendance and participation in STEM classes	Provide students with hands-on learning experiences in STEM	% increase in student attendance and participation in STEM classes	Hands-on learning experiences will increase student engagement in STEM	Limited resources for hands-on learning experiences
	Improved performance in STEM subjects as demonstrated by test scores	Encourage students to participate in STEM-related extracurricular activities, Provide opportunities for students to apply STEM concepts in real-world contexts	Improvement in test scores in STEM subjects	Opportunities for real-world application will increase student motivation to learn STEM	Lack of student interest in extracurricular STEM activities

Table 2 Stem school log frame matrix

2.11 Conclusion

This chapter overviewed existing research and academic scholarship on STEM education. It presented a systematic and critical analysis of published literature, summarised, and synthesised the current state of knowledge on STEM intervention programs. The context and background of the study lead to the identification of gaps in the field of STEM education from a South African perspective. This supported the need for actionable data to be synthesised to give actionable insights for developing STEM education in South Africa.

The parts of the literature that will be important for this study are those that result in positive educational outcomes in Mathematics and Physical Sciences. These include factors that increase student engagement such as the nature of the institution and the funding government puts into the STEM programs. Curriculum plays a major role as stakeholders need to appreciate the worth of the intervention. Good leadership and quality of the teachers add to the effective implementation of STEM initiatives as such are deemed a crucial factor from the literature review. Context in which the program is implemented is also vital because the program must be accepted by the community and seen as something of value.

Chapter 3 : RESEARCH METHODOLOGY

3.1 Introduction

Chapter one established the questions this study seeks to answer. The literature review presented recurring themes, emphasising the history of STEM intervention programs, their philosophical orientation and factors that contribute to the success of STEM. Antagonistic perspectives of STEM education were also explored, as argued by critics. This chapter narrows the focus to the case studies under investigation and explains how data was collected and analysed. It, therefore, forms the first step in understanding the complexities of South African STEM schools, specifically at Curtis Nkondo and how they compare to ordinary government schools such as Freedom Park Secondary school in Soweto.

This chapter details the data.

3.2 Research Strategy/Approach

Creswell (2013) argues that a research approach also known as a research strategy is a broad philosophical perspective which deliberates on underlying assumptions and beliefs about the nature of the research problem and appropriate methods of investigating it.

The empirical findings of this study were gathered through a mixed-methods research design. It is argued (Creswell, 2013) that an integrated data analysis approach involving both quantitative and qualitative data has the advantage of complementing the results from either method.

3.3 Research design

According to Creswell et al. (2007), a research design is a researcher's strategy to conduct a study. Inherent in it are the methods, steps and techniques that were used to collect and analyse data. The research design is instrumental in answering questions on how data is collected and analysed, as well as steps taken to ensure the validity and reliability of the results. It is a detailed study plan (Myers, 2019). This study used a longitudinal, quasi-experimental sequential exploratory design to gather empirical data and findings.

According to Creswell (2014:224) and Creswell & Clark (2011:77), exploratory sequential mixed methods is a two-phase approach. This study began by exploring quantitative data analysis and then used the findings in a second qualitative phase to develop in-depth interview questions. The overall aim of using exploratory sequential design was to work towards a triangulation design to achieve convergence of data collected. The intent in using triangulation design is to bring together the different strengths and non-overlapping weaknesses of quantitative methods (i.e., large sample size, trends, generalisation) with those of qualitative methods (i.e., small sample size details, and in-depth research (Creswell & Clark, 2011; Creswell, 2014).

3.4 Research procedure and methods

According to Wotela (2017), this section "is the most practical part of the research process and, therefore, provides for actual research tools, products or outputs". The research design and strategy document the research orientation (Wotela, 2017). In this section, a detailed procedure of what happened is provided. Ivankova et al.(2006) provide a comprehensive procedure for a sequential mixed methods design procedure. Figure 2 shows a modified version that was used in this research. Figure 2 outlines the research procedure.

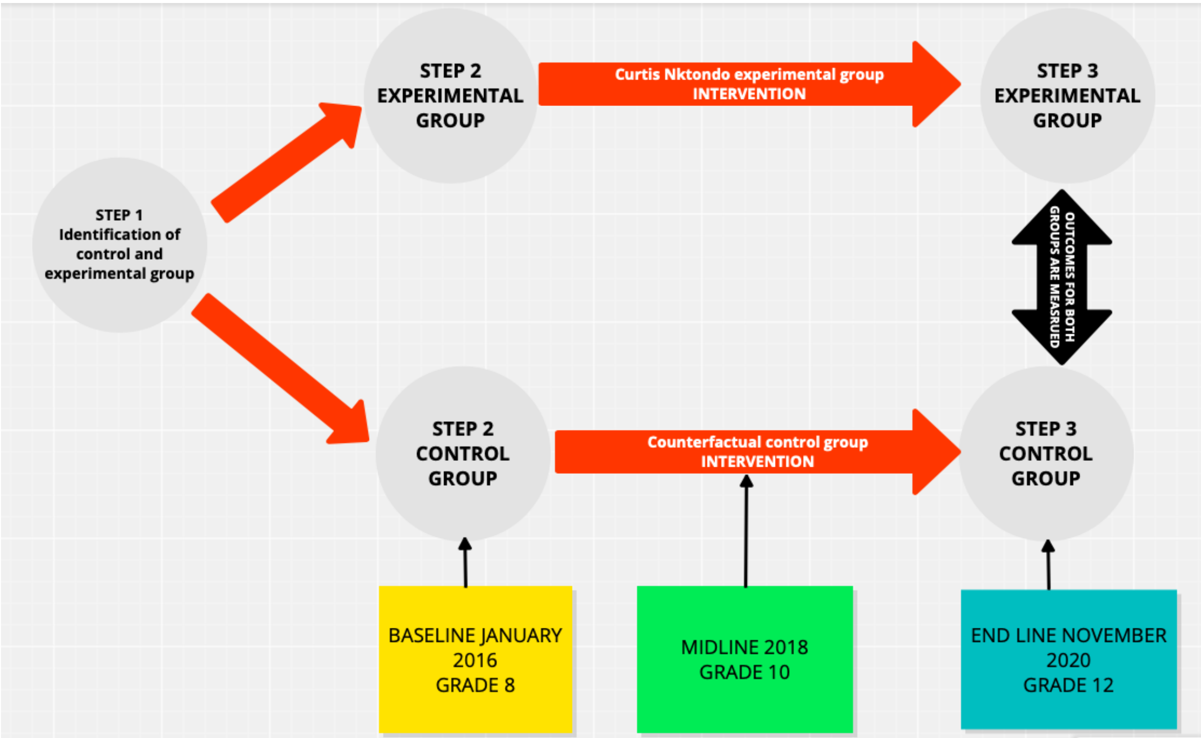

Figure 2 Diagrammatic outline of the research process.

The first stage entails data collection from school records. This was in the form of Mathematics and Science scores of the 2016 grade eight cohorts as they commenced secondary school education at Curtis Nkondo and Freedom Park High School as the treatment school. Choosing a comparison school from the same district was essential to minimise the differences between the schools. A school in a different district would require further justification as to why the schools can be compared. Observable factors considered when selecting the comparison school include class sizes, the presence of governance systems in the school, facilities, teacher qualifications and experience. This baseline data must show no significant difference in the learners' performance. The second data collection point was in 2018, which will provide mid-line longitudinal data. The product of this was numeric, and data was analysed to establish if, indeed, there are improvements. Endline data analysis in 2020 was based on Matric results in Mathematics and Physical Science.

The second stage analyses the performance of both groups using the difference-in-difference method. Longitudinal data were collected from 2016- 2020 for the two cohorts, first in 2016 (baseline), followed by 2018 (midline) and endline in 2020. The numeric data collected was used to feed into the qualitative section of this report. It will help select and develop interview questions (Ivankova et al., 2006).

Stage three involved qualitative data collection through individual in-depth interviews of Maths and Science teachers, heads of departments, principals, and district officials of the two schools. The product of this was text data transcripts that were analysed using the qualitative data software NVivo. The text codes were used to understand quantitative data analysis better. In the last stage, I will triangulate the quantitative and the qualitative results. This entails interpreting and explaining the quantitative results based on the qualitative findings. Gaps in quantitative findings may find explanations in the qualitative results. This will likely lead to logical discussions and implications of this research based on the results obtained.

3.5 Data and information collection instruments

Quantitative baseline data was collected for both groups before the intervention took place. Considering the research was conducted after the intervention, baseline data was collected historically based on secondary data available at the schools and the Gauteng Department of Education. These records contained information related to parental income, household size and type of family, and learner academic attainment in grade seven for mathematics, natural science, and English. These confounding variables were used to develop a baseline establishing similarities between learners at the start of grade eight.

According to Babbie (2015:248), a data collection instrument is a “document containing questions and other types of items designed to solicit (research data and) information”. Several

data collection instruments can be used in qualitative research, namely, in-depth interviews, observations, document analysis and surveys (Creswell, 2013). This study used in-depth interviews because the one-on-one conversation between the interviewer and interviewee helps to gain a deep understanding of participants' experiences and perspectives on a particular topic (Babbie, 2015). Qualitative data was collected through face-to-face open-ended interviews.
This study was mainly quantitative as such qualitative data was used to give possible reasons and meaning to the numbers obtained.

3.6 Target population and sampling of respondents

3.6.1 *The research sites.*

Both Curtis Nkondo and Freedom Park high schools are in Soweto, a predominantly black township in the Gauteng province of South Africa. Soweto is one of the first Townships established by the Apartheid government to house natives. For this reason, it bears historical significance in the fight for South African freedom. Soweto is the home of prominent struggle icons such as Nelson Mandela and Desmond Tutu. In modern-day South Africa, Soweto is a primary tourist attraction site with a rich cultural heritage. As of the last published national census results of 2011, Soweto had a population of about 1.3 million people with a population density of 6357 per Km^2. Table 3 shows more information on the population of Soweto's gender, population group and languages spoken as of the 2011 census.

Gender	Population	%
Female	640 588	50.38
Male	631 040	49.62
Race	**Population**	**%**
Black	1 253 037	98.54
White	1 421	0.11
Coloured	13 079	1.03
Asian	1 418	0.11
Other	2 674	0.21

First Language	Population	%
isiZulu	350 940	40.87
isiXhosa	88 474	10.3
Afrkaans	5 639	0.66
Sesotho sa Leboa	41 179	4.8
Setswana	106 419	12.39
English	3 047	0.35
Sesotho sa Borwa	157 263	18.32
Xitsonga	62 157	7024
SiSwati	8 696	1.01
Tshivenda	29 498	3.44
isiNdebele	2 801	0.33
Other	2 531	0.29

Table 3 Population Structure of Soweto (Stats,2011)

It categorises the population into different racial and ethnic groups, including Black African, white, Asian, coloured, and other groups. According to the table, much of the population in Soweto is Black African, with a total of 1,253,037 individuals belonging to this racial group. The next largest group is coloured, with 13,079 individuals, followed by other groups, with 2,674 individuals. The population of white and Asian individuals in Soweto is relatively small, with only 1,421 and 1,418 individuals, respectively.

Error! Reference source not found. provides valuable insights into the demographic makeup of Soweto to understand the population and its characteristics better. It also provides information on gender. Specifically, it indicates that there are 631,040 males and 640,588 females in this population. 50.4% of the population of Soweto is female, and 49.6% is male. 98.5% of the population is black. Most people in Soweto speak Isizulu 37.3%, followed by Sotho and Tswana-speaking people, who make up 15.6 and 13% of the population, respectively. Other languages spoken in Soweto include English Tsonga and Afrikaans.

3.6.2 *Curtis Nkondo*

This research was conducted at Curtis Nkondo secondary school (the experimental group). Curtis Nkondo School of Specialisation is a public specialised school. It is located in Emdeni Extension, a section of Soweto. This institution is an urban education institution by The Gauteng Education Department. The schools' vision is to 'provide education excellence, using technological design, economic and social research drive approaches to studying issues of our time, such as urbanisation, technological change, economic empowerment, sustainability, migration, and globalisation'. Its focus is on mathematics, science, engineering ICT, and entrepreneurship. As alluded to in Chapter one, the STEM program at Curtis Nkondo is different to ordinary public schools in South Africa. It enjoys a more flexible curriculum, selection tests to choose who can attend the school, better funding, and a management style.

According to the *National Department of Basic Education(* 2016), Curtis Nkondo follows the P-Tech Model programme. Inherent in this program is equipping learners with tertiary qualifications while they are still at school. The *National Department of Basic Education(* 2016) plans that this will be implemented through a collaboration with the Institute of Business Management (IBM), business South Africa as well as other stakeholders. Learners will have access to on-the-job training and mentoring programs and be equipped to overcome professional barriers. Additionally, learners at Curtis Nkondo receive career guidance and counselling and bursaries for pursuing careers in STEM after completing high school.

The STEM program at Curtis Nkondo receives more funding from the government compared to other ordinary government schools with the same school establishment *National Department of Basic Education (*2016). This extra funding enables the school to run initiatives developed by learners. These initiatives aim to come up with self-sustainable projects that be used to generate income and from which learners can earn a living.

To ensure that the implementation of the program goes according to plan, Further Education and Training (FET) officials conducted monitoring and support visits to Curtis Nkondo. Officials support the practical usage of digital teaching and learning resources as well as provide mediation with multimedia digital content.

Government funding and donors ensure the availability and utilisation of learning tablets in the classroom, which has benefited learners greatly from loaded e-content resources, including videos. Further, the department is continuing to train ICT Schools on the use of Resource Management Systems (RMS). The RMS is a web-based programme which will enable individual ICT schools to complete curriculum profiling and requisitioning electronically. The program follows a modified curriculum which allows teachers to structure content in such a way as to deliver STEM subjects in a seamless and coordinated manner. This is done through projects which span different STEM subjects and require the application of cross-cutting content.

