Teachers' perceptions and practices of science, technology, engineering and mathematics Education Life sciences classrooms

BY

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ABSTRACT

This study was motivated by an observed need for more comprehension of the integration of science, technology, engineering and mathematics education by teachers. To gain more insights into the research problem, this study explored teachers' perceptions and practices of science, technology, engineering and mathematics education in life sciences classrooms. A conceptual framework of Constructivism and STEM education was used to guide the study. The study was conducted using a qualitative research approach, an interpretive paradigm and an exploratory case study design. Purposive sampling techniques were used to select three life science teachers who taught Grades 10-12 in different schools from Thabo Mofutsanyana District of the Free State Province of South Africa. Data were gathered by means of semi-structured interviews with the teachers, lesson observations, and document analysis to elicit teachers' perceptions and practices of STEM education integration in life sciences. The data generated from the three instruments were triangulated and analysed thematically as guided by the subsidiary questions. Four themes were identified as teachers' perceptions of STEM education, the practice of STEM education in life sciences classrooms, challenges encountered during STEM integration, and opportunities provided by proper instruction of STEM education. Four significant findings emerged. First, teachers were aware of STEM education and the integrative nature of the STEM disciplines. However, the second finding showed that they were inadequately prepared to incorporate STEM integration approaches in their teaching lessons. The teachers struggled to integrate STEM disciplines into their classroom practices. Regardless of their comprehension of STEM education, their classroom practices were divorced from what STEM integration demands. Thirdly, it emerged that teachers encountered many challenges regarding STEM education. Other than individual challenges experienced by teachers, such as a lack of pedagogical strategies and being under-prepared to implement STEM education integration, there were also contextual factors which inhibited proper instruction of STEM education. The contextual factors included a lack of resources to carry out successful experiments and design projects, frequent power outages in the area, and overcrowding of learners. The study recommends the provision of sufficient support through conducting relevant workshops.

Keywords: STEM education, constructivism learning theory, curriculum, interpretive paradigm.

DEDICATION

I am grateful to the Almighty God, who has guided me throughout the journey. Without his wisdom, I would not have done this. It was through his grace that I saw the completion of this project.

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LIST OF ACRONYMS AND ABBREVIATIONS

STEM: Science, Technology, Engineering and Mathematics

LSLC: Life Sciences Learning Centre

SET: Science, Engineering and Technology

PIRPOSAL: Problem identification, Ideation, Research, Potential solution, Optimization, Solution evaluation, Alteration and Learned outcome phase

DEEP: The Digital Education Enhancement Project

PjBL: Project Based Learning

6E: Engage, Explore, Explain, Engineer, Enrich, Evaluate

HOTS: Higher Order Thinking Skills

TPS: Think Pair Share

PBL: Problem-Based Learning

SASA: South African School Act

PTR: Pupil-Teacher Ratio

IBP: Internet Broadcast Project

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ORIENTATION OF THE STUDY

1.1 Introduction to the study

Science, Technology, Engineering, and Mathematics (STEM) education is a curriculum innovation aimed at enriching learners' knowledge and application of these four essential disciplines (Marrero, Gunning & Germain-Williams, 2014). It is considered a "meta-discipline," where various disciplinary knowledge is integrated to create a new and comprehensive understanding (Ejiwale, 2013:64). In today's rapidly evolving world, STEM disciplines are crucial to addressing the challenges of the 21st century (Bybee, 2010).

STEM education has proven to be a powerful tool for nurturing students' problem-solving, critical thinking, and analytical skills, while also establishing stronger connections between theoretical concepts and real-world applications (Brown, Brown, Reardon & Merrill, 2011). Despite its potential, there have been concerns that the focus on "no child left behind" in the United States has inadvertently diminished the emphasis on science education, with less attention given to the promotion of STEM fields (Bybee, 2010). To ensure economic development, it is essential to address the shortage of skilled workers required to support STEM-related industries (Bybee, 2010). STEM literacy plays a pivotal role in meeting these challenges and providing opportunities for a well-prepared workforce.

The purpose of this study is to explore teachers' perceptions and practices regarding the integration of science, technology, engineering, and mathematics education in life sciences classrooms. This research holds significance as it sheds light on the potential of STEM education to enrich life sciences classrooms and enhance students' learning experiences. The findings will contribute to our understanding of how STEM can be effectively integrated into the existing curriculum. This chapter outlines the background of the study, research interest, research objectives and questions, purpose of the study, significance of the study, methodology, and delimitation of the study.

1.2 Background to the study

Science, Technology, Engineering and Mathematics (STEM) education requires the use of interdisciplinary approaches, which, when effectively implemented, support meaningful learning.Mansour and El-Deghaidy (2015) conducted a study and found that science teachers lacked pedagogical knowledge to integrate STEM education into their classroom practices. Kennedy and Odell (2014) recommend thorough instruction of STEM integration and a perfectly outlined curriculum for learners to be engaged in high-quality STEM education programmes. For instance, the Life science learning centre is a widely recognised program that has disseminated its curriculum materials nationwide through teacher professional development programs (Alcena-Stiner & Markowitz, 2020). In the same vein, Kelley, Knowles, Han and Trice (2021) advise that teachers need to pair as engineering, technology and Life sciences teachers to implement integrated STEM lessons.

Scholars in the developed countries have proposed that the teaching of STEM disciplines be integrated into one subject (Hooker, 2017).The reviews in the United States indicate that the research in STEM is growing, with research in integrative STEM constituting the main focus in terms of subject matter (Lee, Chai & Hong, 2019). In the USA, the Obama administration introduced a range of STEM initiatives to help promote the teaching and learning of STEM subjects(Williams, 2011).These programmes serve to ensure that learners are taught STEM education to become innovators needed in the 21st century economy.These programs, introduced by the Obama administration, include ‘Educate to Innovate’,which aims to raise the United States from middle to the top of the pack in science and mathematics (Burke & McNeill, 2011). The United States Department of Education grants bonus points for STEM initiative programs that focus on STEM instruction (Piro, 2010). This funding was in addition to the nearly $700 million the federal government already spent on science and mathematics education programs within the National Aeronautics and Space Administration, the National Science Foundation, and in other agencies (Piro, 2010). Furthermore, the monetary support was, according to Stevenson (2014),a response to confirmations by the business world that there was a shortage of STEM workers.

Whileimplementing STEM education in one study, learners were given project-based and problem-based activities(Ntemngwa & Oliver, 2018). The project-based activity required learners to build models that applied concepts of acceleration, deceleration, directional acceleration and velocity, by programming-built robots to follow a certain path. The project-based activity was achieved by learners building robots with the materials provided by the teacher and programming them to follow a predetermined path. Learners were also given a problem-based activity to understand and apply asteroid concepts. To achieve this, learners used the content on solar systems they had already learnt to make their solar systems and present them as working models to other learners. In this way, learners were engaged in learner-centred activities that exposed them to discovery learning leading to the construction of new knowledge and problem solving, giving practical solutions to real-world tasks. To successfully construct new knowledge, learners had a preceding session where the science and technology teacher jointly introduced the project and explained the importance of coding and robotics in society. As part of the preparation, learners were asked questions to ascertain their prior knowledge prior to the learner-centred instructional strategies in which the science and technology teachers assumed the role of facilitators.

The United Kingdom appointed a national STEM Director, followed by initiatives to promote the STEM agenda (Williams, 2011). The United Kingdom government was concerned about the overreliance on outsourcing engineering graduates from countries such as India and the Pacific Rim,due to the rapid decline of engineering graduates in the country (Williams, 2011). The four countries in the United Kingdom have their own distinct education system, with England, Wales and Northern Ireland having a population of 53 million, 3 million and 2 million respectively, and having similar practices. However, Scotland, with a 5million population, differs from the othersin practice, particularly at secondary level (Tomei, Dillon & Dawson, 2014). On the issue of practice, LaConte (2020) conducted a study investigating STEM experiences for diverse learners in the United Kingdom classrooms. The author found that the teachers reported not having enough time with their colleagues to set up a conducive STEM learning environment for learners.Lack of funding and other support hindered the creation of a successful environment that caters for STEM learning to diverse learners in the United Kingdom classrooms (LaConte, 2020). Additionally, fewer young people in the United Kingdom chose post-16 STEM subjects (Reiss & Mujtaba, 2017).

Integrated STEM education in South Korea is a strategic approach to prepare a competent and technologically literate workforce to thrive in a highly technology-based society (Kang, 2019). In this educational framework, a technology teacher and a science teacher collaborated to design a captivating lesson centred around the theme of 'light.' The ultimate objective was to culminate the day's activities with a project where learners would construct LED lamps in various shapes and colours.To initiate the project, students were provided with the necessary materials and shown a brief video clip demonstrating the appearance and functionality of an LED lamp. Throughout this process, the learners acquired fundamental knowledge from each subject, laying the groundwork for the project's execution, which was primarily carried out during the Technology class (Kang, 2019). This interdisciplinary integration exemplified the essence of integrated STEM education.Problem-based learning (PBL) served as a prominent method for integrating STEM disciplines within this educational context. Learners were presented with complex problems that did not possess a single correct solution. Working collaboratively in groups, students identified the resources and information needed to address the given problem effectively. By engaging in self-directed learning (SDL), they applied their newfound knowledge to devise solutions, reflected on the lessons learned from the process, and brainstormed the efficacy of potential strategies (Kang, 2019).The goals of implementing problem-based learning include nurturing learners to develop adaptable knowledge, effective problem-solving skills, the ability to collaborate harmoniously, intrinsic motivation, and self-directed learning capabilities (Kang, 2019). By emphasising these objectives, integrated STEM education in South Korea equips students with essential skills and competencies vital for thriving in a technology-driven society.

India has the capacity to produce the highest number of young skilled manpower to lead the world and restore national strategies for STEM education (Sharma &Yarlagadda, 2018). However, this is not the case because many factors have influenced STEM education implementation in India (Sarukkai, 2015). The factors in question include high levels of teacher absenteeism and poor facilities (Kingdon, 2007). To correct the latter, the government of India is determined to train the young population in order to meet the demands of the industries (Sharma & Yarlagadda, 2018). The most crucial thing to Indian STEM educators and learners is accepting the different ways in which science knowledge can be constructed, by adopting the world scientific views as their realities (Thomas & Watters, 2015). Active learning and inquiry-based learning inform integrated STEM education (Rosicka, 2016). Active learning is achieved by learners using multiple senses and interacting with others and with material to solve a problem. Inquiry-based learning is achieved through guidance, provision of structure, and scaffolding by the teachers to guide learners through a hands-on and problem-based activity, where learners develop more than one specific domain of skills and knowledge. Through these pedagogies, learners collaborate, follow areas of interest, get creative, and solve real-world problems.