The management of Curtis Nkondo is mainly transformative, collaborative, and participative. These attributes of democratic leadership allow everyone to feel valued and inspired to contribute and open channels so that the voices of all stakeholders can be heard. Within the classroom, teachers act as facilitators of learning and follow a constructivist approach. Collaboration, creativity, communication, and critical thinking. This is in line with the pillars of STEM education tailored to foster innovation development.

Lastly, Curtis Nkondo selects the correct type of learner to enter the school in grade eight through rigorous selection criteria involving assessments in Mathematics, Science and the

English language. This selection is deemed important to allow the right learner to maximise the program. Table 4 summarises the STEM program at Curtis Nkondo.

STEM PROGRAM AT CURTIS NKONDO SCHOOL OF SPECIALISATION	DESCRIPTION
Curriculum	STEM program follows a modified curriculum that allows for seamless coordination of STEM subjects through cross-cutting projects.
P-Tech Model Program	Equips learners with tertiary qualifications whilst still in school through collaboration with IBM, Business South Africa, and other stakeholders.
Funding	Receives more funding from the government compared to other ordinary government schools with the same school establishment, enabling the school to run self-sustainable projects.
Classroom Management	Teachers act as facilitators of learning and follow a constructivist approach that fosters collaboration, creativity, communication, and critical thinking.
Learner Selection	Curtis Nkondo selects learners for grade eight through a rigorous selection process that involves assessments in Mathematics, Science, and English language to maximise the program's opportunities.
Career Guidance and Counselling	Learners receive career guidance and counselling, as well as bursaries for pursuing careers in STEM after completing high school.
Digital Teaching and Learning Resources	FET officials conduct monitoring and support visits to support the practical usage of digital teaching and learning resources, including loaded e-content resources and videos.
School Management	The school management is transformative, collaborative, and participative, allowing all stakeholders to feel valued and inspired to contribute and be heard.

Table 4 STEM program at Curtis Nkondo secondary school

3.6.3 *Freedom Park High School*

Freedom Park High School in Soweto was chosen as the Comparison group based on similar characteristics such as teacher qualifications, resources, size of the school, and school governance. Freedom Park High School is an ordinary public school that offers a range of academic programs and sports, cultural, and other extracurricular activities. The school is known for its focus on providing high-quality education and for its commitment to preparing students for success in their future careers. Freedom Park Secondary school is known for its committed staff and school management. Table 5 summarises the main features of an ordinary public school in South Africa, such as Freedom Park Secondary School.

Such schools usually follow a standard curriculum that the government mandates. The admissions process typically follows a district-based enrolment system where students are assigned to schools based on their residential address. The government provides funding for traditional public schools based on the number of enrolled students, and the amount may vary depending on the location and socio-economic status of the school.

Teachers in traditional public schools follow a traditional lecture-based teaching approach, and classroom management is typically hierarchical, with students expected to follow the teacher's lead. Learner support services such as counselling and academic tutoring may be available, but they may be limited due to resource constraints.

Digital teaching and learning resources may be available, but access to these resources may vary depending on the school's budget and infrastructure. The school management is typically hierarchical, with decisions made by administrators and teachers following established protocols. Career guidance and counselling may be limited, and students are generally expected to seek out opportunities for post-secondary education or employment.

ORDINARY PUBLIC SCHOOL	DESCRIPTION
Curriculum	Follows a standard curriculum mandated by the state or district education department.
Admissions Process	Typically follows a district-based enrolment system where students are assigned to schools based on their residential address.
Funding	The government provides funding based on the number of enrolled students, and the amount may vary depending on the location and socio-economic status of the school.
Classroom Management	Teachers follow a traditional lecture-based teaching approach, and classroom management is typically hierarchical, with students expected to follow the teacher's lead.
Learner Support Services	Essential learner support services such as counselling and academic tutoring may be available, but they may be limited due to resource constraints.
Digital Teaching and Learning Resources	Digital resources may be available, but access to these resources may vary depending on the school's budget and infrastructure.
School Management	The school management is typically hierarchical, with decisions made by administrators and teachers following established protocols.
Career Guidance and Counselling	Career guidance and counselling may be limited, and students are generally expected to seek post-secondary education or employment opportunities.

Table 5 Features of an ordinary government school.

Purposive sampling was used for the experimental group because Curtis Nkondo was the first STEM school to be commissioned in South Africa and has been in operation for more than five years. This makes it a suitable data collection site. The comparison school was described in the following paragraphs. Schools in South Africa are classified according to quintiles. In South Africa, quintiles are used to classify public schools based on their levels of poverty and need (Department of education, 2006). According to Mestry (2013), the quintile system allocates government funding to schools to ensure that schools serving disadvantaged communities receive the necessary resources to provide quality education.

According to the Department of Education (2006), there are five quintiles, with Quintile 1 being the poorest and Quintile 5 being the least poor. Quintile 1 schools serve the most economically disadvantaged communities and are fully funded by the government. Quintile 2 schools serve slightly less disadvantaged communities and receive additional support from the government. Quintile 3 schools serve middle-income communities and receive some support from the government. Quintile 4 schools serve higher-income communities and receive limited support from the government. Quintile 5 schools serve the least economically disadvantaged communities and are not supported by government funding. The quintile system ensures that schools serving the most disadvantaged communities receive the resources they need to provide quality education and reduce the gap in education outcomes between different socio-economic groups.

Curtis Nkondo is a quintile one school. There are two other quintile one schools in Soweto, namely Altmont Technical High School and Freedom Park Secondary School. After identifying comparable characteristics (based on school and Gauteng Education data), it was found that these two schools were similar to Curtis Nkondo. The school data was based on school size, teacher qualification, class size, average distance learners travel to school, the presence of a functional school governing body as well as the availability of laboratories for science pupils.

Both Freedom Park secondary and Altmont Technical High School were input into a computer for selection, and Freedom Park Secondary School was randomly selected Excel to reduce researcher bias. This school also was ideal for this study because a difference in difference was used as an analysis tool. One of the key features of this method is the need to avoid spillages. Freedom Park High School is situated seventeen kilometres from Curtis Nkondo Secondary School. This is further than Altmont Technical High School, six kilometres from Curtis Nkondo. Freedom Park High School pupils and teachers have a lower chance of sharing resources than Altmont Technical High School, thereby reducing spillover effects.
Furthermore, the following officials were purposively sampled: the Headmistress of Curtis Nkondo, secondary school, heads of departments for mathematics and science, one

mathematics teacher and one Science teacher. The same was done for Freedom Park High School. In addition, subject specialists in mathematics and science from the Gauteng North district, where both schools are located, were interviewed.

Non-probability, purposive sampling was used for this research to gain a deep contextual understanding of the program from the participants. This sampling method involves choosing respondents that are available and willing to participate (Bhattacherjee, 2012). In this case, only a few schools have been commissioned for this program, and Curtis Nkondo was the first and has been in operation for five years. This will enable the researcher to collect data collected over a reasonable period. An advantage of this sampling is that it has a bearing on ecological validity in that similar results could be obtained in similar contexts. However, it needs to be stronger in population validity as the results obtained cannot be generalised to the entire population of South African schools.

3.7 Ethical considerations

This study was a low-risk study which did not involve minors or vulnerable groups. Several steps were taken to ensure that the study was conducted responsibly and respectfully.

The researcher obtained ethics training from an internationally recognised institution and passed the test after training. The ethics training was on a set of principles and guidelines that are used to ensure that research is conducted in a responsible and ethical manner. These principles are designed to protect the rights and welfare of research participants, as well as to maintain the integrity and quality of the research. Some key ethical principles in research included:

- Respect for persons: the study must respect the autonomy and dignity of research participants and ensure that they are fully informed about the research and any potential risks involved.
- Beneficence: the research must aim to maximize the potential benefits of the research while minimizing any potential harm to participants.
- Non-maleficence: the research must take steps to ensure that the research does not cause harm to participants and must minimize any risks involved.
- Justice: the research must ensure that the benefits and risks of the research are fairly distributed across different groups in society.

To ensure that these principles are upheld, research ethics committee at Witwatersrand University ensured that the study meets ethical standards. This was enforced as the study was

required to obtain informed consent from participants, maintain confidentiality, and ensure that data is collected, analysed, and reported in an ethical and responsible manner.
This is shown in appendix one. Furthermore, ethical clearance was obtained from the University of Witwatersrand ethics committee and is attached as appendix two. Additionally, permission was sort and granted by the Gauteng Department of Education (appendix three) as well as Curtis Nkondo (appendix four) and Freedom Park high school (appendix five). Participants gave informed consent (appendix Six), and their privacy and confidentiality were protected.

3.8 Data Management

3.8.1 *Data and information collection and storage*

To ensure data security, the researcher signed a non-disclosure agreement as part of the engagement process. Raw data was kept on a password-protected hard drive to prevent others from accessing it. It was kept in a locked safe for at least five years before being destroyed.

3.8.2 *Processing in preparation for analysis*

Wotela (2017) argues that this section of a research report is made up of two interrelated parts, namely, data processing in preparation for analysis and the actual data analysis. Table 6 shows a modified version of the steps that were followed in preparing data for analysis as adopted by Wotela (2017)

QUALITATIVE INFORMATION PROCESSING		QUANTITATIVE DATA PROCESSING	
1	Transcribing data from recordings	1	Editing school and district spreadsheets
2	Conceptualising themes from the literature review	2	Entering into computer
3	Formulation of codes from literature review	3	Using STRATA to obtain inferential statistics
4	Conceptualising themes from empirical data		
5	Formulating codes from themes obtained from empirical themes		

Table 6 Data and information processing steps for both qualitative and quantitative research approaches (Wotela 2017:236)

Microsoft TEAMS automatically did a transcription of data from audio to text. This needed checking as TEAMS missed some of the words. Therefore, playing the audio against the transcripts was necessary to verify and correct errors.

Empirical data-driven themes were obtained by coding qualitative data obtained from interviews. The codes were packaged into themes using NVivo qualitative software. These were compared with theory-driven themes to establish similarities or differences with data-driven themes from the literature review. Figure 3 shows a structure of a thematic network that will be used in this study.

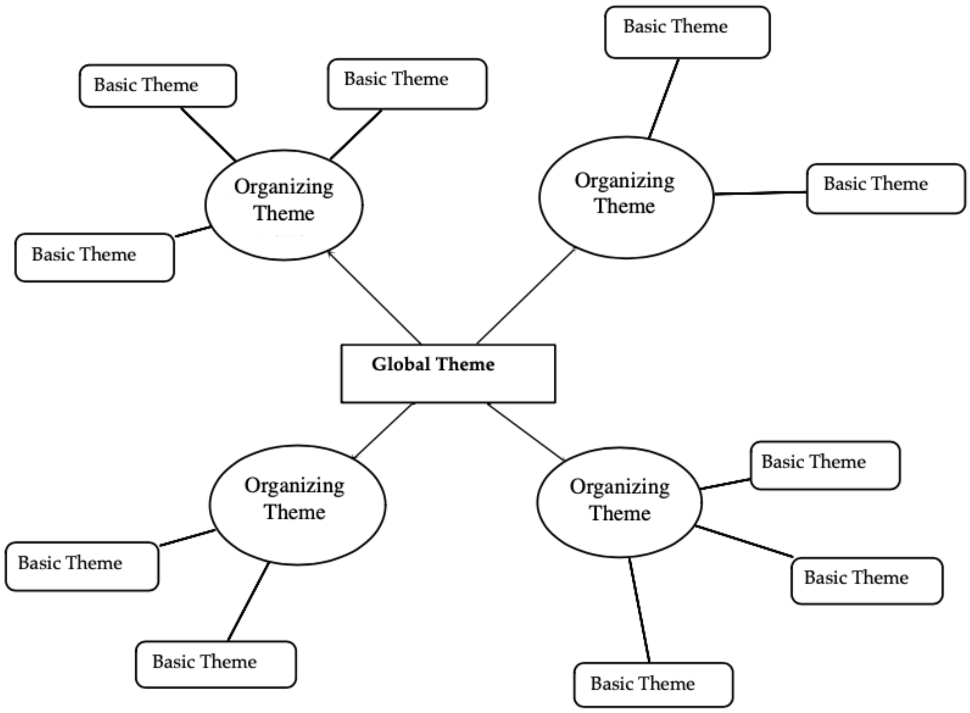

Figure 3 Structure of a thematic network (Attride-Stirling, 2001:388)

According to Attride-Stirling (2001), identifying a global theme in the thematic analysis involves synthesising the organising and basic themes to develop a cohesive and comprehensive understanding of the data. Figure 3 shows that Organising themes are broad categories identified in the data, while basic themes are more specific patterns or ideas linked to the organising themes. To identify a global theme, one must first review the organising themes and basic themes that have emerged from the data and look for patterns and connections between them (Boyatzis, 1998). They may also consider the broader context of the research, including the research questions and the relevant literature. Once patterns and connections between the organising themes and basic themes have been established, global themes emerge that capture the central idea or message of the data. According to Braun & Clarke (2006), global themes should be based on the most significant and recurring patterns and provide a comprehensive understanding of the data. Chapter 4 will give a more detailed understanding of how thematic analysis was used in this study.

Fifty learners meeting baseline criteria were identified from each school. These learners needed to have been in the school in grade eight and then went further to choose mathematics and science in grade ten and matriculating with the subjects in grade 12. Having done that, twenty-five learners were randomly selected from each school. Those from Curtis Nkondo made the experimental group, whilst those from Freedom Park High School were the control group. Final Matriculation results were obtained, and the results were documented.

Quantitative data was edited to remove the students who did not meet the criteria from the spreadsheets. The data was input onto the computer, and quantitative software STRATA was used to obtain inferential statistics, most notably establishing if there was a significant difference between the mean scores in Physical Science and mathematics at the two schools.