Thomas and Watters (2015) opine that the teaching method in developing countries is still traditional and didactic and learners in developing countries are more disposed to STEM-related careers than Western counterparts. Developing countries in Asia have encountered several problems in the actual implementation of STEM education (Le, Tran & Tran, 2021). Countries, such as Indonesia, have been called upon to deal with recent STEM demands by developing qualified human resources through educational reform (Kumano &Suwarma, 2019). STEM education in Indonesia was carried out using learning models Like ProjectBased Learning (PjBL), Engage, Explore, Explain, Engineer, Enrich and Evaluate (6E), Higher Order Thinking Skills (HOTS) assessment based-learning, inquiry, Think Pair Share (TPS), Problem-Based Learning (PBL), android game, digital and learner book based-learning. The PjBL is the widely used method in STEM education implementation in Indonesia (Khotimah, Adnan, Ahmad &Murtiyasa, 2021). However, Permanasari, Rubini and Nugroho (2021) assert that many teachers do not apply the STEM approach in their classroom practices, leading to weak comprehension of STEM and its integration on the learners' side.

Secondary education in Africa should lay the foundational skills for self-employment and entrepreneurship (Tikly, Joubert, Barrett, Bainton, Cameron & Doyle, 2018). Studies show low learner attainment of STEM learning at the secondary level in Africa, and are also evident at the primary level (Tikly*et al.,*2018).Nicia and Luisa (2020) note that the participation of women in these disciplines in Mozambique remains low. Mozambique Department of Education advocates the adoption of 'EdTech' as a method of tackling the learning crisis that prevails in the region (Oberdieck, 2021). Dekeza and Kufakunesu (2017) claim that rural secondary schools in Zimbabwe are incapacitated to implement STEM education due to several factors—these include a lack of laboratories and adequately trained teachers for integrative STEM teaching. South African learners continue to perform poorly in Mathematics and Science compared to other African countries (Feza, 2014). This is due to a lack of foundational knowledge (Feza, 2014). In the study by Williams (2011), South Africa deems the grouping of STEM subjects as an interdisciplinary approach. Science, Engineering and Technology (SET) was initiated to promote STEM education learning in South Africa. Science, engineering and technology (SET), was undertaken to promote STEM education learning in South Africa. The Inkanyezi Project, funded by the Zenex Foundation in South Africa aims to enhance learners' knowledge of Science and Mathematics (Tikly*et al*., 2018). There is a gap in the literatureon how SET, as an initiative of integrated STEM education, is implemented in South Africa. It is against this background that this study aims to explore teachers' perceptions and practices of science, technology, engineering and mathematics education integration.

The summary of essential steps of technological and engineering designs is undertaken and shown in Table 1.1 below. According to Kang (2019:4), for a successful technological design, learners need to identify a problem with the criteria and constraints that the problem may pose. They need to explore various solutions that can possibly be employed, develop a system for the model, and evaluate solutions from the ones brainstormed. They should observe the design and communicate about it with others. To produce an engineering design, learners must identify the engineering problem; outline the purpose of the design and identify possible constraints that may hinder the successful design. They need to brainstorm possible solutions to a problem and then carry out the process of making the design with the possible solutions. They then need to refine the design and conclude on the efficiency of the design to the problem.

Table 1-1: Steps that are crucial for learners in undertaking technological and engineering-based prototypes or models (Kang, 2019:4)

Technological design	Engineering design
- Identify a design problem - Identify criteria and constraints - Refine a design by using prototypes and modelling - Evaluate the design solution using conceptual, physical, and mathematical models - Develop and produce a product or system - Evaluate final solutions - Communicate observation, processes, and results	- Define and delimit an engineering problem (design purpose, criteria and constraints of a successful solution) - Develop possible solutions: using models including mathematical models - Optimize the design solution: evaluation of multiple solutions, making trade-offs

1.3 Statement of the problem

The 21st-century workforce requires highly skilled individuals. STEM disciplines expose learners to integrating science, technology, engineering and mathematics, to equip learners with the necessary 21st century skills. Wells (2016) comments that the implementation of discipline-specific models in teaching STEM is problematic because they are associated with not only a method for teaching the content a discipline, but also a method for preparing the practice of a discipline. Close inspection of models reveals that they do not achieve what is intended by STEM education, andneed to be more adequate for conveying an integrative teaching approach to STEM education (Marrero et *al*., 2016). According to Marrero *et al.* (2014), educational systems employ discipline-specific domains with little or no interdisciplinary. That disadvantages learners because real-world problems require a set of skills. The integrative or interdisciplinary approach to teaching is a new phenomenon in the context of teaching and learning.

DeSutter and Stieff (2017) regard spatial thinking as an important component of STEM learning. However, learning environments that focus on spatial thinking are incomplete. Teachers lack pedagogical knowledge of integrating STEM education into their classroom practices (Mansour & El-Deghaidy, 2015). Marrero *et al*. (2014) highlight that we live in times when STEM workers are in high demand. Therefore, STEM education is one way to increase innovation capacity and provide future employment (Reynante, Selbach-Allen & Pimentel, 2020). Few people in South Africa study technological or scientific subjects, which puts the economy at a disadvantage because businesses cannot find workers in those critical fields (Charette, 2013). This skill shortage problem is also observed in other countries (Charette, 2013).

Anwari, Yamada, Unno, Saito, Suwarma, Mutakinati and Kumano (2015) posit that the advantages of STEM education approaches is that learners are provided many opportunities to develop their thinking skills (metacognitive skills, critical and creative thinking. Further benefits afforded by STEM education approaches are highlighted by Sungur Gul, Saylan Kirmizigul, Ates and Garzon (2023) which are arranged into six categories (learner achievement, learner skills, learner career development, learner STEM dispositions and learning experience).

1.4 Main research question

What are the teachers' perceptions and practices of science, technology, engineering and mathematics education in life sciences classrooms?

1.4.1 Sub-research questions

- What are the teachers' perceptions of STEM education integration in life sciences classrooms?
- How do teachers integrate STEM education in life sciences classrooms?
- What are the challenges of STEM education integration in life sciences classrooms?
- What are the perceived opportunities for integrating STEM education in life sciences classrooms?

1.5 Purpose of the study

To explore teachers' perceptions and practices of science, technology, engineering and mathematics education in life sciences classrooms.

1.6 Research objectives

- To elicit teachers' perceptions of STEM education integration in life sciences classrooms.
- To describe how teachers integrate STEM education in life sciences classrooms.
- To explore the challenges of STEM education integration.
- To determine the perceived opportunities for integrating STEM education in life sciences classrooms.

1.7 Significance of the study

This study is significant because it outlines the various perceptions held by life sciences teachers towards STEM education integration. The perceptions and practices held by teachers are essential in preparing educational means that can be implemented to improve STEM learning. There is a growing demand for STEM professionals worldwide; hence, learners must be STEM literate. Comprehension of problems encountered by teachers during the integration of STEM teaching can lead to the development of mitigating strategies, resulting in improved teaching and learning of STEM. Children should be exposed to STEM subjects because they equip them with the 21st century skills required in the corporate world (Mansour & El-Deghaiddy, 2015). However, learners cannot be equipped with such if proper research is not done to understand how to better equip teachers with pedagogical strategies to teach STEM. Teaching the STEM disciplines effectively will afford learners the skills needed in the real world, of critical thinking, problem solving, and informed decision makingabout future careers.

1.8 Research methodology

A qualitative approach was employed in this study. The choice of the interpretive paradigm was based on the premise that understanding is possible based on observation and interpretation (Ling & Ling, 2017). An explorative case study was used in this study to get various insights about the phenomenon under research. Semi-structured interviews were employed together with observations for data generation. Purposive sampling was used to select three life sciences teachers who taught grades 10-12 and had at least one year experience. They had to be teaching in Thabo Mofutsanyane district, circuit 10 in the Free State, QwaQwa. Thematic categories were used to analyse the data. Table 1.2 shows the research strategy plan.

Table 1-2: Research strategy plan

Guiding Research Topic	
Exploring teachers' perceptions and practices of science, technology, engineering and mathematics education in Life Sciences classrooms	
Interpretive paradigm	
Epistemological Model	The study makes use of interpretive research paradigm
Research approach	

Methodological Model	The study makes use of the qualitative research approach
Research Design	
Single-explorative case study design	
Population and sampling procedure	
Sample type: Qualitative sample (Teachers) Sampling strategy:	Sample size: 3 Purposive sampling
Data Collection Instruments	
Data Collection Methods: Semi-structured interviews Observations Document analysis	Data Collection tools: Open-ended questionnaire Observation checklist Lesson plan checklist
Data Analysis and Interpretation	
Descriptive data analysis Interpretive data analysis	Biographic information Thematic categories
Trustworthiness	
Credibility	Triangulation strategy and member checking
Dependability	Examination of semi-structured interviews and practical lesson observations
Transferability	Analysis of transcripts and purposeful selection
Confirmability	Triangulation of data through semi-structured interviews, practical lesson observations and analysis of documents
Ethical Considerations	
Ethical Elements attended to Informed consent Anonymity & confidentiality Permission	 Teachers No personal identifiers Ethical Clearance by the General Human Research Ethics Free State Department of Basic Education
Conclusions: The elicitation of teachers' perceptions yielded the conclusion that they were	

aware of STEM education and the integrative nature of the STEM disciplines. However, it emerged that teachers struggled to integrate STEM disciplines into their classroom practices. Regardless of the comprehension that some possessed with regard to STEM education, the classroom practices were far from what STEM integration demands. It was also noted that there were many challenges that teachers encountered regarding STEM education. Other than individual challenges experienced by teachers such as lack of pedagogical strategies and being under prepared to implement STEM education, there are also contextual factors which inhibited proper instruction of STEM education. The contextual factors in question included lack of resources to carry out successful experiments and design projects, frequent power outages in the area, and overcrowding of learners thatinhibited proper facilitation of activities\experiments. However, there were various opportunities afforded by STEM education integration. Careers such as architecture, computer programming require individuals with a certain set of skills like one provided by STEM disciplines integration.
Recommendations: Teachers need workshops that thoroughly familiarize them with the STEM concept, its purpose for instructional purposes, and the methods and strategies of incorporating these disciplines in their lessons.Future research is recommended to determine how teachers can be assisted pedagogically regarding STEM education integration.

1.9 Delimitation

STEM education is an integrative approach pursued in this study. In terms of boundary, this case study is geographically bound as only Life sciences teachers in circuit 10 under the Thabo Mofutsanyane district took part in the study.The study only focused on grade 10-12 life sciences teachers. Interviews, observations and document analysis were the only techniques employed to generate data, and only life sciences teachers will be interviewed to collect data. The teachers to be interviewed are only teaching in high schools.

1.10 Definition of terms

STEM: is a term used to describe the four disciplines which are science, technology, engineering and mathematics (Pimthong& Williams, 2018).

Classroom practices: are the methods that teachers use to deliver the content to the learners (Cho, 2015).

Perceptions:is man's primary form of cognitive contact with the world around him (Efron, 1969).

Conceptual framework: is the end result of combining together concepts that relate to one another (Imenda, 2014).

1.11 Chapter outline

Chapter 1: Introduction & orientation of the study

This chapter dealt with the introduction, background, research interest, objectives and questions, purpose of the study, significance of the study, methodology and delimitation of the study.

Chapter 2: Literature review & theoretical framework

This chapter reviewed the literature within four sections namely, teachers' perceptions regarding STEM education, STEM education and its integrative nature, challenges encountered by teachers during the integration of STEM disciplines, finally, perceived opportunities of STEM education integration.

Chapter 3: Research methodology

This chapter covered research methodology aspects employed in the study. It outlined the paradigm that underpinned the study, the research approach that was employed, the relevant research design, the sampling, data collection instruments, aspects pertaining trustworthiness of the collected data, data collection procedures, the stages that were undertaken to analyze the data, and ethical issues.

Chapter 4: Presentation and discussion of findings

Interpretive analysis primarily deals with the common themes that emerged from semi-structured interviews, lesson observations and document analysis. The themes that emerged were: teachers' perceptions of STEM education; the practice of STEM education in Life-sciences classrooms; challenges encountered during STEM integration; and opportunities rendered by proper instruction of STEM education.

Chapter 5: Findings, conclusions and recommendations

This chapter thoroughly discussed the findings of the study as per the themes that were aligned with the research topics.

1.12 Summary

This chapter outlined the introduction, background, research interest, objectives and questions, purpose of the study, significance of the study, methodology and delimitation of the study. STEM education is crucial for the future of learners. This program entails four disciplines which equip learners with the 21st-century skills when effectively implemented. The main aim of the study was to explore teachers' perceptions and practices of science, technology, engineering and mathematics education in Life sciences classrooms. STEM education, in the context of the study, is regarded as an integrative and interdisciplinary approach to the process of teaching and learning. The next chapter is reviews existing literature related to the topic under investigation.

CHAPTER TWO

THEORETICAL FRAMEWORK&LITERATURE REVIEW

2.1 Introduction

The previous chapter discussion was based on introduction and background, research interest, objectives and research questions, purpose of the study, significance of the study, methodology and delimitation of the study. This chapter reviews the existing literature about the study. Literature is reviewed based on three themes; teachers' perceptions of STEM education integration, the integration of STEM education, and challenges experienced by teachers when integrating STEM education. Perceived opportunities for integrating STEM education and empirical studies that were carried out on perceptions and practices of STEM education in science classrooms are discussed. Furthermore, the theoretical framework underpinning the study in question is explored and grounded theory is fully outlined.

2.1.1 Theoretical framework and its importance

Theoretical framework is a blueprint for the entire dissertation that serves as a guide to build and support the study (Osanloo& Grant, 2016). Theory guides practice and research. Abraham (2008) notes that theory-driven research has advantages of growth and development of the discipline of chemical education. Theoretical framework is sufficiently general to ground further research to define theoretically valid elicitation methods for important parameters (Mikkola, Martin, Chandramouli, Hartmann, Pla, Thomas, Pesonen, Corander, Vehtari, Kaski&Burkner, 2021). Moreover, Osanloo and Grant (2016) highlight that the study becomes clear and well-structured with the use of a theoretical framework.

2.1.2 Theoretical framework in the context of the study

Constructivism learning theory was employed to inform this study.According to Fosnot (2005), constructivism is a theory about knowledge and learning that describes what constitutes "knowing" and how people come to know. Bada and Olusegun (2015) say constructivism is a theory where learning is an active process and learners construct their own understanding and meaning. Constructivism can be linked to STEM education because the curriculum innovation requires learners to be active and at the front of their learning process through hands-on activities. Hands-on activities enable learners to learn how things work in the real-world while the teacher is the facilitator. Models of real-world products are produced in STEM classrooms, and in the process, learners construct their own knowledge and solve complex real-world problems. This can be achieved by adopting constructivism as a grounded theory for learning that stipulates that new learning is achieved through experience and prior knowledge.

In constructivism, each person is responsible for their learning by relating new knowledge with previous knowledge or experiences (Dennick, 2016). On that note, STEM education and constructivism theory can integrate, with constructivism employed to ensure learners possess prior knowledge needed for discipline integration at foundation and intermediate phase.Nadelson, Callahan, Hay, Pyke, Dance and Pfiester (2013) believe that foundational instruction of STEM at an early age can help learners.Margot and Kettler (2019) emphasise that prior experience is an important and influential aspect of STEM instruction.

Radloff and Guzey (2016) approach STEM education through a constructivist lens, asserting that constructivism acknowledges experience and directly affects our existing knowledge and knowledge acquisition. In a study conducted by Sevda and Sevim (2018),teachers stated that STEM education and the constructivist approach ensure that teaching and learning processes are learner centred. Learners' development, intelligence, and learning preferences are considered when STEM is taught using this approach. Sayary, Forawi and Mansour (2015) highlight that constructivism shapes the cognitive process through learners incorporating new knowledge into existing experiences because constructivism is the backbone of problem-based learning. This study also aims to use constructivistlearning theory to study the teaching of STEM education.

2.1.3 Summary of tenets of constructivism learning theory

Obikwelu and Read (2012) state that individual representation of knowledge, active knowledge through exploration, and learning through social interaction or collaboration, make up the basic principles of constructivism. They further explain that, as opposed to behaviourist learning theory, constructivism deems the learner an active processor of information. Additionally, the principles of constructivism are that knowledge is constructed, learning is active and social,and is constructed based on prior experiences. Learners create concepts based on existing knowledge, and constructivist strategies are helpful for teachers and learners to communicate optimally (Powell & Kalina, 2009). The view of constructivist learning theory is that learning is an active and constructive process (Bada & Olusegun, 2015). Furthermore, the authors assert that social interaction is an essential and effective method of teaching that allows collaboration. This essence relies on an epistemology that stresses subjectivism and relativism, the concept that while reality may exist separate from experience, it can only be known through experience, resulting in a personally unique reality .

In addition to the above-mentioned principles, Hall (2007) posits that socio-constructivist approach is a blend of constructivism. Vygotsky deems the environment as the starting point for learning, and that the learner-centred learning should be designed within the Zone of Proximal Development (Hall, 2007).

Constructivist classrooms cater for knowledge construction based on prior experiences. Scaffolding and interactive modes are used in constructivist classrooms (Zhou, Li &Nie, 2022). The teacher helps learners to better explain their thinking by providing scaffolding instructions (Analazi, 2016). Marine (2021) says teachers facilitate the educational process by scaffolding and fostering constructive social interactions among learners. Moreover, Samuel (2014) explains that active learning is catered for in constructivist classrooms when learners self-reflect with the guidance of the teacher (scaffolding) where there is a need. Collaboration among learners enables them to effectively construct knowledge.

Conceptual framework

2.1.3.1 Integrated STEM education

Integrated STEM education ensures that learners can make connections in their learning process. According to Mansour and El-Deghaidy’s (2015) study, integration of STEM education is crucial in developing 21st century skills. STEM education can shift the process of teaching and learning from traditional lecture to problem-based teaching. Integration of STEM disciplines ensures that learning is more contextualised, authentic and meaningful (Bryan, Moore, Johnson &Roehrig, 2016). Similarly, Stohlmann, Moore and Roehrig (2012) assert that integrated STEM education is one way to make the process of learning connected and relevant for learners. Furthermore, Kelley and Knowles (2016) illustrate the complexity of a global society and further advise educators to help learners prepare for this shift. Vaquez et *al*. (2013) allude that disciplinary, interdisciplinary, multidisciplinary and transdisciplinary increase levels of integration in the STEM classroom (Table 2.1).

Table 2-1: Proposed way of increasing levels of integration in STEM classrooms (Vasquez et al., 2013)

Form of integration	**Features**
Disciplinary	Concepts and skills are learned separately in each discipline.
Multidisciplinary	Concepts and skills are learned separately in each discipline but within a common theme.
Interdisciplinary	Closely linked concepts and skills are learned from two or more disciplines to deepen knowledge and skills.
Transdisciplinary	Knowledge and skills learned from two or more disciplines are applied to real-world problems and projects, thus, helping to shape the learning experience.

2.1.4 Teachers' perceptions of STEM education integration

2.1.4.1 Teachers deem the integrated STEM education as beneficial to learners

One teacher from Wang, Moore and Roehrig (2011) highlighted that STEM integration helps learners to think independently and to work as a team. In another study, teachers perceived the program of robotics as a useful tool for the teaching and learning of STEM education (Kiaie & Khanlari, 2015). Teachers in Mansour and El-Deghaidy's (2015) study assert that STEM education greatly enhances learners'21st century skills.In a similar context, Brown *et al.* (2011) observed that teachers in their study said STEM education was important for building learners' problem-solving skills, and critical and analytical thinking.Elicitation of teachers' perceptions regarding STEM education integration is vital to successfully implement these disciplines using an interdisciplinary approach because STEM education is significant and enables learners to grow up having a certain set of skills required for the 21st century workforce.

2.1.4.2 Teachers deem STEM education challenging to implement

In a study conducted by Stubbs and Myers (2016), a teacher said that STEM education was just a new concept being used to explain an old phenomenon that had been enacted from a long time ago. Some teachers felt that it was rather difficult to implement STEM education in their classrooms (Khuyen, Bien, Lin, Lin & Chang, 2020). According to Kiaie and Khanlari (2015), the majority of teachers in their study did not perceive robotics as a useful tool to facilitate learning of primary mathematics. However, the authors highlighted that some teachers stipulated that they didnot have adequate knowledge about the administration of robotics itself.

In a study, Bell (2016) noted that teachers had a limited understanding of STEM, that resultedin them not knowing how to effectively incorporate it in the classroom. The findings of the study conducted by Mansour and El-Deghaidy (2015) showed that teachers considered themselves under-prepared for STEM teaching. Brown *et al.* (2011) noted that one of the teachers in their study claimed that there was not enough time for STEM education. Bybee (2013) indicates that the importance of STEM is not clear and distinct. Moreover, the author highlights that most professionals in STEM-related fields lack an understanding of the acronym itself. This study aims to gain more insight on teachers' perceptions and issues underpinning teachers' lack of understanding, with the aim to improve their STEM practices.

2.1.4.3 Teachers' perceptions of STEM education integration in developed countries

An integrated approach explores teaching and learning between\among any two or moredisciplinesin theteaching and learning process (Sanders,2009). Krathwohl (1993) alludes that it also makes provision for a realistic viewof how research is done, accompanied by a useful framework for designing, implementing and evaluating studies. Moreover, it pulls together criteria into a single, easy-to-remember model. Moore, Stohlmann, Wang, Tank, Glancy and Roehrig(2014) highlight that an integrated approach is a combination of disciplines based on connections between subjects and real-world problems. Similarly, Kelley and Knowles(2016) characterise STEM as bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance learning. Honey, Pearson and Schweingruber (2014) give an insight that integrated approach in STEM education is achieved through connections that bring together concepts from more than one discipline, such as connecting the concept of one discipline with the practice of another. An example is applying properties of geometric shapes (mathematics) to engineering design,or combining two practices like conducting an experiment (science inquiry) where the data obtained from the experiment can be applied (engineering design).