3.8.3 *Data analysis*

According to Khandker et al. (2009), the difference-in-difference (DiD) is a method of estimating the impact of an intervention essentially by comparing outcomes on treatment and non-treatment groups over a time relative to outcomes observed at the pre-intervention period (baseline). Panel data sections are drawn from the same aggregate unit (cohorts). The difference in difference method assumes that unobserved heterogeneity in participation is present but that such factors are time-invariant.

According to Khandker et al. (2009), unobserved heterogeneity refers to differences among individuals or groups that cannot be directly observed or measured by the researcher. It is argued that this can occur in statistical analyses where certain factors important for explaining a particular outcome or behaviour are not accounted for (Khandker et al., 2009). Unobserved heterogeneity in an educational intervention may include individual or group characteristics that are difficult to measure or quantify, such as motivation, family support, school culture, family support and community characteristics.

Individual motivation can play a significant role in the success of an educational intervention. However, it can be challenging to measure or account for in an analysis. Students have different learning styles, which may affect how well they respond to an educational intervention. However, the study may not observe or measure these learning styles. Family support can also play a significant role in the success of an educational intervention, but it may not be measured or observed in the study. The culture of the school can also affect the outcomes of an educational intervention, such as the level of support provided by teachers and other staff members. However, it cannot be easy to quantify or measure this factor. Characteristics of the community in which the students live, such as poverty, crime rates, or access to resources, can also affect the outcomes of an educational intervention.

Unobserved heterogeneity can create a challenge in evaluating the effectiveness of educational interventions, as these factors may confound the study's results. However, the use of statistical methods to control for these unobserved factors, such as random effects models or fixed effects models, attempts to account for factors that vary across individuals or groups. The Difference-in-Difference method assumes that such factors are time-invariant.

In the context of the difference-in-differences (DiD) method, "time-invariant" means that a particular characteristic or variable does not change over time for the treatment and control groups (Khandker et al., 2009). This is important for the validity of the DiD method, as it allows the researcher to assume that any differences in outcomes between the treatment and control groups after the intervention can be attributed to the intervention itself rather than other factors that may have changed over time. In an educational intervention program, time-invariant characteristics include a baseline level of knowledge and socio-demographic and geographic location characteristics of the participants.

This study aimed at improving mathematics and science outcomes; it was essential to ensure that the treatment and control groups had similar baseline levels of skill or knowledge. The socio-demographic characteristics of the participants might include factors such as age, gender, race, socio-economic status, or previous educational attainment. It was important to ensure that the treatment and control groups were similar concerning these characteristics, as they could affect the outcomes of the intervention. Again, it was important to ensure that the treatment and control groups were similar concerning the location or context in which the intervention was being implemented. In this case, both schools were chosen from the same township.

According to Khandker et al.(2009), ensuring that these characteristics are time-invariant is vital for the validity of the evaluation of the educational intervention program, as it allows the researcher to attribute any differences in outcomes between the treatment and control groups after the intervention to the intervention itself, rather than other factors that may have changed over time. Figure 4 is a diagrammatic illustration of how a difference in difference is performed.

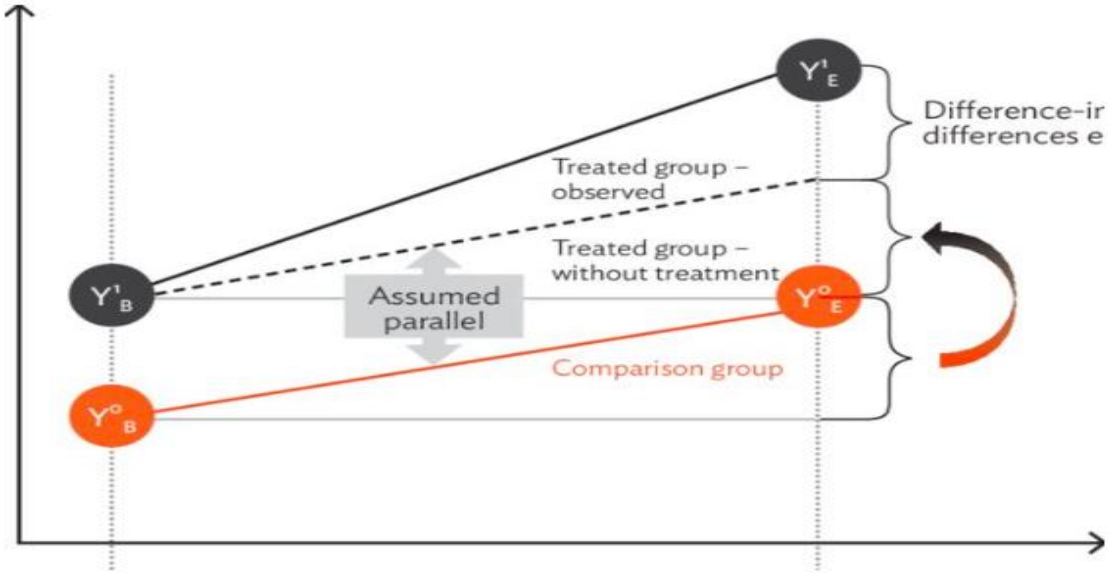

Figure 4 Difference in difference analysis adopted from Khandker et al. (2009)

Y^o_B represents the mean of the 25 learners from Freedom Park high school, and Y^1_B represents the mean of the 25 learners from Curtis Nkondo Secondary School at the start of the intervention. Y^1_E and Y^o_E show the mean scores at Curtis Nkondo and Freedom park secondary schools after the intervention, respectively. Given a two-period setting where $T = 0$ before the program (2016 in this case) and $T = 1$ after program implementation (2020 in this case), and letting Y^1_E and Y^o_E be the respective outcomes for a program beneficiary and nontreated units in time T, the DD method will estimate the average program impact as follows:

$$DD=E(Y^1_E - Y^1_B \ |T=1)-E(Y^o_B - Y^o_E \ |T=0)\cdot$$

In the equation, $T_1 = 1$ represents Curtis Nkondo (the experimental group) , whereas $T_1 = 0$ represents the control group (Freedom Park high school). A two-sample t-test was used to test if there was a significant difference between the two means after the intervention.

3.9 Background description of research respondents

Qualitative primary data was obtained from research participants (RP) that are identified with a numerical number after RP to distinguish them in Chapter 4. The Research participants included education officials permanently employed by the Gauteng Department of Education with more than five years of experience in their current positions. This was important because qualitative data obtained from in-depth interviews needed to be reliable and valid, more years of experience in the current role meant that the officials would have good institutional memory that would give more accurate answers to the institutions for this research. Wotela (2017:237) argues that ‘this authenticates the key informants as appropriate providers of research data’.
These research participants included district mathematics and physical science subject specialists, the principals of both the control and experimental groups, academic heads, and senior maths and science teachers. All participants had at least a bachelor's degree in the subject of their specialisation. This was to ensure the learners were taught by equally qualified teachers or teachers deemed competent by the Gauteng Education Department. Equally qualified teachers attempt to ensure that the learners receive similar instruction and school leadership.

Curtis Nkondo is, however, better resourced than Freedom Park High school. At the time of data collection, the Freedom Park school governing body had closed the school, protesting the lack of furniture in the school. At Curtis Nkondo, the school was functioning normally. The above information gives more insight into the research site and will be used in the next chapter when analysing results and making recommendations in chapter 5.

3.10 Research strengths: Reliability and validity measures

Ecological validity establishes if research findings can be extended to different sections of the population that may be related in some way. Population validity, on the other hand, looks at whether the sampling method can allow for the research findings to be generalisable to the whole population. Ecological and population validity is highly compromised in this research because sampling is not random.
Considering that the respondents were selected from non-randomly selected schools, this poses severe threats to the internal validity of my research. As posited by Bhattacherjee (2012) this could have resulted in a biased sample in which participants may not represent the population. Consequently, it compromises the generalisability of the research to the population. The different methods of data collection and triangulation of results strengthen the reliability of the

research. It is expected that a different researcher would come up with similar results. The research can be relied on considering strict adherence to data collection and analysis methods, as argued by McLeod (2001) was followed.

3.11 Research weaknesses: Inherent Technical as well as administrative limitations.

It was anticipated that data would be available from the schools and the district for periods before starting the intervention. This would enable this research to establish parallel trends before the intervention. However, because grade 8 results reflected no significant difference, the study relied on these results and demographics to show that the comparison and control groups were similar. This was a limitation considering the difference in difference assumes parallel trends before the intervention.

Due to time limitations, this research was a longitudinal study of one cohort. The results could have been strengthened by using different cohorts between 2016 and 2020. This would have given a broader understanding and impact of the STEM program. Other limitations of this study are:

- It was not possible to get all data required as some of the data had been destroyed. Schools are only to keep data for at least five years.
- Some biographical data of learners was not available from both schools.
- The researcher had to work on assumptions based on the average conditions of the school to assume learners were identical and could be used as a control and experimental group.
- Some targeted participants were unwilling to participate, fearing for their safety and job security.
- Due to load shedding, contacting some participants was difficult because it affected WI-FI connectivity.
- This study is the first mixed methods study the researcher has conducted and was a learn as one proceeded with the study.

3.12 Conclusion

This chapter described the research methodology, the purpose of which was to validate answers to the research questions. This was achieved by using a mixed method, a post-positivist approach. This approach provided answers to pertinent issues being investigated based on the impact of Curtis Nkondo's school of specialisation program. Since the research was based on secondary data analysis, it was deemed essential to describe how primary data was collected, as this has implications for the validity of the findings as well as in terms of ethical concerns. The participants were morally and ethically protected by observing the principles of human dignity.

The difference-in-difference method and inferential statistics provided a tool that enabled the study to establish the program's impact. In-depth, open-ended interviews put meaning to the numbers obtained to give a better understanding of contextual factors contributing to the findings obtained.A combination of the factors stated above provided a solid methodology through which valid findings could be obtained. Chapter four discusses the empirical findings. In conclusion, this chapter aimed to achieve the research objective of providing a framework for data analysis, thus setting the foundation for determining valid results.

Chapter 4 : EMPIRICAL FINDINGS

4.1 Introduction

The preceding chapters laid the foundation for the investigation of this intervention. The main objective of this study was to investigate the impact of the School of Specialisation program at Curtis Nkondo Secondary School. This was done through a quasi-experimental design comparing mathematics and physical science test scores over five years between 2016 and 2020. The quasi-experimental design used mixed methods research design, where quantitative data used secondary data sources of mathematics and physical science test scores from 2 schools, namely Curtis Nkondo Secondary School, referred to here as the 'treatment' school, and Freedom Park High School, referred to here as the 'control' school. Qualitative methods included primary data collection of Key Informant Interviews (KIIs) with school Heads, subject specialists, departmental heads and mathematics and science teachers. This chapter's findings are contextual and based on the respondents and the research sites. They reflect the situation at Curtis Nkondo and Freedom Park High School. Central to this chapter is the analysis of both quantitative and qualitative data. Chapter two concluded by highlighting some theoretical themes surrounding STEM education and associated theoretical frameworks. In this chapter, the relationship between these is explored regarding Curtis Nkondo School of Specialisation.

4.2 Framework for analysis

Figure 5 is the framework of analysis and shows how quantitative data will be analysed for mathematics and science.

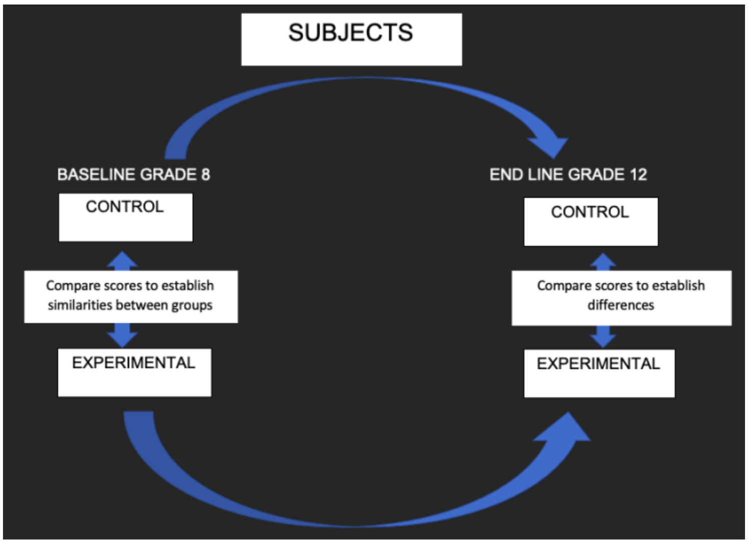

Figure 5 Results analysis framework.

The analysis begins by comparing the baseline mathematics and science scores for the control and experimental groups. As alluded to in chapter three, it is essential that these two groups are similar and is one of the conditions if a difference in difference method is to be applied. This will be followed by comparing the endline and baseline scores of the experimental group to establish if the intervention resulted in any improvement. The same will be done for the control group. Finally, the mean scores of the experimental group and control group will be compared and tested for significance.

4.3 Selection of equivalent schools for the study

This study followed a quasi-experimental design because there was only one maths and science school of specialisation commissioned in 2016. It was therefore not feasible to do a randomised control test. The comparison school was selected as described in chapter three. The factors that were crucial in selecting the schools were school size, school budget, class size, teacher qualification and experience. Both schools were in the same township. This helped eliminate differences brought about by different contextual situations. Table 7 shows some of these variables.

CHARACTERISTIC	CONTROL GROUP	EXPERIMENTAL GROUP
Type of school	state	state
Total Enrolment	1150	1140
Teacher qualification	Bachelor’s degree	Bachelor’s degree
location	Soweto	Soweto
Governance	School governing body	School governing body
Class sizes	30	30

Table 7 Similarities between the control and experimental schools.