This approach is gaining a lot of popularity in developed countries such as United States, South Korea, China and Australia (Bahrum, Wahid & Ibrahim, 2017). Developed countries proposed the teaching of STEM education at secondary schools, and these initiatives should be integrated into one subject (Hooker, 2017). Freeman,MarginsonandTytler(2019) highlight that countries such as United Kingdom, Canada, Australia and, New Zealand and other Western or European countries countered the 'STEM crisis' by having policies in place about STEM skills and effective ways of securing international competitiveness within an increasingly globalised economy. The authors say countries such as Japan, China and South Korea have national science and technology policies and plans regarding the successful integration of STEM disciplines. Rifandi and Rahmi (2019) say that Korea is ranked as one of the best countries in PISA assessments, even though Korean teachers believe that including art in STEM education would help promote learning through convergent thinking, creativity and character building. However, the teachers struggle to manoeuvre around STEM education implementation because of lack of administrative support, difficulty in preparing STEM lessons, increased workloads, and difficulty using new media and experimental equipment.

2.1.4.4 Teachers' perceptions of STEM education in developing countries

Ismail (2018) notes that developing countries need technologies that will reduce poverty and add value to natural resources, that are already used by high-income countries. These technologies are not prevalent in developing countries. Engineering education provides skilled individuals for industries and solutions relevant for local development (Lwakabamba&Lujara, in Ismail, 2018)—Rifandi and Rahmi (2019) identify teachers' perceptions regarding STEM implementation in three developing countries. Saudi Arabian teachers are under-prepared to implement STEM initiatives in their classroom practices, and the majority of them lack comprehension of the 'T' in STEM. Similarly, the teachers' understanding of STEM disciplines is insufficient in Malaysia due to authorities lacking comprehension of these disciplines. Malaysian teachers also highlighted that STEM education because of a lack of motivation, skills, facilities, learner involvement and a responsive environment. Thailand had a massive decrease in the number of life sciences learners, as well as extremely low scores in science and mathematics. The Thai government believes that perceptions held by teachers are key to the successful implementation of STEM education. The results presented by Pimthong and Williams (2018) from their study indicate that pre-service teachers knew about STEM education even though they were unable to fully explain the integration of STEM. Hence, the authors recommended that pre-service teachers be presented with the opportunity to study STEM integration at higher institutions of learning.

The quality of STEM education in African countries is poor due to budget cuts enacted in the 1890s, which resulted in reduced Technical, Vocational, Education and Training (TVET) colleges that could possibly be used to improve STEM learning (Ismail, 2018). Badman and Omosewo (2020) contemplate that classroom integration limitations regarding STEM learning in African countries could be resolved by the use of robotics. Trends in International Mathematics Science Study (TIMSS) and United Nations Educational, Scientific and Cultural Organization (UNESCO) indicate that the performance of African learners in mathematics and science is persistently low (Hooker, 2017). Nigeria is one of the African countries that are ambitious about economic development targets, which require a highly skilled workforce, and STEM education can contribute to this, particularly in the manufacturing sector (Ohize, 2017). South Africa has established national policies focusing on quality education and industry development, termed South African National Development Plan (Freeman, Marginson&Tytler, 2019). However, the authors highlight that The Digital Education Enhancement Project(DEEP) pilot show that there is a limited range of new technologies adopted in professional development. Furthermore, South Africa has the National Science and Technology Forum, which uses SET (Science, Engineering and Technology) as a method of integrating STEM disciplines (Williams, 2011).

2.1.5 The integrated STEM education

2.1.5.1 Integration approaches toSTEM education

2.1.5.1.1 Disciplinary approach

Vasquez, Sneider and Comer (2013) say the disciplinary approach involves concepts and skills learned separately in each discipline. Within this approach, Aguilera, Lupianez, Vilchez-Gonzalez and Perales-Palacios (2021) posit that science, technology, engineering and mathematics are incorporated in the same activity, but each discipline has its own learning goals, and one STEM discipline is dominant over the others (disciplinary\nested).

2.1.5.1.2 Interdisciplinary approach

This approach is the "introduction of closely linked concepts and skills from two or more disciplines with the aim of deepening understanding and skills'' (English, 2016:1). STEM education in schools should be enacted through interdisciplinary curricula where teachers of the disciplines in question come together to discuss projects that can be produced from topics of their respective disciplines, which learners undertake to integrate two or more disciplines in STEM classrooms (Holmlund, Lesseig & Slavit, 2018). Similarly, STEM initiative is an educational approach in which the content of the disciplines may be addressed as ideas integrated into the process of real-world problem solving (interdisciplinary). This approach attempts to integrate the contributions of several disciplines and seeks harmonious relationship among various disciplines (Kaufman, Moss & Osborn, 2003).

2.1.5.1.3 Multidisciplinary approach

The approach "includes core concepts and skills being taught separately in each discipline but housed within a common theme'' (English, 2016:1). Freeman *et al*. (2019) observe that science, technology, engineering and mathematics education should be guided by a multidisciplinary approach. Hsu and Fang (2019) note that in STEM education, the content of the disciplines involved may be addressed as a group of isolated ideas (multidisciplinary). This approach is highly recommended for use when learners have a low level of STEM literacy associated with teaching methods such as inquiry-based learning or engineering design (Aguilera et *al*., 2021). Moreover, inquiry-based teaching, together with the adoption of a centred approach, and informed by project-based activities, is core to the successful implementation of STEM education in the classroom (Wood, 2017). STEM education was designed to collectively address the four disciplines through problem-based learning (Neslihan & Banu, 2020). Rifandi and Rahmi (2019) claim that the best approach to teaching STEM disciplines is the integrated approach because, unlike the embedded, SILO and many other approaches, it eliminates boundaries between the components of STEM. Kennedy and Odell (2014) highlight that STEM education is a meta-discipline and an integrated effort designed to remove traditional barriers to teaching. This enhances innovation and applied processes to develop solutions to real-world problems.

2.1.5.1.4 Transdisciplinary approach

Aguilera et *al.* (2021) observe that the transdisciplinary approach implies setting goals that transcend the STEM disciplines. It focuses on the problem to be solved. This approach acknowledges that "knowledge and skills from two or more disciplines are applied to real-world problems and projects to shape the total learning experience'' (English, 2016:1). Unlike the interdisciplinary approach that begins with disciplines, the transdisciplinary approach starts with the issue or problem, and through the process of problem-solving, brings along the knowledge of those disciplines that contributes to a solution (Kaufman et *al.*, 2003).

2.1.5.2 Teachers are not well prepared to incorporate integrative STEM education

Findings from a study conducted showed that science and mathematics teachers lack pedagogical knowledge as far as integrative STEM education is concerned (Mansour &EL-Deghaidy, 2015). Brown *et al.*(2011) pose the question of whether STEM education is only plausible when the four disciplines are incorporated together or if Sander (2009) was right by stipulating that STEM has always been in place but just taught in different classes. In a study conducted by Brown *et al.* (2011), participants were asked if the integrated STEM classroom would be beneficial to learners, and some of the teachers responded with 'no'. It has been highlighted by Mansour and El-Deghaidy (2015) that after completing educational programs, teachers teach their subject domains independently and individually, which shifts the focus of having STEM education in an integrated manner. This shows teachers' little to no knowledge of STEM education and its integrative nature.

2.1.5.3 Empirical studies that were carried out on perceptions and practice of STEM education in science/Life science classrooms

Guzey, Ring-Whalen, HarwellandPeralta (2019) analysed life sciences teachers' enactment of three design-focused life science units together with learners' performances over a period of three years. They found that explicit engineering integration in instruction resulted in higher learning gains in science and engineering. Additionally, there was evidence that points out that there are positive effects of implementing the engineering design-based science unit on learners' performance (Guzey, Moore, Harwell & Moreno,2016). According to Adkins, Rock and Morris (2017), integrating STEM education disciplines in science classrooms requires creative art to foster attention and sharpen and encourage critical thinking.

Wood (2017) advises that the department of Life Science should move towards inquiry-based teaching using the learner-centred approach informed by project-based activities. Additionally, Alcena-Stiner and Markowitz (2020) highlight that the Life science learning centre aims to expose learners to hands-on, experiential learning activities across Life sciences. According to Pollard, Hains-Wesson and Young (2018), a senior academic in Life Sciences, teachers need to shift from the traditional teaching method to an interdisciplinary method of teaching. However, the authors highlight that senior academics acknowledge the struggles that come with this method.

Teachers differ in terms of how they integrate STEM education in the classroom. Kennedy and Odell (2014) assert that learners are engaged in STEM education through inquiry, incorporating engineering design and technology in science and mathematics curriculum, and by ensuring that learners experience knowledge that is being disseminated through the design of projects in the classroom. In a similar context, Stohlmann et *al*. (2012) note that it is essential that the teaching and learning of these disciplines is based on prior knowledge. The authors also highlight that the learning of STEM disciplines should be based on the social construction of knowledge. Construction tools need to be in place for proper implementation of STEM (Stohlmann et *al*., 2012).

There are emerging challenges during the implementation of STEM education in the classroom. Bybee (2013) observes that the inclusion of technology and engineering poses major challenges. Little is known about how to effectively integrate STEM disciplines in one lesson, and the extent to which integrated STEM can foster learners' creativity, support the development of higher order thinking, or positively impact their epistemological belief and views about science learning (Hsu & Fang, 2019). Bybee (2013) highlights that significant challenge centres around the introduction of STEM-related issues and further developing competencies to address such issues that learners will be confronted with as citizens at a later stage.

2.1.5.4 STEM education practice in the classroom

The practice of STEM education in the classroom is implemented by encouraging multiple pathways to solving problems through scaffolding (Alanazi, 2016). Arlinwibiwi, Refnawati and Cartowagiran (2020) stipulate that the implementation process in Indonesia is initiated by selecting materials and appropriate class where the teacher searches for learners' capacities in various subjects that are closely related to the project at hand. The authors further highlight that the teacher is responsible for ensuring the learners' abilities are sufficient to sustain them during STEM education-related activities. Learners are grouped accordingly to design the model with the provided materials upon the chosen pathway to solve a particular problem. In Japan, the scratch application loaded on tabletsis used to teach STEM education whereby elementary school learners are prepared to make conditional statements and to solve the problem displayed on the screen (Yamamori, 2019). The application aims to prevent the 'frog' from eating child insects displayed on their screens. Wells (2016) explains ''PIRPOSAL'' as a term that outlines how STEM education should be practised in the classroom. The PIRPOSAL model stands for problem identification, ideation, research, potential solution, optimisation, solution evaluation, alteration, and learned outcome phase (Wells, 2016). The first step to the practice of STEM is 'problem identification', where learners recognise and define a problem and suggest reasons why the problem at hand requires engineering and technological solutions. 'Ideation phase' is the phase where learners group themselves together according to their different levels of understanding to discuss the problem and propose possible design solutions to the problem. A 'research phase' is informed by investigations of prior solutions which seemed promising to the acquisition of new knowledge.'Potential solution phase' is the analysis of potential viable solutions from the ones that emerged during the ideation phase. 'Optimisation' of potential designs is guided by large-scale questioning and experimentation of how well the selected designs will function. 'Solution evaluation' is where learners test the design concepts through actual trials and observations. 'Alteration phase' is about identifying, redesigning and retesting. Then, the 'learned outcome phase' involves learners communicating graphically, verbally and in writing about what they have come to know and are able to do as a result of their engagement.