Table 7 shows the data characteristics of both Curtis Nkondo and Freedom Park High School. The type of school, enrolment, teacher qualification, location, governance, and class sizes for both the control group and experimental groups are shown. Both schools are public schools that are government funded. The enrolment for the control group is 1150, while the experimental group has 1140 students enrolled, which indicates that the size of the two groups is very similar. Both the control group and experimental group have teachers with bachelor’s degrees, indicating that the level of education among the teachers is consistent across both groups. The location for both groups is Soweto, which suggests that the two groups are in the same area. It is worth noting that Soweto has a vast demographic difference however the school sin this study experience the same socio-economic circumstances. The governance of both groups is a School governing body, which suggests that the schools are governed by a board that oversees their operation. The class sizes for both groups are 30, which indicates that the number of students in each classroom is the same for both groups.

Based on the data characteristics in the table, the control and experimental groups are very similar in terms of the type of school, teacher qualifications, location, governance, and class sizes. The only significant difference between the two groups is the enrolment size, which is only slightly different. It was initially intended that similar students would be identified and then randomly selected. However, the study used all the learners taking mathematics and science in the treatment and control schools. This was because the control group only had 30 learners who did mathematics and science. Learner scores for the same students were used over five years, baseline (2016) and endline (2020).

4.4 Descriptive statistics for Grade 8 Maths and Grade 12 Maths

According to Khandker et al. (2009), an independent t-test (also known as a two-sample t-test) is a statistical test used to determine if there is a significant difference between the means of two independent groups. It is called an "independent" t-test because the two groups being compared are unrelated to each other (Peck & Devore, 2011). For example, we might use an independent t-test to compare the average scores of two different groups of students on a test.

The independent t-test assumes that the data is normally distributed and that the variances of the two groups are equal. The test calculates a t-value and a p-value, which indicates whether the difference between the means of the two groups is statistically significant or just due to chance. If the p-value is less than a pre-determined significance level (usually 0.05), we can conclude that the difference between the means is statistically significant(Myers, 2019). Table 8 shows the treatment and control groups' baseline test scores for mathematics.

T-Test

Group Statistics

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
MATGR8	TREATMENT	95	52.66	12.999	1.334
	CONTROL	32	53.88	13.912	2.459

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
MATGR8	Equal variances assumed	.092	.762	-.448	125	.327	.655	-1.212	2.704	-6.564	4.140
	Equal variances not assumed			-.433	50.475	.333	.667	-1.212	2.798	-6.830	4.406

Independent Samples Effect Sizes

				95% Confidence Interval	
		Standardizer[a]	Point Estimate	Lower	Upper
MATGR8	Cohen's d	13.231	-.092	-.492	.309
	Hedges' correction	13.311	-.091	-.489	.307
	Glass's delta	13.912	-.087	-.488	.315

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

Table 8 Baseline test scores for mathematics of the treatment and control groups.

The mean difference between the treatment and control group is -1.212 percentage points in favour of the control group, which has a higher mean of 53.88. Levene's test for equality shows that equal variance between the two groups can be assumed. We use the first row of the independent t-test because the significance value of 0.762 is greater than the threshold of 0.05.

Also, $p>0.05$ indicates that the difference between the mean baseline scores for the control and treatment groups is not statistically significant. This was important for this research because we had to ensure that the two groups were equal and could be compared. The equality here is not violated because the p-value is greater than 0.5. That is why we use the top row to interpret the results.

4.5 Descriptive statistics for mathematics control group baseline and endline.

Within-treatment group change is shown in Table 9 and Table 10. Paired t-test was used to compare baseline and endline outcomes. A paired t-test (a dependent t-test) is a statistical test used to compare the means of two related groups (Osborne, 2008). The two groups being compared are related because they consist of the same participants at two different points in time or under two different conditions.

According to Osborne (2008), the paired t-test assumes that the data is normally distributed and that the differences between the two groups are approximately normally distributed. The test calculates a t-value and a p-value, which indicates whether the difference between the means of the two groups is statistically significant or just due to chance. If the p-value is less than a pre-determined level of significance (usually 0.05), we can conclude that the difference between the means is statistically significant.

Table 9 and Table 10 below show the mean differences in scores between the treatment group and the control group in mathematics.

Paired Samples Test[a]

		Paired Differences					t	df	Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			One-Sided p	Two-Sided p
Pair 1	MATGR12 - MATGR8	-11.726	23.709	2.433	-16.556	-6.896	-4.821	94	<.001	<.001

a. GROUP = TREATMENT

Table 9 Mean difference within treatment endline and baseline score.

Paired Samples Test[a]

		Paired Differences					t	df	Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			One-Sided p	Two-Sided p
Pair 1	MATGR12 - MATGR8	-19.562	17.116	3.026	-25.734	-13.391	-6.465	31	<.001	<.001

a. GROUP = CONTROL

Table 10 Mean difference between control endline and baseline.

It is seen that for both groups, there is a decrease in the performance of the learners. The treatment group decreased by 11.726 percentage points, whilst the control group decreased by 19.562 percentage points. It can be noted that even though there is a decrease, the experimental group decreases much less than the control group. Implying that the intervention works to improve the resilience of the learners in achieving better outcomes by almost 1.67 times.

4.6 Descriptive statistics for mathematics grade 12 treatment and control groups.

Table 11 shows the statistical table of the treatment and control group's mean grade 12 scores for mathematics.

T-Test

Group Statistics

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
MATGR12	TREATMENT	95	40.94	21.854	2.242
	CONTROL	32	34.31	11.383	2.012

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
MATGR12	Equal variances assumed	15.384	<.001	1.638	125	.052	.104	6.624	4.043	-1.377	14.626
	Equal variances not assumed			2.199	103.265	.015	.030	6.624	3.013	.649	12.599

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	Upper
MATGR12	Cohen's d	19.781	.335	-.069	.737
	Hedges' correction	19.901	.333	-.068	.733
	Glass's delta	11.383	.582	.152	1.004

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

Table 11 Mean control and treatment mathematics scores at grade 12.

In grade 12, the table above shows that the equality of variances assumption is violated because sig.<0.001. As such, we use the second row to interpret our findings. When Levene's test is performed, one will get a p-value, which tells you the probability of observing the test statistic (the F-statistic) or a more extreme value, assuming that the null hypothesis is true. A p-value less than the chosen level of significance (0.05) indicates that the null hypothesis should be rejected in favour of the alternative hypothesis. In this case, a p-value of sig. < 0.001 means that the p-value is less than 0.001, which is a very small value. We, therefore, reject the null hypothesis and conclude that there is strong evidence that the variances of the groups are not equal. In this case, we reject the null hypothesis, which states that:

"The *mean mathematics outcomes of the experimental group is not significantly different from the mean mathematics outcomes from the control group*"

4.7 Difference in difference for maths

The difference in difference (DiD) is a strategy used to estimate causal effect from observational data that is longitudinal. By longitudinal, is meant the study of a cohort over time

(2016-2020 in this case). The DiD uses pre-test and post-test analysis as well as control and treatment group analysis. Table 12 shows the scores used and how the differences can be calculated.

Mathematics school Achievement Data			
	2016	2020	Difference
Experimental Group	53	41	12
Control Group	54	34	20
Difference	1	7	8

Table 12 Difference in difference in mathematics scores.

For mathematics, the first source of variation is over time. We examined how test scores changed between 2016 and 2020. We plot the data for the control group between 2016 and 2020 (orange line). The same was done for the experimental group (blue line). In this study, we see that the decrease over time is less for the treatment group compared to the control group. The impact of the SOS program on educational outcomes is calculated by assuming parallel trends. The parallel trends assumption says that if the treatment group had not received the intervention, then the treatment group will follow the exact trend over time as the control group. This is shown by the black line in Figure 6. In this case, we expect the treatment group to obtain a mean score of 33% in grade 12. This is called the counterfactual, and it tells us what would occur if the treatment group had not received an intervention. The treatment effect is the gap between the counterfactual (black line) and treatment group. The treatment effect is the impact of the intervention.

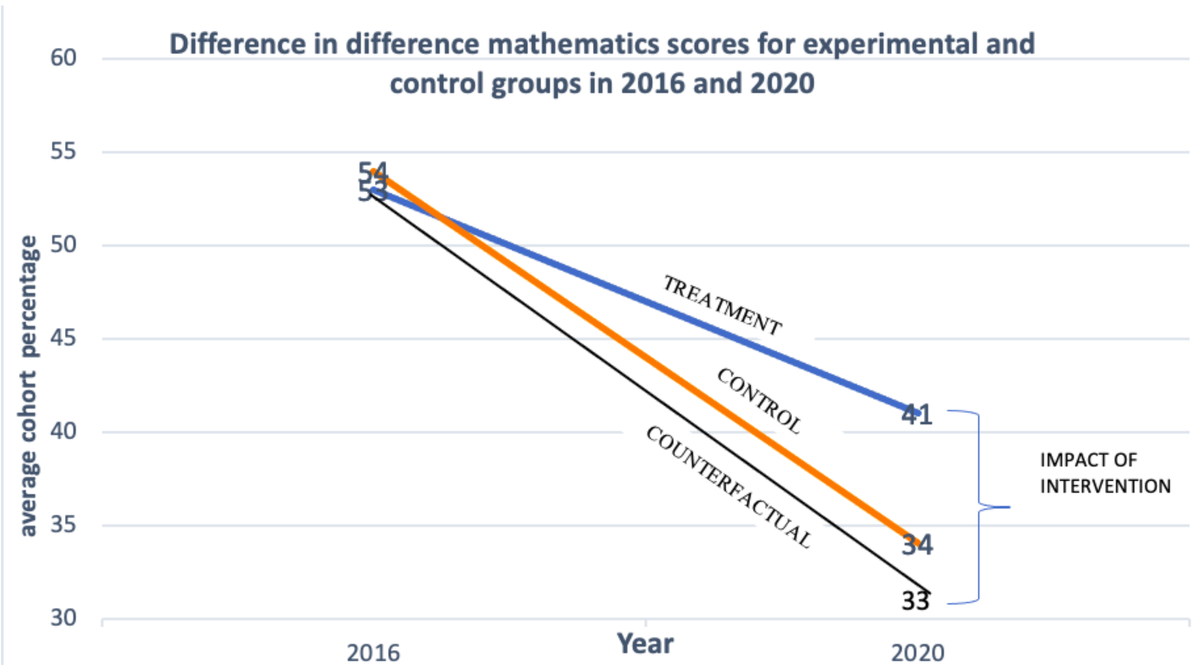

Figure 6 Difference in difference for maths score.

The impact of the intervention for mathematics is 11 percentage points.

4.8 Science baseline at grade 8 comparing mean scores for science of treatment and control groups.

Table 13 shows a statistical table for mean baseline marks of both the control and experimental group.

T-Test

Group Statistics

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
PSGR8	TREATMENT	95	53.15	13.075	1.341
	CONTROL	32	52.13	11.609	2.052

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p			Lower	Upper
PSGR8	Equal variances assumed	.149	.700	.393	125	.347	.695	1.022	2.601	-4.126	6.171
	Equal variances not assumed			.417	59.568	.339	.678	1.022	2.452	-3.882	5.927

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
PSGR8	Cohen's d	12.727	.080	-.321	.481
	Hedges' correction	12.804	.080	-.319	.478
	Glass's delta	11.609	.088	-.314	.489

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor. ...

Table 13 Baseline mean marks for both the control and experimental groups.

The mean difference between the treatment and control group is 1.022 percentage points in favour of the treatment group, which has a higher mean of 53.15. Levene's test for equality shows that equal variance between the two groups can be assumed. We use the first row of the independent t-test because the significance value of 0.700 is greater than the threshold of 0.05. Also, p>0.05 indicates that the difference between the mean baseline scores for the control and treatment groups is not statistically significant. This was important for this research because we had to ensure that the two groups were equal and could be compared. The equality here is not violated because the p-value is greater than 0.5. That is why we use the top row to interpret the results.

4.9 Comparing treatment Science baseline and end-line mean scores

We compare the mean endline and baseline scores for science in the control and treatment groups. This is to establish if there are any differences at the end of the program compared to the beginning.

Paired Samples Test[a]

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	PSGR12 - PSGR8	-14.568	22.748	2.334	-19.202	-9.934	-6.242	94	<.001	<.001

a. GROUP = TREATMENT

Table 14 Endline and baseline science scores for treatment group.

Paired Samples Test[a]

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	PSGR12 - PSGR8	-17.844	14.288	2.526	-22.995	-12.693	-7.065	31	<.001	<.001

a. GROUP = CONTROL

Table 15 Endline and baseline science scores for the control group.

Table 14 and 15 above show the differences between the treatment and control groups in physical sciences. It is seen that for both groups, there is a decrease in the performance of the learners. The treatment group decreased by 14,568 percentage points, whilst the control group decreased by 17.844 percentage points. Even though there is a decrease, the experimental group decreases less than the control group. Implying that the intervention works to improve the resilience of the learners.

4.10 Comparing Science grade 12 treatment and control group.

This section compares the science mean scores of the treatment and control groups. This is to establish if there are any differences between science scores obtained in the final grade 12 results between the two groups. Table 16 shows the statistical results.

T-Test

Group Statistics

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
PSGR12	TREATMENT	95	38.58	19.622	2.013
	CONTROL	32	34.28	10.215	1.806

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
PSGR12	Equal variances assumed	13.298	<.001	1.184	125	.119	.239	4.298	3.630	-2.887	11.482
	Equal variances not assumed			1.589	103.319	.058	.115	4.298	2.704	-1.066	9.661

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
PSGR12	Cohen's d	17.760	.242	-.160	.643
	Hedges' correction	17.868	.241	-.159	.639
	Glass's delta	10.215	.421	.004	.832

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

Table 16 Grade 12 science endline results for control and treatment group.

In grade 12, the table above shows that the equality of variances assumption is violated because the sig.<0.001 is a low value compared to the threshold of 05. As such we use the second row to interpret our findings. The null hypothesis of Levene's test is that the variances of the groups are equal. The alternative hypothesis is that at least one group has a different variance from the others.