Integration of STEM content requires a multidisciplinary and interdisciplinary approach, and content integration involves an integrated curriculum with equal attention to two or more STEM disciplines. Additionally, curriculum integration with focus on content knowledge requires explicit integration of concepts from more than one discipline, translation of representations from different STEM disciplines, connections among learning goals, principles, concepts and skills across discipline-specific domains (Thibaut, Ceuppens, De Loof, De Meester, Goovaerts, Struyf, Boeve-de Pauw, Dehaene, Deprez, De Cock, Hellinckx, Knipprath, Langie, Struyven, Van de Velde, Van Petegem, &Depaepe, 2018). Neslihan and Banu (2020) say that initiating STEM practice in the classroom starts with activities that address real-life problems and present them to learners. The activities should integrate two or more disciplines. The whole process is learner-centred, with the teacher merely facilitating the educational process. The activity should be adapted to the characteristics of a project tackled through inquiry-based learning. The authors highlight that group work should be configured during the activity. These activities should be accompanied by constant redesigning and design evaluation.

Kelley and Knowles (2016:8) summarise how science and engineering practices are carried out in STEM classrooms, as illustrated in Table 2.2. Science practice begins with a phenomenon which requires models to develop explanations for it. A necessary approach is employed in the laboratory to explore scientific concepts, followed by thorough analysis and interpretation of data obtained from the scientific investigation. Relationship among variables is distinguished where the initial scientific theory is rejected or accepted based on the arguments that can be backed by evidence to emphasise the scientific practice in question. However, engineering practice begins with a problem that requires an engineering solution. Models are explored and analysed to determine if they can counter the problem. Engineering investigation is carried out to identify the challenges and criteria of the set design, which will then be tested. These tests are followed by thorough analysis and interpretation to locate optimal design solutions. Design solutions are explored through a relevant approach to solve the engineering problem at hand through theincorporation of scientific knowledge.

Table 2-2: Comparison of science and engineering practices (Kelley & Knowles, 2016: 8)

Science practices	Engineering practices
Begins with a question about a phenomenon. Uses models to develop explanations about natural phenomena.	Begins with a problem, need, or desire that leads to an engineered solution. Use models and simulations to analyse existing solutions. Engineering investigation to obtain data

Scientific investigation in the field or lab using a systematic approach.	necessary for identifying criteria and constraints and to test design ideas.
Analysing and interpreting data from scientific investigations using a range of tools for analysis (tabulation, graphical interpretation, visualisation, and statistical analysis) locating patterns.	Analysing and interpreting data collected from tests of designs and investigations to locate optimal design solutions.
Mathematical and computational thinking are fundamental tools for representing variables and their relationships. These ways of thinking allow for making predictions, testing theory, and locating patterns or correlations.	Mathematical and computational thinking is integral to design by allowing engineers to run tests and mathematical models to assess the performance of a design solution before prototyping.
Constructing scientific theory to provide explanations is a goal for scientists and grounding the explanation of a phenomenon with the available evidence.	Constructing designing solutions using a systematic approach to solving engineering problems based on scientific knowledge and models of the material world. Designed solutions are optimised by balancing constraints and criteria off existing conditions.
Arguments with evidence are key to scientific practices, providing a line of reasoning for explaining a natural phenomenon. Scientists defend explanations, formulate evidence based on data, and examine ideas with experts and peers' understandings.	Arguments with evidence are key to engineering for locating the best possible solutions to a problem. The location of the best solution is based on a systematic approach to comparing alternatives, formulating evidence from tests, and revising design solutions.

2.1.5.5 STEM teaching methodologies

2.1.5.5.1 Inquiry-based teaching

Aguilera *et al.* (2021:5) points out that inquiry-based teaching "is a process that, from the identification and analysis of a problem, allows one to understand the different way in which scientists carry out their work; evaluate the potential of observations; develop the ability to formulate researchable questions and produce hypotheses; use different types of data to search for patterns and confirm or reject predictions; build and defend models and arguments; consider alternative explanations; achieve a better understanding of the provisional and evolutionary nature of Science; and show the relationship between Science and human activity, and the context and the culture in which it develops and is used''. Similarly, Toma and Greca (2018:1385) describe this teaching methodology "as a set of activities that seek to assimilate the learning of science and the processes and strategies that scientists follow to resolve real-world problems".

2.1.5.5.2 Project-based teaching

"Project-based learning directs the teaching–learning process thereof'' (Aguilera *et al*. 2021:5). PBL drives the process of teaching and learning towards the production of a report, device or another type of product that represents the solution. Duke, Halvorsen and Strachan (2016) assert that the popularity of project-based teaching has been driven in a large number of STEM schools and programs. Kingdon (2007) highlights that the most commonly used teaching approach in India is project-based teaching. Han, Yalvac, Capraro and Capraro (2015) observed teachers during their lessons. He found that the classroom enactment of the project-based education did not convey the understanding they initially portrayed in the preceding session of interviews. As learners engage with the STEM-PjBL approach, they mirror the processes used by scientists and engineers to solve real-world problems by actively constructing new knowledge (Flores, Knaupp, Middleton & Staley, 2002).

2.1.5.5.3 Problem-based teaching

Aguilera *et al*. (2021:5) posit that problem-based teaching "Focuses on analysing the problem and the knowledge necessary to solve it. So, in problem-based learning, the solution of the problem can be part of the process, but the focus is on the management thereof, not on obtaining a clear and delimited solution as occurs in project-based learning." Lou, Tsai and Chung (2017) refer to problem-based teaching as one concerned with setting the goal first, then making a plan, carefully designing the guidance problems, evaluating the plan, formulating the professional plan, and lastly, managing the process.

2.1.5.5.4 Engineering design

Engineering design can be defined as "a process that starts with the identification of a problem specifying its limitations; it continues establishing those criteria and restrictions that will guide the design; and it ends with a practical solution to the problem. This design process is generally creative, iterative, and open'' (Aguilera *et al*. 2021:6). Shahali, Halim, Rasul, Osman and Zulkifeli (2016) say engineering design generates an ideal context to connect science, mathematics and technology in real-world situations, with the aim of increasing learners' interest towards STEM disciplines. Engineering provides the educational context ,which establishes how to solve the problem proposed in this educational experience.

2.1.6 Challenges of integrated STEM education

2.1.6.1 STEM education poses challenges in the implementation process

The implementation of STEM education in the classroom comes with certain challenges (Bybee, 2013). Mansour and EL-Deghaidy (2015) highlight that one of the most significant issues facing teachers is recognising STEM education for what it really is. Bybee (2013) says STEM education is regarded as a conglomerate term rather than an integrative one. The other challenge teachers encounter is incorporating the 'T' in their classroom practices (Bybee, 2013). To add, Hsu and Fang (2019) note that there are only a few research studies that have been conducted on teacher preparation for STEM teaching.

Moreover, STEM is often mistaken for science and mathematics education only, disregarding the other two disciplines (Bybee, 2010). Ramli and Talib (2017)observed, through the eyes of the participants, that lack of motivation, poor syllabus interpretation skills, inadequate facilities, poor learner involvement and an unresponsive environment are barriers encountered by several teachers when faced with the implementation of STEM. Additionally, it was observed by Nadelson et *al.* (2013) that a foundation of STEM at an early age is a crucial factor. Brown *et al.* (2011) highlight that participants in their study felt it pointless for STEM subjects to be integrated because not all learners were heading that direction. This study sought to identifychallenges encountered by teachers in the implementation process, and how STEM fields can eradicate or counter those challenges.

2.1.6.2 STEM education suffers identity problem

Bybee (2013) points out that STEM education presents several challenges. Bybee (in Giamellaro and Siegel 2018) added that STEM is an academic discipline that is not well defined. People do not understand the actual identity of STEM education, as many misinterpretations arise when the term is used. The goal of STEM education needs to be clarified and well-defined for instructional purposes (Bybee 2013). Stohlman*et al.* (2012)

note that quality STEM education is essential for the future of learners. However, teachers need to gain pedagogical knowledge of integrating STEM education into their classroom practices (Mansour & El-Deghaidy, 2015). Giamello and Siegel (2018) put forward that STEM education is a concept that is not clearly defined for the purpose of instruction. Furthermore, Timms, Moyle, Weldon and Mitchell (2018) agree that the STEM curriculum is unbalanced, discouraging learners and teachers. It is paramount for the operation of STEM in schools and its identity in the classrooms to be fully understood by all parties involved, through a wide range of research.

2.1.6.3 Challenges encountered in STEM education

Besides, the issue of identity is the challenge experienced by individuals involved therein. Reyes (2011) notes that women of colour experience challenges in STEM fields. The researcher also points out that teachers of a certain colour and individuals who were transferred from community colleges to universities to practice STEM majors are ill-treated because they are deemed inadequate prepared for STEM majors(Reyes, 2011). The other issue is that teachers need to be better equipped to teach these disciplines in an integrated manner (Mansour& El-Deghaidy, 2015). Ramli and Talib (2017) indicate that these teachers lack skills for implementing STEMinits' integrative nature. There are six barriers identified by Ramli and Talib (2017): poor motivation, poor syllabus integration, inadequate skill, inadequate facilities, learners' poor involvement, and an unresponsive environment are barriers encountered by several teachers when faced with implementation of STEM. Challenges in the implementation of STEM also arise with individual teachers in the field.

2.1.6.4 Foundational knowledge of STEM education can be a hindering\promoting factor

In a study, Nadelson *et al*. (2013) observed that learners' foundational knowledge of STEM at an early age can be a promoting or a hindering factor. Learners need to be taught STEM subjects from as early as elementary school. Participants in a study conducted by Brown *et al.* (2011) content that it is pointless to have STEM education as it may prove useful to other learners not intending to pursue STEM majors for their careers. They highlighted that participants deemed STEM education implementation too demanding for both teachers as well as learners. It is paramount for learners to be introduced to interdisciplinary STEM at elementary school because it gets difficult for learners to shift from learning science as a specific domain on its own to having to learn the four disciplines integrated. It goes without saying that it is essential for learners to start receiving the basics of STEM from elementary school so that it grows with them and it becomes less of a problem in high school and at tertiary level.

2.1.7 Perceived opportunities for integrating STEM education

According to Weis, Eisenhart, Cipollone, Stich, Nikischer, Hanson, Leibrandt, Allen and Dominguez (2015), STEM education presents learners with varying skills which shape them to be responsible citizens. Similarly, Li (2014) asserts that the emerging fields of STEM education present fascinating opportunities because these fields have been widely recognised as crucial to a nation's prosperity and security worldwide. Scientific and technological literacy delivered through the integration of STEM teaching and learning offers enormous potential for all learners (Sanders, 2009).