As argued in section 4.4, we reject the null hypothesis, which state that ‘ the mean science outcomes of the experiment group is not significantly different from the mean science outcomes of the experimental group’ and accept the alternative hypothesis, which states that ' the mean science outcomes of the experimental group is significantly greater than the mean science outcomes of the experimental group.'

4.11 Difference in difference for science

Similar calculations were done for mathematics, and the following were obtained. Table 17 shows the scores used and how the differences can be calculated.

Physical Science school Achievement Data			
	2016	2020	Difference
Experimental Group	53	39	14
Control Group	52	34	18
Difference	1	5	4

Table 17 School achievement data for physical science

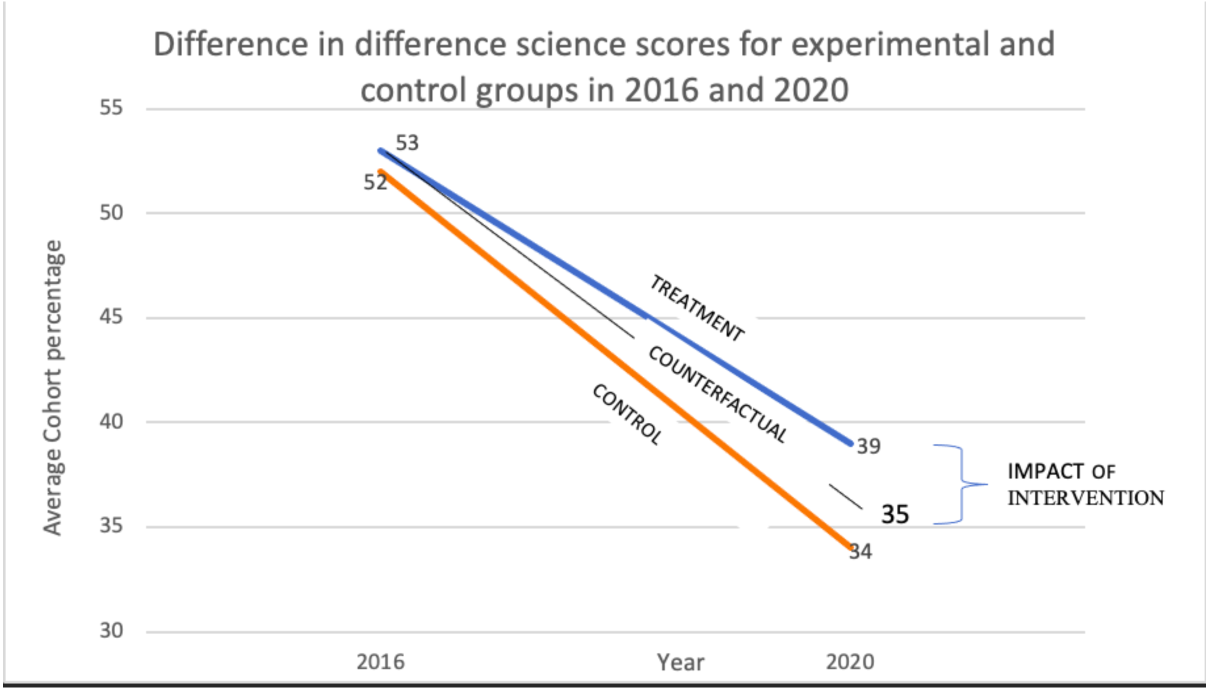

Figure 7 Difference in difference Physical Science

The impact of the intervention on science is four percentage points and is illustrated in Figure 7. This is seven percentage points below that for mathematics. For both subjects, the impact of the intervention is relatively low compared to the investment that goes into it.

4.9.2 Trends in the distribution of maths and science marks from 2016 to 2020

Table 18 and 19 show the average marks for maths and science for both the control and experimental groups.

Experimental Group		
Average	Experimental maths	Experimental science
Grade 8 (2016)	53	53
Grade 9 (2017)	54	62
Grade 10 (2018)	34	40
Grade 11 (2019)	38	39
Grade 12 (2020)	41	39

Table 18 average percentage marks for maths and experimental science group

Control Group		
Average	Control Maths	Control Science
Grade 8 (2016)	54	52
Grade 9 (2017)	34	46
Grade 10 (2018)	25	35
Grade 11 (2019)	31	35
Grade 12 (2020)	34	34

Table 19 average percentage marks for maths and science Control group

To give a better illustration, these trends are shown in Figure 8 andFigure 9.

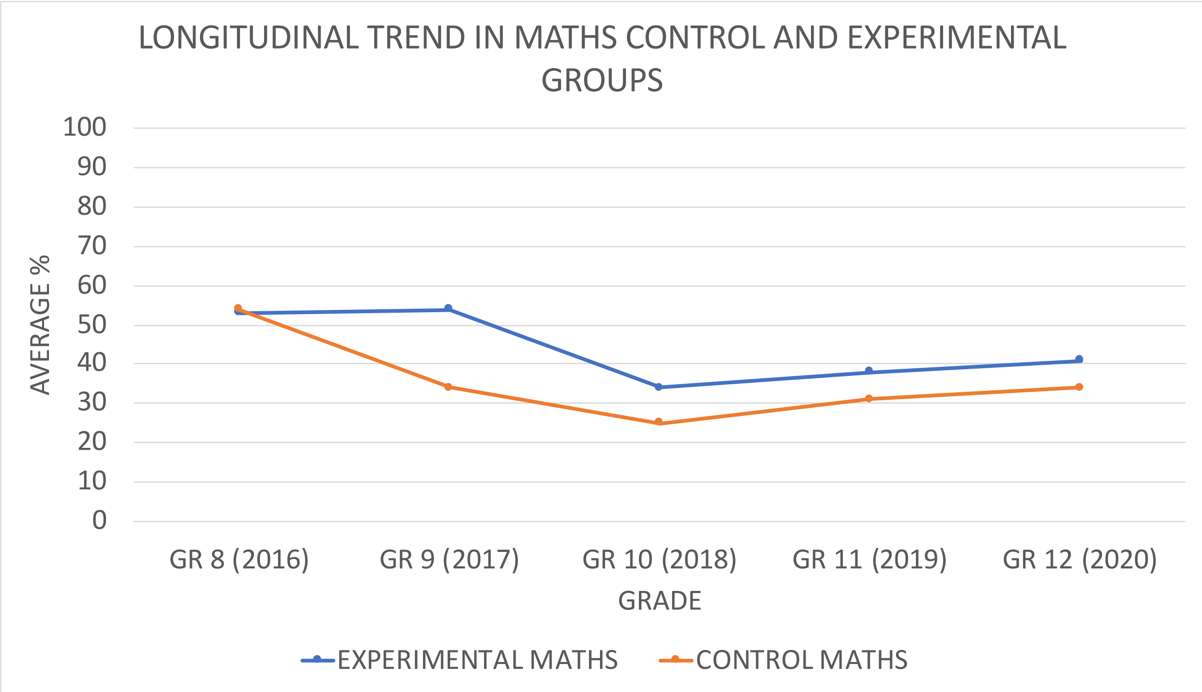

Figure 8 Mathematics trends for the control and experimental group (2016-2020)

Figure 8 shows the trend in mathematics for both the control and experimental groups. The scores started similarly in 2016. The control group marks a decline in 2017 and again in 2018. The experimental group increased slightly in 2017 but declined in 2018. A decline in marks is expected between grade 9 and grade 10 because of the change in assessment policy in grade 10. In grades eight and 9, the exam makes up 25% and the coursework makes up 75% of the end-of-year mark. In grade 10, these percentages are reversed, exam making 75 % and coursework 25%. From the researcher's experience in teaching, Grade 10 content is also more challenging compared to grade 8 and 9 as concepts become more abstract. The trend for both subjects increases in grade 11 and again in grade 12 for both the control and experimental and control group. However, the experiment group has a higher grade 12 mark in science compared to the control group. Similar trends are observed for science, as shown in Figure 9.

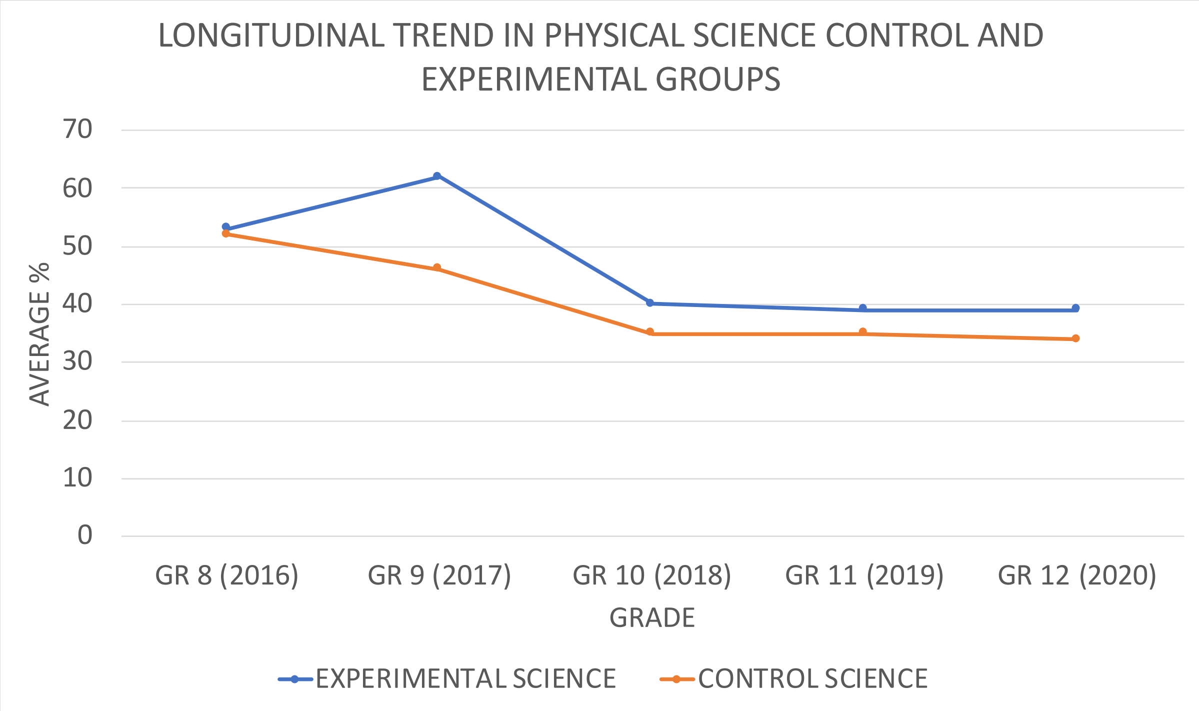

Figure 9 Physical Science trends for the control and experimental group (2016-2020)

4.12 Interpretation of statistical findings

According to Peck & Devore (2011), a one-sided test is used when the research question is focused on whether there is an effect in a specific direction. In this study, we wanted to test the hypothesis that the School of Specialisation (SOS) program at Curtis Nkondo will improve mathematics and science outcomes. Informed by research question 2, which read "Did the school of specialisation program at Curtis Nkondo school of specialisation cause an improvement in the Mathematics and Science outcomes?", the following hypothesis was formulated:

Null hypothesis (H_0):

The mean mathematics and science outcomes of Curtis Nkondo students are not significantly different from the mean mathematics and science outcomes of Freedom Park high school students.

Alternative hypothesis (H_A):

The mean mathematics and science outcomes of Curtis Nkondo students are significantly greater than the mean mathematics and science outcomes of Freedom Park high school students.

To test these hypotheses, data on the mathematics and science outcomes of the SOS students and a control group of non-SOS students at Freedom Park High School was collected. A one-sided t-test statistical analysis was used to compare the means of the two groups. Quantitative data shows that there is no increase in the outcomes due to the intervention. However, the intervention increases the learners' resilience and prevents them from getting worse results. Again, it is worth noting that the resilience in question could be more profound—eleven percentage points for mathematics and four for science. Qualitative findings will give more insight into these results in the next section.

4.13 Qualitative findings

This study, among other objectives, sought to investigate the elements contributing to the achievement of educational outcomes at Curtis Nkondo School of Specialisation. The preceding section gave quantitative insight into the program. This section looks at the qualitative aspect and seeks to give better insight into the outcomes observed quantitatively.

In-depth interviews involve one-on-one interviews between a researcher and a participant. Like focus interviews, these can also be conducted remotely and can be structured and unstructured. The interview process involves recruiting participants, developing an interview guide, conducting the interview, recording and transcribing the interview and analysing the data (Braun & Clarke, 2013). This study used key performant interviews (KIIs) from purposively selected participants.

According to (Creswell, 2013; Kawulich, 2012; Peck & Devore, 2011), key informant interviews are a qualitative research method involving one-on-one interviews with individuals with specialised knowledge or expertise related to the topic under investigation. The purpose of key informant interviews is to gather detailed information and insights from individuals who are knowledgeable about the topic and can provide a unique perspective. Key informant interviews have the added advantage of increasing the validity of data because they provide valuable insights and perspectives that can help to validate data collected through the quantitative analysis discussed above. They can also help identify the barriers faced by the facilitators to implementing an intervention or program. This study collected qualitative primary data from Key Informant Interviews (KIIs) with school Heads, subject specialists, departmental heads and mathematics and science teachers.

4.14 Thematic analysis

According to Braun & Clarke (2013:79), ' thematic analysis is a method for identifying, analysing and reporting patterns (themes) within data. The data in this study were analysed using six steps of thematic analysis as defined by Braun & Clarke (2013:79). Themes were categorised into basic, organisational, or global. According to Attride-Stirling (2001), basic themes are statements from participants in the form of premises. When these statements are grouped in a common theme, they are now called organisational themes because they are a 'cluster of significance that summarises the principal assumption of basic themes' (Attride-Stirling,2001:389).

Thematic analysis was conducted on primary data collected from Key Informant Interviews and grouped into themes related to the attainment of educational outcomes. Table 20 shows the themes obtained based on the research questions asked.

Interview Question (See Annexure A)	Theme	Specific Content
Describe your working day?	Daily Routine	Lesson planning, grading, student conferences, administrative tasks
What is it about the work that you like?	Job Satisfaction	Working with students, seeing student growth, feeling fulfilled
What is it about your work that you do not like?	Job Dissatisfaction	High workload, low pay, lack of support, feeling undervalued
Can you describe for me a successful lesson/Term?	Successful Lessons/Terms	High student engagement, strong student performance, positive teacher feedback
What have you done to overcome challenges?	Factors Contributing to Success	Effective lesson planning, appropriate resources, student motivation
What challenges do you face?	Unsuccessful Lessons/Terms Factors Contributing to Lack of Success	Low student engagement, poor student performance, resources, disrupted lessons due to extra-murals, and learner absenteeism. Inadequate lesson planning due to lack of time, insufficient resources, and student behaviour issues.
What is your philosophy on STEM education?	Definition of the school of specialisation	Curriculum focus on maths and science, partnership with industry, selective admissions
What makes a school of specialisation different compared to ordinary schools?	Differences from ordinary government schools	Curriculum specialisation, extracurricular opportunities, higher academic standards
What is it about the work that you like?	The success of the school of specialisation Factors contributing to the success	High student achievement, positive teacher feedback, community support
Do you think this type of school is sustainable?	Sustainability	Long-term funding, stable enrolment, community support

Table 20 KIIs Themes.

Table 20 summarises some of the questions relevant to this analysis. The rest can be seen in Annexure 1. For a factor to become an organisational theme, it had to be raised by at least three of the respondents.

4.15 Literature review and KII themes

The outcome of these themes was then compared to those obtained from the literature review and the theoretical framework used in this study. The aim is to link those themes emerging from the literature review with those established in this study. The themes from the KIIs were then aligned with themes from the literature review.

Literature review	Key Informant Interviews
Design pedagogy: • Integration of STEM subjects into one • Collaboration and communication • Innovation and optimism • Creative problem solving • Global and social awareness • Interactive content • Authentic experiences • Student engagement	• Curriculum focus, • partnership with industry • use of technology
Teacher quality	• Effective lesson planning • Content knowledge
Government support	• Increased resources • improved facilities • targeted professional development for teachers
Stakeholder and community support	• partnership with businesses
Institutional arrangements & leadership	

Table 21 Literature and KIIs themes

4.16 Basic, organisational, and global themes

Table 22 shows the basic organisational and global themes that were established in the KIIs, which were used to develop thematic networks.

BASIC	ORGANISATIONAL	GLOBAL
‘ there are opportunities to study further, and they are fully funded by the government.	Teacher Skills are important for the implementation of STEM	Educational outcomes are affected by government input, the input of stakeholders, the socio-economic conditions of the learners and the community, the school as an institution and teacher skills.
‘the type of funding is more than that of ordinary schools with the same enrolment. However, it decreased every year until there is no finding because the school is supposed to be self-sustaining'. ‘ we do not have enough funding and the parents do not assist financially even though we are a non-fee paying school’ ‘companies sponsor our learners into tertiary STEM subjects, they deliver on their promises	Funding	

‘we get donations from companies, especially in the automotive industry		Educational outcomes are affected by government input, the input of stakeholders, the socio-economic conditions of the learners and the community, the school as an institution and teacher skills.
‘absenteeism does not affect us that much and when one teacher is absent, we have the technology that allows one teacher to teach more than one class at the same time ‘we absorb shocks like Covid-19 by being innovative, we started using online teaching even before covid’	leadership	
‘ our teachers are innovative and use technology such as smart boards, and educational apps' ‘ a successful day is a result of good planning ‘ there are free online teacher development courses	Teacher quality	
'The SOS program was commissioned by the government'.	Government intervention	

‘ we have a good budget that enables us to buy a gadget for teaching'		
‘ because of collaboration with institutions of higher education and businesses, our learners obtain certificates that enable them to start their businesses, for example, servicing cars'. ‘ our learners have opportunities to visit companies to gain work experience	Stakeholder involvement	
‘ our learners leave the school in grade 12 with skill and do not need to go look for a job ‘ even though we teach these subjects separately, we give our learners projects that encourage them to apply knowledge learnt across the board’ ‘ as teachers, we collaborate by sharing ideas among different departments’	Content and curriculum	

Table 22 Basic, Organisational and Global Themes

4.17 Thematic networks

According to Attride-Stirling, (2001:388), thematic networks are ' a web-like representational means…which makes explicit the procedures that may be employed in going from text to interpretation'. They give a more vivid visual illustration of themes. It precisely shows the lived experiences of teachers and administrators as they implement the STEM program. The thematic network for the school of specialisation program at Curtis Nkondo is shown in figure Figure 10.

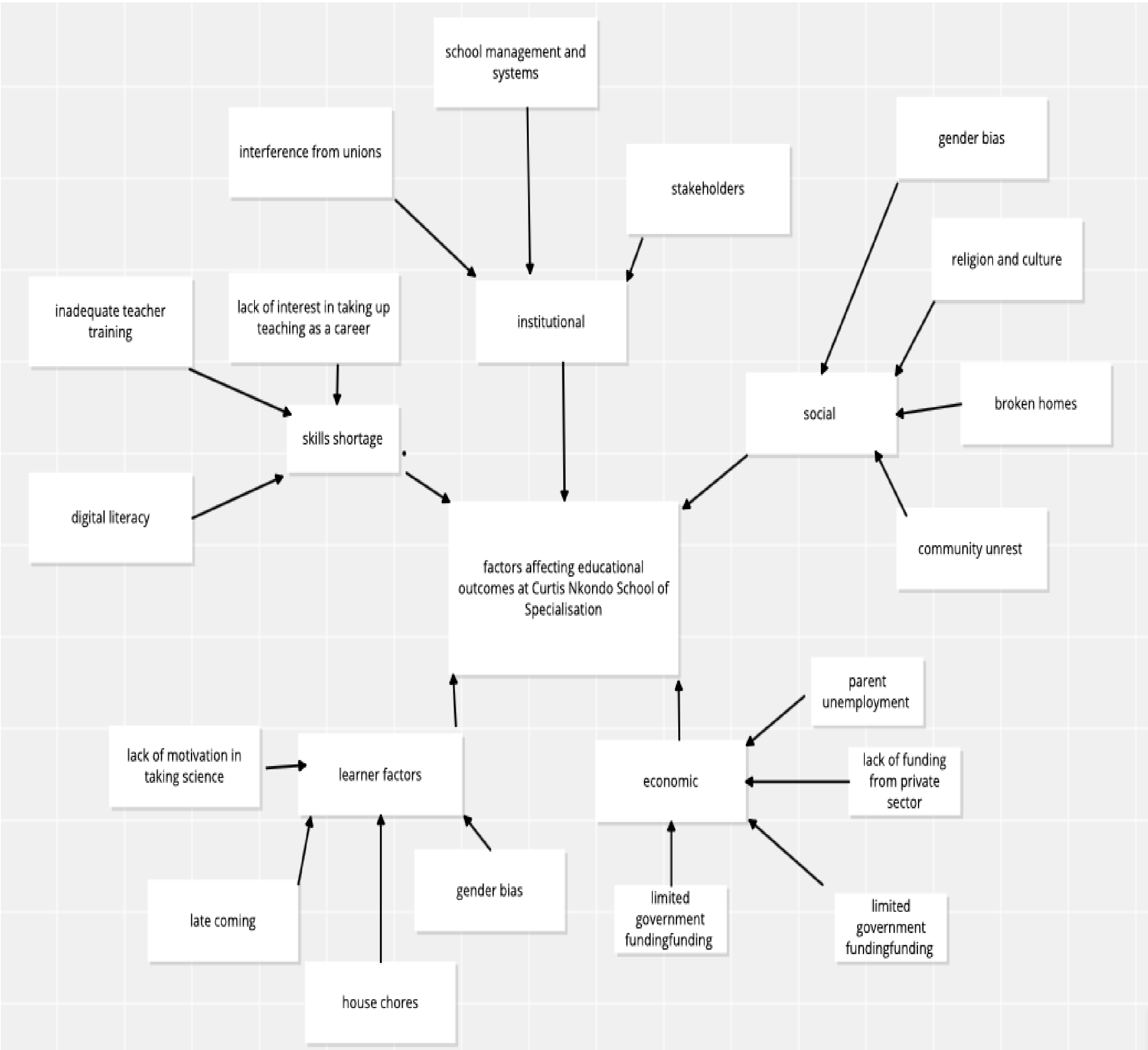

Figure 10 Thematic network analysis: structure of the factors affecting educational outcomes at Curtis Nkondo.

4.18 Description and exploration of thematic networks

Table 23 gives more insight into the research participants and is coded to maintain confidentiality.

Research participant (RP)	Descriptor
1;2	Subject specialist
3;4	Member of the school executive (School head/ Deputy)
5;6	Senior teacher (maths/Science)

Table 23 Table detailing research participants.

Subject specialists are officials from the district office specialising in either mathematics or science. Their role is to assist teachers in the implementation of policy. They are also former maths/ science teachers who are selected based on a good track record of outcomes in their subjects at matric level. Members of the school executive are school principal or deputy principals who were available for the in-depth interviews. Senior teachers are teachers who have been teaching for a minimum of five years and teach up to matric level.

The purpose of this report is to analyse the factors affecting educational outcomes at Curtis Nkondo. Figure 10 shows the thematic network and reveals that economic, institutional, social, learner, and skill are the main factors affecting educational outcomes at the school. The research participants provided valuable insights into these factors. This report will focus on economic factors, institutional factors, and skills affecting educational outcomes at Curtis Nkondo.

4.18.1 *Economic factors*

According to Blackley & Howell (2015), STEM education comes about as a deliberate effort by the government to build institutions and formulate policy. One of the major economic factors affecting educational outcomes at Curtis Nkondo is funding. The school receives funding from the government as alluded to by research participant 1 (RP1) who states that:

> *'The SOS program was commissioned by the government'.*

The South African government is thus spearheading STEM education by building institutions that facilitate the implementation of STEM. RP 1 continues to say:

'The type of funding is more than that of ordinary schools with the same enrolment'.

This is further emphasised by RP 3 who adds:

''We have a good budget that enables us to buy gadgets for teaching".

In chapter 2, DeJarnette (2012) argues that government investment should be continuous to ensure the sustainability of STEM programs. The South African government has offered training in the form of bursaries to teachers in STEM schools. As RP 5 explains:

"There are opportunities to study further, and they are fully funded by the government".

From the theoretical and conceptual framework, it was established that Intervention from stakeholders such as industry and the communities form the identity of a STEM school. The thematic network shows that Curtis Nkondo benefits from contributions made by local businesses as alluded to by RP 5 who argues that:

"Companies sponsor our learners into tertiary STEM subjects, they deliver on their promises. we get donations from companies, especially in the automotive industry".

He goes on to say that:

"They (companies) send their workers to our school, and they help learners with technical skills, for example our leaners can electrically wire a house".

However, RP 3 argues that even though they receive funding:

"The parents do not assist financially even though we are a non-fee-paying school, and the funding is decreased every year by government until there is no finding because the school is supposed to be self-sustaining after some time".

South Africa seems to be following the same implementation plan as its Singapore counterparts. Not all schools will be STEM schools. RP 3 argues that:

"Schools of specialisation are very expensive and cannot be sustainable'.

In line with this thinking and like Singapore, South Africa is establishing centres of excellence for STEM fields where learners with the capabilities and passion for science are enrolled so that they can receive the targeted support to fulfil their roles in STEM careers. Literature

(Hallinen, 2015; Jackson et al., 2015) also argues in favour of targeted support as an important attribute that can ensure that funding brings out the best return on investment.