Fitzallen (2015) notes that effective and proper implementation of science, technology, engineering and mathematics education in recent times is perceived as an opportunity for innovation and change. In a similar context, improving science, technology, engineering and mathematics education is recognised as pivotal to nations' long-term economic growth and security (Xie, Fang &Shaumann, 2015). Moreover, Mohr-Schroeder, Bush and Jackson (2018) highlight that a thorough instruction in these disciplines produces citizens who are capable of separating personal beliefs from scientific matters.

2.2 Previous empirical studies

2.2.1 Findings from empirical studies about teachers' perceptions of STEM education

Wang *et al*. (2011) found the following in their study regarding teachers' perceptions of STEM education:Firstly, problem solving process is a major component ofSTEM education integration. Secondly, teachers of different STEM disciplines have different perceptions about the integration of STEM education, which ultimately leads to different classroom practices. Thirdly, teachers claim that technology in the four disciplines of STEM is the hardest to integrate. Lastly, teachers acknowledge the need to add more content knowledge in their STEM integration. Margot and Kettler (2019) found that the majority of teachers reported various barriers of a pedagogical, curriculum, and structural in nature; as well as concerns about their learners, assessment, and lack of teacher support. These authors also highlight that the teachers claimed that support that would highly improve their effort to implement STEM education included collaboration with peers, quality curriculum, support from the district, prior experience, and effective professional development programs (Margot & Kettler, 2019).

Khuyen *et al.'s* (2020) results indicated the need to design effective teacher professional development programs to sustain STEM education. Altan and Ercan (2016) agree that professional development programs are necessary because they positively affect teachers' views of STEM education. They propose that in-service training programs should be developed for teachers to raise awareness of the necessity of STEM education integration, and to enhance their competencies in planning, implementing and evaluating STEM instruction (Altan & E.can, 2016). They also found that novice teachers had more positive views on STEM education in terms of comprehension of STEM education and assessing STEM competencies. However, there were no statistically significant differences in teachers' difficulties among teaching experience groups, although their educational background differed according to their educational background, STEM education and STEM education competencies but equal difficulty in the implementation of integrative STEM education (Khuyen et *al*., 2020). Bell's (2016) findings indicated that teachers' knowledge deficiency results in limited learning for learners.

2.2.2 Findings from empirical studies about STEM education practice intergration

The motivation for integrated STEM disciplines at the secondary school level nationwide was a response to vocational needs and economic aspirations in the USA (Williams, 2011). Wang *et al*. (2011) note that technology has proved to be the most challenging aspect of STEM education integration. The authors highlight that the most important key to the integration of STEM education is the process of problem-solving. Ismail (2018) says the integrative STEM approach undermines technology training. Collaboration among the STEM community is required for developing and implementing STEM activities (Ozturk, 2021) because integrated STEM education is one way to make learning more connected and relevant for learners

(Stohlmann *et al*., 2012). The integration of STEM disciplines varies with reference to multidisciplinary, interdisciplinary and transdisciplinary approaches (English, 2016).

Goodpaster, Adedokum and Weaver (2012) noted that participants encountered resistance when they sought to change their teaching practices during STEM integration. One teacher mentioned that there was a challenge of introducing integrative-type learning when learners were used to more conventional approaches (Goodpaster*et et al*., 2012). The practice of STEM education in the classroom using scratch application to enhance learners' skills was much easier as scratch application presents learners with problems that need to be solved, and presents learners with the opportunity to work on tasks that make them think more according to the given problem (Yamamori, 2019). The practice of STEM education through robotics showed a significant positive effect on learner outcomes. It allowed learners to apply science skills while affording teachers the ability to develop open-ended and extended-inquiry (Rosicka, 2016).

Kennedy and Odell (2014)observed that the practice of STEM includes rigorous mathematics and science curriculum instruction. One should integrate technology and engineering into the science and mathematics curriculum through engineering design and problem-solving (scientific/engineering) processes, centred around identifying a problem, brainstorming solutions, carrying out a prototype, evaluating and redesigning the prototype to develop a practical understanding. Promoting inquiry is the process of asking questions and conducting investigations to develop a deep understanding of nature and the designed world. This can be achieved through grade-appropriate materials, hands-on, minds-on, and collaborative approaches to learning. Addressinglearners'outcomes and reflecting on the most current information andunderstandings in STEM fields by providing opportunities to connect STEM educators and their learners with the broader STEM community and workforce is encouraged. They further highlight that it is crucial to present learners with interdisciplinary, multicultural, and multiple perspectives to demonstrate how STEM transdisciplines (Kenedy& Odell, 2014).

2.2.3 Findings from empirical studies about the challenges of STEM education

Teachers have varying difficulties regarding STEM disciplines. These include a lack of digital technology resources, a STEM curriculum which is not clearly defined for instructional purposes (Wang *et al*., 2011). The learning of science engineering poses as a major challenge. Berland (2013) says problem-based challenges emphasize science and mathematics learning goals whiledesign-based challenges target both disciplines. STEM-based approach lacks clarity for instruction and undermines technology training (Ismail, 2018). The worst and most pressing challenge of STEM education is recognising what STEM is and what it is not (Portz, 2015). The other pressing challenge is the lack of interdisciplinary knowledge, poor teaching methods, and practical constraints and beliefs about effective STEM education (Le *et* al., 2021). Landicho (2020) noticed that lack of time, financial constraints, heavy workload and lack of exposure were some of the challenges identified by his respondents. Ozturk (2021) found that teachers haddifficulties in integrating diverse disciplines and technologies into their STEM activities. The operationalisation of STEM remains a great challenge as educators lack comprehension of STEM education (Mpofu, 2019). The introduction of learner-centred learning and inquiry-based approaches across SSA policy posed real challenges to teachers, often due to high learner-teacher ratios (Tikly*et al*., 2018). A strategic, holistic approach is required to successfully tackle these challenges.

2.2.4 Findings from empirical studies about opportunities for integrated STEM education

According to Weis *et al*. (2015), STEM education affords learners with varying skills. Fitzallen (2015) notes that an effective and proper implementation of science, technology, engineering and mathematics education in recent times is perceived as an opportunity for innovation and change. Similarly, Li (2014) asserts that the emerging fields of STEM education affordfascinating opportunities crucial to a nation's prosperity and security worldwide. Sanders, (2008) alluded that scientific and technological literacy delivered through integration of STEM teaching and learning offers enormous potential for all learners. Improving science, technology, engineering and mathematics education is recognised as pivotal to nations' long-term economic growth and security (Xie *et al*., 2015). Thorough instruction in these disciplines produces citizens who are capable of inventing practical solutions to real-world problems (Mohr-Schroeder *et al*., 2018).

2.3 Summary

This chapter reviewed the literature within four sections. The first section was about teachers' perceptions regarding STEM education. This section was further divided into four sub-headings. Firstly, teachers deemed the integration of STEM education as beneficial to learners. Secondly, teachers perceived STEM education as confusing and difficult to implement effectively. Thirdly, teachers' perceptions about STEM education integration in developed countries. Lastly, teachers' perceptions about STEM education integration in developing countries.

The second section was about STEM education and its integrative nature. This section was divided into four sub-headings: integrated STEM education as vital to the future of learners; secondly, teachers not being well-equipped to implement STEM education; thirdly, exploring empirical studies carried out on perceptions and practice of STEM education in science and the practice of STEM education in the classroom; and integration approaches forSTEM education.

The third section was about the challenges encountered by teachers during the integration of STEM disciplines. The section was divided into four sub-headings: first, STEM education challenges in the implementation process; second, STEM education's identity crisis; third, individual teachers' challenges in the STEM field; and last, foundational knowledge of learners being a challenge to the teaching and learning of STEM education; finally, perceived opportunities of STEM education integration. The next chapter is about the methodology used in the study.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The previous chapter reviewed literature within four sub topics, i.e. teachers' perceptions of STEM education, the integrative nature of STEM education, challenges teachers encounter during STEM education implementation, and the perceived opportunities of STEM education integration. Moreover, it drew on empirical studies carried out on perceptions and practices of STEM education in science classrooms. This chapter outlines the research methodology used. It specifically outlines the research paradigm, approach, design, population and sampling, data collection instruments, trustworthiness, data collection procedures, data analysis, and ethical issues relating to the study.

3.2 Research approach

There are various approaches researchers can employ to explain their studies, such as qualitative, quantitative and mixed method approaches. The approach that was chosento explain the study was qualitative approach. A qualitative approach is a systematic enquiry into social phenomena in natural settings (Tehereni, Martimianakis, Hayes, Wadhwa & Varpio, 2015). Babchuk (2018) defines qualitative research as an umbrella term used to designate a family of various approaches. This approach was relevant for the study because it entails analysis of words and allowed the researcher to fully comprehend the case under study, which was the integration of STEM education. Merriam and Tisdell (2015) highlight that updated and expanded qualitative research provides an essential guide to understanding a phenomenon. Wadawi, Herbst and Bresler (2011) assert that the advantage of qualitative approach is that it makes it easier to observe and comprehend the level of risk, and one can easily evaluate the most important areas of risk. The disadvantage of this approach is that it is possible that the reality is not defined correctly because of the subjectivity of the researcher (Wadawi *et al*., 2011). Baber (2015) explored the dilemmas facing STEM education integration successfully using qualitative approach. Bahrum, Wahid and Ibrahim (2017) and Widowati, Purwanto and Akbar (2021) conducted their study using a qualitative approach.

3.3 Research paradigm

Paradigms are described as frameworks that guide thinking throughout the research process (Ling & Ling, 2017). The authors highlight several paradigms that are employed in education research, such as positivist, neo-positivist, pragmatic, transformative, interpretive and super complexity paradigms. Kivunja and Kuyini (2017) note that a paradigm is a lens through which a researcher looks at the topic under investigation. This study was underpinned by the interpretive paradigm. Interpretive paradigm was suitable for the nature of the study and the research questions that needed to be answered. STEM education, in an integrative way requires learners to be at the forefront of their learning process and construct knowledge on their own by drawing on prior experiences and observing how real-world products are done to make models of real-world products in the classroom. The interpretive paradigm is based on the premise that understanding is possible based on observation and interpretation (Ling & Ling, 2017) and allows numerous methodologies for the construction of knowledge (Goulding, 1999). Ponelis (2015) successfully explored research in doctoral studies using an interpretive paradigm. Similarly, Alvermann and Mallozzi's (2010) and Permanasari*et al*. (2021) research was explained through an interpretive paradigm as well.

3.4 Research design

Research design is a strategic framework for action that serves as a bridge between research questions and the execution of the research (Durrheim, 2006). There are various research designs that inform the chosen research approach, such as case-study, ethnography and grounded theory. An exploratory case study was used to get various insights about the case under research. The case study design is a methodology that allows researchers to study complex phenomena within their context (Baxter & Jack, 2008). Yin (2003) states that exploratory case study is a study used to explore situations in which the interventions being evaluated have no clear or single set of outcomes. STEM education, as an integrating approach, is pursued in this study. In terms of boundary, this case study was conceptually and place bound as only Life sciences teachers in circuit 10 under the Thabo Mofutsanyane district took part in the study. Furthermore, this design was suitable for the study as it allowed the researcher to elicit individual teachers' perceptions and practices to comprehend their stance on integrative STEM education. Guetterman and Fetters (2018) assert that case studies have a tradition of collecting data to comprehensively understand the case under study, which also made this design relevant for the study. The advantage of case study design is that raw data is available for independent inspection (Baxter & Jack, 2008). Mansour and El-Deghaidy (2015) successfully pursued STEM education implementation utilising case study design. Wang, Choi, Benson, Eggleston and Weber (2020) conducted a study about teachers' role in fostering pre-scholars' computational thinking using explorative case study. Rajala and Tibdsrom (2017) employed single exploratory case study as their design.