4.18.2 *Institutional factors*

The conceptual underpinning of this study points to entrepreneurship as part of design pedagogy. Entrepreneurship is part of the pedagogy and culture of a STEM school. This is inferred by RP1 who alludes to the fact that:

> *"Our learners leave the school in grade 12 with skill and do not need to go look for a job".*

This indicates that the school has established partnerships with external institutions to provide learners with skills that are relevant to the job market and to start their own businesses.
RP 1 goes on to say that:

> *"because of collaboration with institutions of higher education and businesses, our learners obtain certificates that enable them to start their businesses, for example, servicing cars".*

The above statement is established as a theme from the literature where according to Gallant (2010) there is a collaboration between the government, the private sector and institutions of higher learning. The theoretical framework of this study points to project-based learning in which students address real world problems. Curtis Nkondo fosters this by affording learners assistance-ships in collaboration with industry as stated by RP 6 who says:

> *"Our learners have opportunities to visit companies to gain work experience".*

Effective school management plays an integral role in the institutional arrangements at Curtis Nkondo. RP 3 argues that:

> *"Absenteeism does not affect us that much and when one teacher is absent, we have the technology that allows one teacher to teach more than one class at the same time".*

This is further supported by RP 5:

> *"a successful day is a result of good planning".*

One of the eight pillars that forms the theoretical framework of a STEM school points to giving learners authentic experiences as well as interactive content. This is achieved through good planning. RP 3 adds to this and stated that:

> *"We have systems in place, once systems are established, a school day runs smoothly, everyone is clear as to what they are supposed to do and that is what makes up a successful day when there are no glitches in the system".*

Another institutional factor affecting educational outcomes is the use of technology. The school has adopted innovative teaching methods, such as using smart boards and educational apps. As research participant 4 said:

> *"Our teachers are innovative and use technology such as smart boards and educational apps."*

This indicates that the school is using technology to enhance the quality of education. Based on the theoretical framework of this study, for STEM education to be effective, it has to be embedded in the eight pillars as alluded to by the Centre for excellence in STEM education as well as the instructional core (teacher, content, curriculum) by Elmore (2004) in section 2.13 of this study. South African STEM works in the same way as mentioned by RP 1:

> *'Our curriculum is flexible and practical. When you go into our classes it is evident to see creativity and learner-focused learning where teachers provide a conducive environment*

RP5 goes on to say:

> *"We encourage our learners to work in groups not only when doing projects but during lessons".*

4.18.3 *Skills*

Digital skills on the part of the teachers are important in the implementation of a STEM program and for improving educational outcomes. According to Elmore (2004) whose statements form part of the theoretical framework of this study, the teacher, content, and curriculum together form an instructional core for attaining positive educational outcomes. According to RP 5, Curtis Nkondo affords its teachers:

> *"Free online teacher development courses"*

To add to this RP4 asserts that:

> *"Teachers collaborate by sharing ideas among different departments are innovative and use technology such as smart boards, and educational apps".*

Leaner skills are also an important factor affecting educational outcomes at Curtis Nkondo. The school provides learners with opportunities to gain work experience by visiting companies. As alluded to by RP 4 and 1:

> *"Our learners have opportunities to visit companies to gain work experience".*

This indicates that the school is preparing learners for the job market by providing them with practical skills. This adds to the conceptual underpinning of this study which points to entrepreneurship as part of design pedagogy. Entrepreneurship is part of the culture of a STEM school. This is inferred by RP1 who alludes to the fact that:

> *"Our learners leave the school in grade 12 with skill and do not need to go look for a job".*

RP 1 goes on to say that:

> *"Because of collaboration with institutions of higher education and businesses, our learners obtain certificates that enable them to start their businesses, for example, servicing cars".*

The above statement is established as a theme from the literature where according to Gallant (2010) there is a collaboration between the government, the private sector and institutions of higher learning.

As previously mentioned by Merrill & Daugherty (2009) STEM education is about the integration of STEM subjects, applying the knowledge learnt in one subject to solve complex problems. RP 3 and RP 4 confirm a similar application of STEM at their institution and concede that:

> *"Even though we teach these subjects separately, we give our learners projects that encourage them to apply knowledge learnt across the board".*

RP 5 adds that:

> *"As teachers, we collaborate by sharing ideas among different departments".*

The researcher understands this to mean that content learnt in science is applied in conjunction with content learnt in mathematics, technology, and engineering to come up with creative innovations. It is worth noting that STEM schools in South Africa add entrepreneurship to their curriculum unlike what is alluded to in the literature where entrepreneurship is not included in other countries in the world. This according to RP 5 is important because:

> *"Companies are not hiring and there are no jobs, we need our learners to go out there and create jobs"*.

4.19 Summary of the thematic network

The attainment of educational outcomes at Curtis Nkondo is centred around six key areas, as shown in the thematic network diagram. These are curriculum and content, government involvement, stakeholder involvement, teacher quality, leadership, and funding.

Government intervention held a tenuous position in these discussions. With the government, it is easier for a STEM program to be initiated and benefit the marginally disadvantaged. Curtis Nkondo is a no-fee paying school providing STEM education in poor communities. The government's intervention, both in terms of policy and funding, is a positive attempt to ensure the sustainability of such programs.

STEM education at Curtis Nkondo is achieved through stakeholder involvement, and these include parents, businesses, and learners. It is evident from KIIs responses that companies play a significant role in the implementation and sustainability of STEM education by providing funding and donations and allowing learners to have work experience. RP 1 and 4 assert that even though the parents cannot make financial contributions, they help motivate learners and are available to help the school in other ways, such as providing labour and school governance by being active members of the school governing body. The learners are central to the implementation of STEM. Their commitment to studies is vital for educational attainment. This is evident in their taking part in collaborative projects and attending extra classes after school hours.

Teacher quality emerged from the participants' narratives. Even though quantitative data shows that there was a decline in the performance of learners in grade twelve compared to grade eight.

Curtis Nkondo saw a smaller decline compared to the control group. This can be because of teacher quality and school leadership. Whereas in times of shocks such as Covid-19 and social unrest, teaching and learning at Curtis Nkondo continues via online teaching and providing materials to learners to study at home. Learners at Curtis Nkondo meet via platforms such as TEAMS and WhatsApp and engage in discussions. This is made possible by the dedication of teachers who motivate the learners. Discussions from KIIs reveal that lost time is caught up by providing extra lessons and subject workshops.

The institutional arrangement at Curtis fosters the uninterrupted delivery of content and effective use of contact time. This is enabled by the systems put in place by the school's leadership. KIIs reveal that the school executive monitors and evaluates activities at the school and is proactive in implementing changes where necessary. They also provide both online and in-person workshops to ensure the continuous development of staff.

The social and contextual environment of a STEM school impacts outcomes. Discussions with research participants revealed that there needs to be a mindset change around education within Soweto. This is because the school had to invest much money to upgrade the security. Since the commissioning of the school, the school has been targeted by criminals who have in the past stolen educational equipment. Additionally, to that, some members of the community target the school in times of social unrest. This has resulted in school closure to ensure the safety of both staff and learners. The downside of this is that it negatively impacts teaching and learning time.

4.20 Interpretation

Statistical data and data from KIIs were very critical in gaining better insight into the educational outcomes at Curtis Nkondo School of Specialisation. The year 2020 showed a decline in physical science and mathematics educational outcomes. However, analysis in Chapter 4 reveals a lower decline in the experimental group compared to the control group. A tailored curriculum and content, government involvement, stakeholder involvement, teacher quality, leadership, and funding influence educational outcomes in mathematical and physical science.

Quantitative data analysis shows a difference in the achievement in favour of the experimental group for mathematics and physical science. The organising themes among the respondents in this research gave plausible reasons for this difference.

Considering the funding and resources available at Curtis Nkondo, a convincing difference in educational outcomes should have been obtained. The study is also aware that this was the first cohort at the school which could have been marred by teething problems and the covid-19 pandemic, which disrupted teaching and learning and affected grade twelve in 2020.

4.21 Conclusion

This chapter explored the empirical findings of this study. This was achieved through the presentation of quantitative findings in tables and charts. A clear description of the difference in different statistical analysis methods was provided, including tests of significance and confidence intervals. Qualitative data showed a difference between the control and experimental groups in favour of the experimental group in mathematics and physical science. This was followed by the presentation of qualitative findings that included quotes and summaries of key themes. Finally, we integrated the findings to show the relationship between the data.

The following chapter presents conclusions, recommendations, and suggestions for further study.

Chapter 5 : CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER STUDY

5.1 Introduction

This study aimed to establish the impact of the School of Specialisation Program at Curtis Nkondo Secondary School and the factors contributing to this. The findings of this study will serve as a guideline for government, non-governmental organisations as well as other stakeholders on a strategic level to implement STEM based on the reality of the group as experienced at the research site in this study. This study highlights the importance of considering all stakeholders in program formulation and implementation. The findings in this study cannot be generalised to the whole of South Africa, but the methods applied can be used for comparative purposes within the same community or elsewhere.

5.2 Attainment of research objectives

Three objectives were stated in the first chapter. Firstly, there was a need to define and explain the theoretical grounding of STEM education, its evolution, and its theoretical underpinnings. This was done in chapter two, utilising an extensive literature review. Chapter three presented a framework and tools to establish the impact of the school of specialisation program. Chapter four presents the empirical findings of this study. The last objective is the focus of this chapter. Conclusions will be drawn and, recommendations for the further study proposed.

5.3 Conclusions

The declining mathematics and science outcomes at the grade twelve level in South Africa have been a growing problematic concern for policymakers, educators, and parents. The purpose of this study was to examine the impact of the Curtis Nkondo School of Specialisation program on mathematics and physical science outcomes. The study aimed to answer three research questions:

1. Did the School of Specialisation program at Curtis Nkondo cause a change in mathematics and physical science outcomes?
2. What are the factors that contributed to the outcomes obtained at Curtis Nkondo School of Specialisation program?
3. What features of the program could be improved to strengthen program effectiveness, efficiency, and sustainability?

5.3.1 *Research Question One*

The first research question sought to determine whether the School of Specialisation program at Curtis Nkondo caused a change in mathematics and physical science outcomes. The quantitative data collected revealed that the program did cause a positive change in the mathematics and science outcomes at Curtis Nkondo. Although the program did not result in an increase in outcomes for the cohort marks in grade twelve compared to grade eight, learners who attended Curtis Nkondo showed greater resilience compared to learners at Freedom Park Secondary School. The difference in difference analysis showed that the program at Curtis Nkondo improved learners' resilience by four percentage points and eleven percentage points for physical science and mathematics, respectively. Therefore, it is conclusive to say that the School of Specialisation program caused a positive change in the mathematics and science outcomes at Curtis Nkondo Secondary School.

5.3.2 *Research Question Two*

The second research question aimed to identify the factors that contributed to the outcomes obtained at Curtis Nkondo School of Specialisation program. The qualitative data collected provided better insight into the program as illuminated by the thematic network generated from Key Informant Interviews (KIIs). The thematic network identified economic, institutional, social environment, skills, and learner factors as contributing to the outcomes obtained at Curtis Nkondo. These factors were interrelated and collectively affected educational outcomes at Curtis Nkondo.

Economic factors played a critical role in the program's success, as it allowed for the provision of resources and infrastructure necessary for effective teaching and learning. Institutional factors, such as school leadership and management, provided a conducive environment for teaching and learning. Social environment factors, such as parental involvement, community support, and learner discipline, were also significant contributors to the program's success. Skills and learner factors were important because they impacted how the program was implemented and how learners engaged with the program. Therefore, these factors collectively contributed to the outcomes obtained at Curtis Nkondo School of Specialisation program.

5.3.3 *Research Question Three*

The study sought to identify features of the program that could be improved to strengthen program effectiveness, efficiency, and sustainability. Qualitative data from research participants showed that better parental involvement, skills development of teachers and principals in implementing STEM, fostering good relations between unions and the government, providing support to learners who are affected by social factors, making communities have a sense of ownership of the school, thus making them safe zones that are crime proof, and adopting a blue-marble approach to the implementation of program intervention are features of the program that could be improved.

Better parental involvement could be achieved through community engagement, including community-based programs to encourage parents to participate in their children's education. Skills development for teachers and principals could be achieved through continuous professional development programs. Fostering good relations between unions and the government could be achieved through dialogue and negotiation. Providing support to learners affected by social factors could be achieved through counseling services and mentoring programs. Making communities have a sense of ownership of the school could be achieved through community involvement and outreach programs. Adopting a blue-marble approach to the implementation of program intervention could be achieved through a holistic approach to education that considers the environment, culture, and social factors that affect learning outcomes.

5.4 Recommendations

Based on the findings of this study, the researcher believes that STEM schools in South Africa have contributed to better educational outcomes in Mathematics and Science. However, a lot still needs to be done to obtain better results. This includes:

- A holistic approach to the implementation of government programs to get buy-in from all stakeholders. As suggested by Patton (2020), a blue-marble evaluation gives a plausible way in which Schools of Specialisation can be planned, commissioned, implemented and evaluated. The STEM program is one top-down program that was imposed on communities.
- Need for public consultation.

- Universities train teachers specifically for STEM education because in-service teachers may need more time to attend developmental courses.
- Better collaboration with industry to allow learners to receive practical training in the working environment.
- Need to train school headmasters on the Identity of a STEM education and how to run it.
- Provide funding targeted at STEM school graduates to start businesses, enabling them to be creators of employment.
- Improve rural infrastructure to enable STEM education in remote areas.
- Use STEM schools as centers to pioneer curriculum change as alluded to by RP 1 who said:

> *'Our curriculum is flexible and practical. When you go into our classes it is evident to see creativity and learner-focused learning where teachers provide a conducive environment '*

Implementing the above can go a long way to improve educational outcomes in Mathematics and Science, thereby fostering government efforts to build a STEM workforce in South Africa.

5.5 Recommendations for future study

The research found the following areas suitable for further research:

- A blue marble intervention that renders itself to the principles of blue marble evaluation
- The gendered study on the impact of a STEM program between boys and girls
- A continued study following up on the impact of STEM education on the livelihoods of STEM graduates later in life.
- Since these results cannot be generalised, more research of this nature can be carried out at STEM schools commissioned after Curtis Nkondo to present a broader assessment of the School of Specialisation program in South Africa.

In conclusion, this study succeeded in identifying some factors contributing to the outcomes at Curtis Nkondo School of Specialisation. Most of these factors added to the evidence in the literature review regarding STEM education in South Africa.

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Appendices

Appendix 1: Ethics Certificate

TRREE

Zertifikat

Certificat

Certificado

Certificate

Promouvoir les plus hauts standards éthiques dans la protection des participants à la recherche biomédicale
Promoting the highest ethical standards in the protection of biomedical research participants

Clinical Trials Centre
The University of Hong Kong

Certificat de formation - Training Certificate

Ce document atteste que - this document certifies that

Nicholas Zambara

a complété avec succès - has successfully completed

Introduction to Research Ethics

du programme de formation TRREE en évaluation éthique de la recherche
of the TRREE training programme in research ethics evaluation

Release Date: 2022/07/21
CID : vmVRplX1LY

Professeur Dominique Sprumont
Coordinateur TRREE Coordinator

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[REV : 20220217]

Appendix 2: Wits ethics clearance letter

WITWATERSRAND JOHANNESBURG | GOVERNANCE UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office:
Lehlohonolo Mmolotsane
Tel: 011 717 3968
Email: Lehlohonolo.mmolotsane@wits.ac.za

Research Ethics Chair:
Rekgotsofetse Chikane
Tel: 0117173869
Email: rekgotsofetse.chikane@wits.ac.za

30 October 2022

Dear Nicholas Zambara

Title: An impact evaluation of Curtis Nkondo School of Specialisation for the period 2016-2020
Student Number: 445179
Degree: Masters in Management
Ethics Clearance Number: WSG-2022-71

All candidates must satisfy the University's ethical standards for research. Your ethics application has been received and reviewed by the Wits School of Governance Human Research Ethics Committee.