3.5 Population and sampling techniques

The study population consisted of teachers who teach life sciences from Thabo Mofutsanyana District, circuit 10 in the Free State, QwaQwa. The teachers were purposefully sampled. Creswell and Guetterman (2019) observe that purposeful qualitative sampling helps develop a detailed understanding of the phenomenon under study because one gets to select a population that is helpful to the study of the phenomena. Three life sciences teachers from three different schools in Thabo Mofutsanyane District who taught grades 10-12 and had at least one year of teaching experience were purposefully selected and interviewed, their teaching observed, and their lesson plans analysed. The interview centred on their perspectives on science, technology, engineering and mathematics education and classroom practices in life sciences classrooms.

3.6 Data collection instruments

Data collection instruments allow us to systematically collect information about our objects of study (Elmusharaf, 2013).

3.6.1 Semi-structured interviews

Semi-structured interviews were used to collect data from the participating teachers. Longhurst (2003) highlights that a semi-structured interview is a verbal interchange where one person, the interviewer, attempts to extract information from another person by asking questions. The researcher interviewed three teachers from three different schools from Thabo Mofutsanyana District in QwaQwa, and each teacher was interviewed for about 50 minutes. The advantage of interviews is that they provide useful information, especially if you cannot directly observe the participants. They also allow the researcher to ask specific questions to elicit information, which then permits participants to provide detailed information. The disadvantage of interviews is that they provide information that is only filtered through the interviewer's views (Creswell & Guetterman, 2019). Baber (2015) employed interviews to generate data in their study. Flores *et al.* (2002) used interviews to collect data in their research. This study required one to get a deeper understanding of teachers' perceptions. Thus, interviews were more appropriate because they gave the researcher an opportunity to elicit teachers' perceptions. I abided by the Covid-19 regulations that were in place. I ensured the wearing of masks at all times during the observation period, sanitisation of learners' and teachers' hands, and social distancing.

3.6.2 Lesson observation

One instrument used for data generation was an observation checklist, as I observed how the teachers facilitated STEM integrative lessons. According to Elmusharaf (2013), observation is an instrument that involves watching and recording the behaviour and traits of living beings. I designed an observational protocol to record descriptive and reflective field notes. Creswell and Guetterman (2019) indicate that the advantage of observation includes the opportunity to record information in a particular setting. This made this instrument relevant for the study as I could make notes of the participants' methods of teaching pertaining to STEM education implementation. However, the disadvantage encountered during lesson observations was limited access to schools. As a result, I could not observe the teachers during the lessons for two consecutive days as anticipated initially. Moreover, each teacher was only observed once on the day that the principal and the teacher in question had agreed upon. The motivation behind the observations was to further comprehend teachers' teaching strategies and methods with regard to the integration of STEM education. Table 3.1 shows a summary of research questions and the specific instruments used to generate data.

3.6.3 Document analysis

The other instrument used to analyse data was use of documents. Bowen (2009) notes that document analysis is the systematic procedure whereby printed and electronic records are reviewed and evaluated. The researcher reviewed lesson plans to corroborate participants from semi-structured interviews and practical lesson observations. The advantage of analysing documents is that they are exact because they include how the actual events will occur (Bowen, 2009). The other advantage of document analysis is that they provide stability because the presence of the researcher does not alter what the documents capture (Bowen, 2009).

Table 3-1: Summary of research questions and their data generation instruments

Research questions	Instruments to be used	Data supply
What are the teachers' perceptions of STEM education integration in life sciences classrooms?	Interview	Participants
How do teachers integrate STEM education in life sciences' classrooms?	Observations & documents	Researcher& teachers
What are the challenges experienced by teachers when integrating STEM education in life sciences' classrooms?	Interview	Participants
What are the perceived opportunities for integrating STEM education in life sciences' classrooms?	Interview& observations	Participants& researcher

3.7 Trustworthiness

Member checking, expert review and analysis of documents such as lesson preparations and learners were utilised. The components of trustworthiness, credibility, dependability, confirmability and transferability, were measured for credibility of the collected data.

3.7.1 Credibility

Credibility establishes whether or not the findings of the research represent plausible information and are drawn from the participants' original views (Graneheim & Lundman, 2004). This study established the rigour of the inquiry by employing triangulation and member checking.

According to Onwuegbuzie and Leech (2007), triangulation involves using multiple and varied sources, methods, investigators and theories to obtain data that support itself. The type of triangulation strategy that was employed is data triangulation, where I used various research instruments such as semi-structured interviews, lesson observations and document analysis to collect data.

3.7.2 Dependability

Dependability refers to the stability of the collected data over time (Bitsch, 2005). The dependability of this study was achieved by the use of an audit trail which involved the examination of the inquiry process and product to validate data (Bowen, 2009). Dependability was obtained by comparing the semi-structured interviews and practical lesson observation notes to generate codes, as well as using actual participant statements as proof of original data.

3.7.3 Confirmability

Confirmability refers to the extent to which results can be confirmed or corroborated by other researchers, and the certainty that the findings are clearly drawn from the data (Tobin &Begley, 2004). For this study, triangulation was used to confirm that the findings were derived from the collected data. The data was stored safely and would be made available upon request. Quotes and materials from various teachers were used to indicate that data was actually drawn from participants.

3.7.4 Transferability

Transferability refers to the ability of the data to be comparable and have external validity (Tobin & Begley, 2004). This criterion of trustworthiness was achieved by using a uniform method of selecting participants, and detailed transcripts are available to show whether or not the data is comparable and can be generalised to other contexts.

3.8 Data collection procedures

3.8.1 Telephonic interviews

I drafted a list of interview questions to ask the participants, together with the consent forms that informed the participants of their responsibilities. I went to the respective schools to request the principals' permission to conduct the study and handed those teachers I was going to work with, the consent forms upon the agreement of the principal and informed them about the dates of the actual extraction of data. I called the participants, one after the other, and interviewed them telephonically based on the list of questions I had drafted, while recording the conversation with their consent. I probed more on some questions with unclear responses from the participants. All three participants were interviewed within one day.

3.8.2 Lesson observations and document analysis

I observed the participants in their classrooms the following week after the interviews. The observation period took approximately 50 minutes for each teacher. All three teachers were observed on three consecutive days. During the observation period, I analysed teachers' lesson plans to check how they were structured in relation to STEM education. The learners' activity books and scripts were also analysed during the observations in relation to the reviewed lesson plan for that particular lesson.

3.9 Data analysis

Data analysis is a process of systematically applying statistical and logical techniques to explain data (Bradley, Curry & Devers, 2007). Thematic content analysis was used to analyse data. Additionally, descriptive analysis was employed for the biographic data of the participants, whereas thematic analysis was used for analysing the data extracted by generating themes. These themes were used to arrange and analyse data from interviews, lesson observations and documents effectively. Creswell and Poth (2018) note that thematic analysis of data provides a better understanding of a complex case. In this study, I usedBabchuk's (2018) five-step guide to thematic analysis, as summarized in figure 3.1 below.

3.9.1 Data analysis for interviews

To successfully analyse the data, the researcher compiled the transcripts, field notes taken during practical lesson observations and review of documents. This brought the researcher closer to the data in terms of familiarising oneself with the data. The segments of data were identified in line with the research questions. Similarities among these segments induced categories which were assigned codes that helped to deduce themes.

Step 1: Assembling materials for analysis

Step 2: Re-familiarising oneself with the data

Step 3: Identifying segments or units of data responsive to research questions

Step 4: Generating categories and assigning codes to them

Step 5: Describing and classifying codes into themes

3.9.2 Data analysis for lesson observations and documents

To successfully analyse the data, the researcher compiled the transcripts, field notes taken during practical lesson observations and reviewing of documents which brought the researcher closer to the data in terms of familiarising oneself with the data. The segments of data were identified in line with research questions. Similarities among these segments revealed categories which were assigned codes that helped to induce themes.

Step 1: Assembling materials for analysis

Step 2: Re-familiarising oneself with the data

Step 3: Generating categories and assigning codes to them

Step 4: Describing and classifying codes into themes

Step 5: The data was cross-checked by the participants for accuracy and resonance with their experiences. An expert can also cross-check the data for possible problems in the study. Figure 3.1 shows the process that was followed to analyse the data.

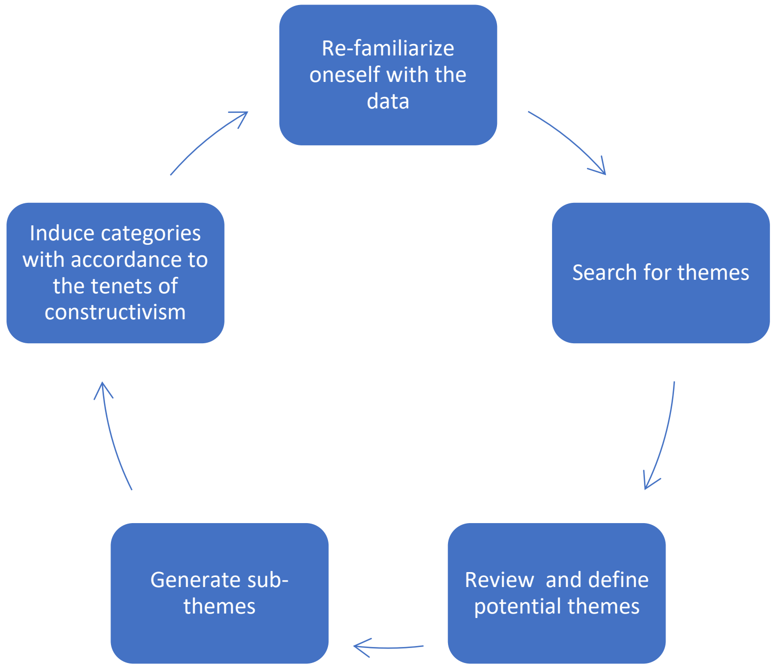


Figure 3-1: Coding process

3.10 Ethical issues

This section will give the details of the ethical issues that were considered before and during the research process.

3.10.1 Informed consent

For purposes, I used consent forms to assure my participants of their safety. I drafted fair consent forms for both the researcher and the participants. The forms were read and signed by participants before the interview period so that they could comprehend their responsibilities and withdraw from the study at any point, should they wish to.

3.10.2 Permission

I sought ethical approval from the ethics committee of the University of the Free State and I requested permission from the Department of Education to conduct the study. I requested permission from the chosen schools' principals to collect data with the usage of consent forms directed to principals. The principals granted the request.