Your ethical clearance has been approved subject to you getting permission to conduct research from all sites where research is conducted. The letter(s) of permission to undertake research must be submitted to the WSG Research Office and kept on file with your final proposal and other ethics documents.

You may commence your data collection under the guidance of your supervisor. In the event that the scope, methodology or nature of the research changes, you are required to submit another ethics application reflecting the changes.

The onus is on you as the candidate, with support from your supervisor, to ensure your research complies with university human research ethics policies and protocols at all stages of the research process.

It is recommended that you keep this letter in a safe place as you are responsible for ensuring you have proof of ethics clearance and have lodged the ethics clearance / protocol number with Faculty before final submission of your research report. If you do not have an ethics clearance number, you are not permitted to graduate.

Please do not hesitate to contact me if you have any queries.

Yours sincerely,

Rekgotsofetse Chikane

Rekgotsofetse Chikane
Research Ethics Chair

www.wits.ac.za/wsg

2 St David's Place, Johannesburg, 2050, Parktown, South Africa
E: admissions.wsg@wits.ac.za or shortcourses.wsg@wits.ac.za | T: +27 717 3520

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Appendix 3: Permission letter Gauteng Department of Education

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	**11 August 2022**
Validity of Research Approval:	**08 February 2022– 30 September 2022** **2022/351**
Name of Researcher:	**Zambara N**
Address of Researcher:	**690 Rubenstein Drive**
	Moreleta Meent
	Moreleta Park
Telephone Number:	**081 430 6973**
Email address:	
Research Topic:	**An impact evaluation of Curtis Nkondo School of Specialisaion**
Type of qualification	**Masters**
Number and type of schools:	**2 Secodnary Schools**
District/s/HO	**Johannesburg Central and Tshwane South**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

12/08/2022

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below are met. Approval may be withdrawn should any of the conditions listed below be flouted:

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *The letter would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. ***Because of the relaxation of COVID 19 regulations researchers can collect data online, telephonically, physically access schools, or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate.***
4. ***The Researchers are advised to wear a mask at all times, Social distance at all times, Provide a vaccination certificate or negative COVID-19 test, not older than 72 hours, and Sanitise frequently.***
5. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s has been granted permission from the Gauteng Department of Education to conduct the research study.*
6. *A letter/document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs, and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
7. *The Researcher will make every effort to obtain the goodwill and cooperation of all the GDE officials, principals, and chairpersons of the SGBs, teachers, and learners involved. Persons who offer their cooperation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
8. *Research may only be conducted after school hours so that the normal school program is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
9. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
10. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
11. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
12. *The researcher is responsible for supplying and utilising his/her research resources, such as stationery, photocopies, transport, faxes, and telephones, and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
13. *The names of the GDE officials, schools, principals, parents, teachers, and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
14. *On completion of the study, the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
15. *The researcher may be expected to provide short presentations on the purpose, findings, and recommendations of his/her research to both GDE officials and the schools concerned.*
16. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a summary of the purpose, findings, and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Mr. Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: 12/08/2022

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

Appendix 4: Permission Letter Curtis Nkondo

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

University of the Witwatersrand,
Wits School of Governance
2 St David's Pl, Parktown, Johannesburg, 2050
011 717 3520

Curtis Nkondo School of Specialisation
2362 Biyela St,
Emdeni South,
Soweto,
1861

27 July 27, 2022

Dear Sir/Madam,

Re: Permission to conduct research at Curtis Nkondo School of Specialisation

My name is Nicholas Zambara

I am studying for a Master of Management in the Wits School of Governance at the University of the Witwatersrand. I am seeking permission to do research at Curtis Nkondo School of specialization.

I am conducting research on the impact of School of specialization program in South Africa. I have chosen this topic because Schools of Specialisation have been adopted by government to produce a STEM workforce that can be able to solve the country's skills gap and come up with innovative ways to solve societal problems. Curtis Nkondo was the first school to be commissioned in 2016 and it will be able to provide data spanning five years.

The research will entail collecting data from Mathematics and Physical Science marks for the period 2016 until 2020. teaching staff limited to HODs, subject teachers as well the Head of the institutions, Subject specialists at the relevant districts.

I will invite individuals from your organisation to participate in this study. These will be limited to Mathematics and Physical Science HODs, Physical Science and Mathematics subject teachers as well the Head of the institutions and subject specialists at the relevant districts. If they agree, they will be interviewed. The interviews will be forty-five minutes long and will take place after hours to avoid interrupting work on the premises or a convenient public place. The interview will be audio recorded.

Participants will be asked to give their written or verbal consent before the research begins. Their responses will be treated confidentially, and identities (their names and the name of the organisation) will be anonymous unless otherwise expressly indicated. Individual privacy will be maintained in all published and written data resulting from the study.

The results will be communicated in my research report and may be published in educational academic journals.

The research participants will not be advantaged or disadvantaged in any way. They will be reassured that they can withdraw their permission at any time during this project without any penalty. There are no foreseeable risks in participating in this study. The participants will not be paid for this study.

All research data will be kept on a password protected laptop and destroyed after five years.

I therefore request permission in writing to conduct my research at your organisation. The permission letter should be on your organisation's headed paper, signed and dated, and specifically referring to myself by name and the title of my study.

Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Yours sincerely,

Nicholas Zambara
0670842612
445179@students.wits.ac.za

Supervisor's name
Dr R. Chikane
+27117173809
rekgotsofetse.chikane@wits.ac.za

Appendix 5: Permission letter Freedom Park

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

University of the Witwatersrand,
Wits School of Governance
2 St David's Pl, Parktown, Johannesburg, 2050
011 717 3520

Freedom Park High Scool
Devland,
Soweto,
1811

27 July 27, 2022

Dear Sir/Madam,

Re: Permission to conduct research at Freedom Park High School

My name is Nicholas Zambara

I am studying for a Master of Management in the Wits School of Governance at the University of the Witwatersrand. I am seeking permission to do research at Freedom Park High School.

I am conducting research on the impact of School of specialization program in South Africa. I have chosen this topic because Schools of Specialisation have been adopted by government to produce a STEM workforce that can be able to solve the country's skills gap and come up with innovative ways to solve societal problems. Curtis Nkondo was the first school to be commissioned in 2016 and it will be able to provide data spanning five years.
Freedom Park High School will be my control group in this study because of the similarities it shares with Curtis Nkondo, only difference being the intervention at Curtis Nkondo.

The research will entail collecting data from Mathematics and Physical Science marks for the period 2016 until 2020. teaching staff limited to HODs, subject teachers as well the Head of the institutions, Subject specialists at the relevant districts.

I will invite individuals from your organisation to participate in this study. These will be limited to Mathematics and Physical Science HODs, Physical Science and Mathematics subject teachers as well the Head of the institutions and subject specialists at the relevant districts. If they agree, they will be interviewed. The interviews will be forty-five minutes long and will take place after hours to avoid interrupting work on the premises or a convenient public place. Alternatively, the interview can take place on TEAMS. The interview will be audio recorded.

Participants will be asked to give their written or verbal consent before the research begins. Their responses will be treated confidentially, and identities (their names and the name of the organisation) will be anonymous unless otherwise expressly indicated. Individual privacy will be maintained in all published and written data resulting from the study.

The results will be communicated in my research report and may be published in educational academic journals.

The research participants will not be advantaged or disadvantaged in any way. They will be reassured that they can withdraw their permission at any time during this project without any penalty. There are no foreseeable risks in participating in this study. The participants will not be paid for this study.

All research data will be kept on a password protected laptop and destroyed after five years.

I therefore request permission in writing to conduct my research at your organisation. The permission letter should be on your organisation's headed paper, signed and dated, and specifically referring to myself by name and the title of my study.

Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Yours sincerely,

Nicholas Zambara
0670842612
445179@students.wits.ac.za

Supervisor's name
Dr R. Chikane
+27117173809
rekgotsofetse.chikane@wits.ac.za

Appendix 6: Participant consent

Consent Form

Title of project
An Impact evaluation Of Curtis Nkondo School of Specialisation for the period 2016-2020

Name of researcher Nicholas Zambara

I, ……………………………………….., agree to participate in this research project.

I agree to the following:

(Please circle the relevant options below)

The research study was explained to me. I understand what this study is about.	YES	NO
I understand that I can volunteer to take part in the study	YES	NO
I agree that the interview may be audio recorded	YES	NO
I agree that direct quotations from my interview may be used by the researcher in their research report	YES	NO
I agree that my participation will remain anonymous (my name will not be used by the researcher in their research report	YES	NO
I agree that other researchers may use the information I provide in my interview depending on their own ethics clearance being obtained) but my name and any personal information will not be used or passed on	YES	NO

…………………………………… (signature)
…………………………………… (name of participant)
…………………………………… (date)

…………………………………… (signature)
Nicholas Zambara
…………………………………… (date)

Appendix 7: Interview questions

HEADMASTER INTERVIEW QUESTIONS (EXPERIMENTAL GROUP)

INTERVIEW QUESTION	WHAT I WANT TO GET FROM THE QUESTION
What is your highest qualification	
Years of experience	
Age range	
Is your school a government school and is it a fee charging school?	
How many teachers in your school	
How many support stuff do you have	
Do you charge extra levies and if so for what ?	
How do you select learners who come to your school	
Describe how your day goes from start to end of day at the school	Leadership and management style
What is it about your work/ work environment that you like	Features of the program/school RQ 2
What is it that you do not like	
Can you describe for me a successful Term	Features of the program/school, RQ2
What contributed to the success of that Term	Features of the program/school RQ2
What is your philosophy (values, nature of existence, epistemology) on STEM Education?	Understanding of STEM
When government started the SOS program was it clear what they expected from you?	
Did you receive additional training for your new role	
An SOS school is different to an ordinary government school. Are there program documents specific to your school as to how government envisages implementation?	
What is the goal of a stem program	Understanding of STEM
What expectations currently exist for collaboration across grades and subjects	Integration of STEM subjects
What is the current budget for the STEM program	The relationship between school spending and educational outcomes.
What support is given to teachers that will enable them to be effective	Teacher working environment
What type professional development are available for all teachers to build STEM skills	Teacher development
What challenges do you face in implementing STEM education in your school	Areas needing improvement/RQ3
How do you manage the integration of subjects eg maths topics in science or technology and science/maths	
Do your learners do projects to allow what is learnt in class to be applied in real life	
STEM IDENTITY is about the 4Cs. How are these 4 cs (creativity; collaboration; visible to anyone who walks into your class	

Did your class of 2020 achieve its objectives in maths and science	RQ1
How effective is the SOS program?	
How do you manage to absorb shocks eg covid, load shedding, social unrest, teacher/learner absetism	

SUBJECT SPECIALIST INTERVIEW QUESTIONS

INTERVIEW QUESTION	WHAT I WANT TO GET FROM THE QUESTION
Describe how your day goes from start to end of day at the school	Support given to teachers
What is it about your work that you like	Features of the program/school RQ 2
What is it that you do not like	
Can you describe for me a successful Term	Features of the program/school, RQ2
What contributed to the success of that Term	Features of the program/school RQ2
Can you describe for me a term when things did not go well	Features of the program/ school RQ2
What contributed to the lack of success	Features of the program/school RQ2
Explain what a school of specialisation school is	Understanding of what a STEM school is
What makes it different compared to ordinary government schools	Teacher understanding of STEM and ordinary school/RQ3
What challenges do you face	RQ3
How have you been able to overcome your challenges	What makes stem schools successful. Answer to RQ 2
What can be done to improve the results	Answer to research question 3
Do you think this type of school is sustainable	Answer to research question /RQ3
Can the program be extended to other locations in SA urban, semi-urban and rural	Answer to research question/RQ3

HOD Interview questions (SAME AS TEACHER QUESTIONS

TEACHER INTERVIEW QUESTIONS

INTERVIEW QUESTION	WHAT I WANT TO GET FROM THE QUESTION
Describe how your day goes from start to end of day at the school	Teacher activities that could lead to outcomes
What is it about your work that you like	Features of the program/school RQ 2
What is it that you do not like	
Can you describe for me a successful lesson /Term	Features of the program/school, RQ2
What contributed to the success of that lesson(S)/Term	Features of the program/school RQ2
Can you describe for me a lesson/term when things did not go well	Features of the program/ school RQ2
What contributed to the lack of success	Features of the program/school RQ2
Explain what a school of specialisation school is	Understanding of what a STEM school is

What makes it different compared to ordinary government schools	Teacher understanding of STEM and ordinary school/RQ3
What challenges do you face	RQ3
How have you been able to overcome your challenges	What makes stem schools successful. Answer to RQ 2
What can be done to improve the results	Answer to research question 3
Do you think this type of school is sustainable	Answer to research question /RQ3
Can the program be extended to other locations in SA urban, semi-urban and rural	Answer to research question/RQ3
What is your philosophy on STEM Education?	Design pedagogy (Pillars of a stem school)
What specific STEM skills do you possess?	Teacher skills (Pillars of a STEM school)
What are the 4 Cs and what do they look like in your classroom?	Design pedagogy /creative problem solving (Pillars of a STEM school)
If you were designing the ultimate STEM space, what are 3 must-have items that you would need?	Authentic experiences (Pillars of a STEM school)
How do you connect content in your STEM classroom with other subject areas?	Interactive content (Pillars of a STEM school)
Are parents and community members in the STEM program?	Collaboration and communication (Pillars of a STEM school)
What community projects do your learners participate in. eg Science Expo	Global and social awareness / innovation and optimism (Pillars of a STEM school)