3.10.3 Anonymity and confidentiality

Anonymity and confidentiality of the participants were alsoensuredwhenparticipants were assured that their identities would be kept anonymous and confidential, and that no results of the study wouldmake mention their identities. The teachers were identified as LST 1, LST 2 and LST 3 instead.

3.10.4 Covid-19 regulations

There were various restrictions in place for covid-19. The researcher abided by all regulations, such as sanitising hands before entering venues, wearing masks at all times, and maintaining social distancing from learners and other teachers during practical lesson observations.

3.11 Summary

This chapter covered research methodology aspects employed in the study. It outlined the paradigm that underpinned the study, the research approach that was employed, the relevant research design, the sampling, data collection instruments, aspects pertaining to the trustworthiness of the collected data, data collection procedures, the stages that were undertaken to analyse the data, and ethical issues. The following chapter focuses on the presentation of data and analysis and discussion of the data.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS & INTERPRETATION

4.1 Introduction

This chapter presents the collected data using thematic analysis. This analysis consists of four themes from which emerging sub-themes followed. Triangulation was used to answer the main research question and to present reliable data. Additionally, semi-structured interviews, observations of lessons, as well as analysis of lesson plans were employed to collect data for the study. To successfully answer the main research question, the data was extracted concerning four sub-research questions derived from the main research question. It is worth noting that all the three schools fell under the Thabo Mofutsanyane district in the Qwaqwa region. Only Life-sciences teachers with at least one year experience took part in the study.

4.2 Data Analysis

4.2.1 Descriptive data analysis

The descriptive data analysis provides an insight into the biographic information of the participants as well as their teaching experience. The pseudonyms LST 1, LST 2 and LST 3 were used to describe Life science teacher 1, Life science teacher 2 and Life science teacher 3 respectively. Table 4.1 presents a summary of the participants' identity, gender, qualification type, years of teaching experience, and subjects and grades taught.

Table 4-1: Biographic information of the participants

Identity of participant	**Gender of participant**	**Qualification type**	**Years of experience**	**Major subjects**	**Grades**
LST 1	Male	M+4	2 years	Life sciences Geography	10 & 11 10

LST 2	Male	M+4	5 years	Life sciences	12
LST 3	Female	M+4	2 years	Life sciences Natural sciences	10 & 11 8 & 9

LST 1= Life-sciences teacher 1, LST 2= Life-sciences teacher 2, LST 3= Life-sciences teacher 3, M+4= Matric + 4 years

4.2.2 Interpretive data analysis

Interpretive analysis mostly deals with the common themes that emerged from semi-structured interviews, lesson observations and document analysis. The themes that emerged based on the sub-research questions were: teachers' perceptions of STEM education; the practice of STEM education in Life-sciences classrooms; challenges encountered during STEM integration, opportunities for proper instruction of STEM education. Under these common themes arose sub-themes.

4.3 Overview of themes

To ensure that the data was in line, adequate, and answered the research question;four themes which aligned with sub-research questions were developed. The main research question for the study was:

What are the teachers' perceptions and practices of science, technology, engineering and mathematics education in Life-sciences classrooms?

The following sub-research questions were explored and answered to successfully answer the main research question:

1. What are the teachers' perceptions of STEM education integration in life sciences classrooms?
2. How do teachers integrate STEM education in life sciences classrooms?
3. What are the challenges of STEM education integration in life sciences classrooms?
4. What are the perceived opportunities for integrating STEM education in life sciences classrooms?

From the above-mentioned sub-research questions, four themes were deduced as indicated below.

1. Teachers' perceptions of STEM education in life sciences.
2. The practice of STEM education in Life-sciences classrooms.
3. Challenges encountered during STEM integration in life sciences classrooms.
4. Opportunities for proper instruction of STEM education in life sciences classrooms.

Presentation of predetermined themes which are aligned with sub-research questions are summarised below (Figure 4.1).

Figure 4-1: Summary of emerging themes

Table 4-2: Summary of sub-research questions, emerging themes, sub-themes& categories

Sub-research questions	**Themes**	**Sub-themes**	**Categories**
What are the teachers' perceptions of STEM education integration in life sciences classrooms?	Teachers' perceptions of STEM education in life sciences	Teachers' knowledge of STEM education in life sciences	1. The obscurity of STEM education for instruction in life sciences classrooms
			2. Incorporation of four subject disciplines in life sciences classrooms
			3. STEM initiatives in life sciences classrooms
		Preparation of STEM classrooms in life sciences	1. Diversity-accommodating environment
			2. Practical aspect of STEM classroom preparation
How do teachers integrate STEM education in life sciences classrooms?	The practice of STEM education in Life sciences classrooms.	Conducive STEM learning	1. Seating arrangements\social interaction
			2. Knowledge construction
		Curriculum coverage	1. Chapters that are inclusive of STEM disciplines

			2. STEM activities
		Promotion of creativity in Life sciences classrooms	1. Designing models\projects
			2. Project-based activities & and application of scientific concepts
		STEM approaches	1. Adoption of STEM approaches
			2. Importance of STEM approaches
		STEM instructional methods	1. Employment of STEM methods
What are the challenges of STEM education integration?	Challenges encountered during STEM integration	Lack of motivation to follow the problem\project-based approach	1.Lack of resources
			2. Overcrowding
		Professional development	1.Teacher-training workshops
What are the perceived opportunities for integrating STEM education in Life sciences' classrooms?	Opportunities rendered by proper instruction of STEM education	Opportunities of STEM education	1. Skills
			2. Careers
		Perceived STEM opportunities for academically challenged learners	1. Learning styles
			2. Decrease in drop-out rate

4.4 Theme 1: Teachers' perceptions of STEM education

The researcher explored and elicited teachers' perceptions ofscience, technology, engineering and mathematics education integration. Two sub-themes emerged as teachers' knowledge of science, technology, engineering and mathematics; and preparation of STEM classrooms. Under the mentioned sub-themes emerged further categories. Three categories emerged under sub-theme 1 which are: (i) the obscurity of STEM education for instruction, (ii) incorporation of four subject disciplines, and (iii) STEM initiatives. However, two categories emerged under sub-theme 2; (i) diversity-accommodating environment, and (ii), practical aspect of STEM classroom preparation. Below is a table that summarises the sub-themes and themes(Table 4.3).

Table 4-3: Categories of teachers' knowledge of STEM education & preparation of STEM classrooms

Sub-theme 1: Teachers' knowledge of science, technology, engineering and mathematics education in life sciences classrooms	**Sub-theme 2:** Preparation of STEM classroom
This sub-theme explores the unclear identity of STEM education for instructional purposes	This sub-theme explores the different ways in which STEM classrooms should be prepared
Category 1: The obscurity of STEM education for instruction in life sciences	**Category 1:** Diversity-accommodating environment
Category 2: Incorporation of four subject disciplines in life sciences classrooms	**Category 2:** Practical aspect of STEM classroom preparation
Category 3: STEM initiatives in life sciences classrooms	

4.4.1 Sub-theme 1: Teachers’ knowledge of Science, Technology, Engineering and Mathematics education

The section provides the data on teachers' knowledge of STEM education.

4.4.1.1 The obscurity of STEM education for instruction

STEM education suffers an identity problem. This is evident in the manner in which the participants provided explanations of STEM education. When asked to explain what STEM is, this is how teachers responded:

> LST 1: ‘’*[Uh] STEM education is an integrated approach to teaching and learning whereby learners are exposed to the world of science, technology, engineering, and mathematics.’’*

The limited knowledge of STEM for instructional purposes is also seen in how LST 1 structured his lesson plans, which showed no adoption of various learning styles. LST 1 also conducted lessons that were teacher-centred. However, the teacher used models in the classroom to provide a clear demonstration of what he is talking about even though learners only observed the model from a distance as it was followed by the researcher. The researcher also observed that learners were overcrowded, and others could not see the model as the teacher waved it in front to show the various bones he was referring to. However, it was worth noting that the teacher searched for prior knowledge at the beginning of the lesson to remove myths that could possibly hinder learning in any way.

LST 3 was asked the same question, where she only provided the explanation of STEM education as:

> LST 3: ‘’*STEM is science, technology, engineering and mathematics, and it is a broad term used to group the four subjects’’*

This is a clear indication that LST 1 and 3 did not comprehend what STEM education for instruction entailed judging from how they vaguely provided an explanation for STEM education. The lesson plan constructed by LST 3 was inclusive of STEM education as it indicated that the lesson would be conducted through models, charts and project-based activity facilitated in class, where learners would be designing structures involving gaseous exchange and demonstrate move between air and blood in the lungs. During this lesson, the researcher observed an impressive lesson that included charts, models and mini videos meant to enhance learners' comprehension of the topic. The lesson conducted by LST 3 was in line with what is stipulated in the lesson plan. However, learners were given the project to design at home because the time was limited in the classroom to do so.

LST 2 provided a detailed explanation of what STEM is by responding to STEM education as:

> LST 2:*''STEM refers to a teaching and learning tool that is immensely vital in a manner that it integrates the four subjects\disciplines that are science, technology, engineering and mathematics into a cohesive interdisciplinary and applied learning approach''*

The explanation provided by LST 2 differed from the ones provided by the preceding participants because this one particularly comprehended what STEM education was and its identity for instructional purposes. However, the lesson plan structured by this teacher was in contrast to the knowledge he had of STEM education. His lesson plan lackedconcrete information on how STEM education lessons were prepared, with no indication of extra tools to be used in the classroom. The objectives of the lesson were not aligned to any other discipline to show that the integration of two or more disciplines wouldtake place. Furthermore, the teacher was fully knowledgeable, but the lessons were not in line with STEM education integration. The actual lessons contrasted with the knowledge that the teacher had about STEM education. This leads to the conclusion that the problem with the incorporation of STEM education in the lesson as Mansour and EL-Deghaidy (2015) pointed out that teachers struggle with the integration of STEM disciplines in their lessons.

4.4.1.2 Incorporation of four subject disciplines

It was common among the three teachers that STEM education comprised the four subject disciplines integrated in one lesson.

> LST 1: ''STEM *education is an integrated approach to teaching and learning whereby learners are exposed to the world of science, technology, engineering and mathematics.*''

LST 2: ‘’*STEM refers to a teaching and learning tool that is immensely vital in a manner that it integrates the four subject\disciplines which are science, technology, engineering and mathematics*’’

LST 3: ‘’*STEM is a science, technology, engineering and mathematics program. It is a broad term that is used to group together these academic disciplines, which are integrative in nature*’’

The teachers collectively had a common understanding that STEM education was an educational tool that includedfour subjects which should be integrated.

4.4.1.3 STEM initiatives

Teachers’ perceptions of STEM education initiatives for instructional purposes varied greatly.

LST 1: *“My perception relating to STEM initiatives for instruction is that mathematics and science are conceptual, but they provide learners with understanding to a certain extent which needs to be topped up with integration of engineering design and technological knowledge. STEM initiatives should be something that ensures that learners are equipped with conceptual and practical knowledge*’’

The teacher further put forward that STEM activities affords learners the ability to be relevant workers for the 21st-century workforce and to be proactive.

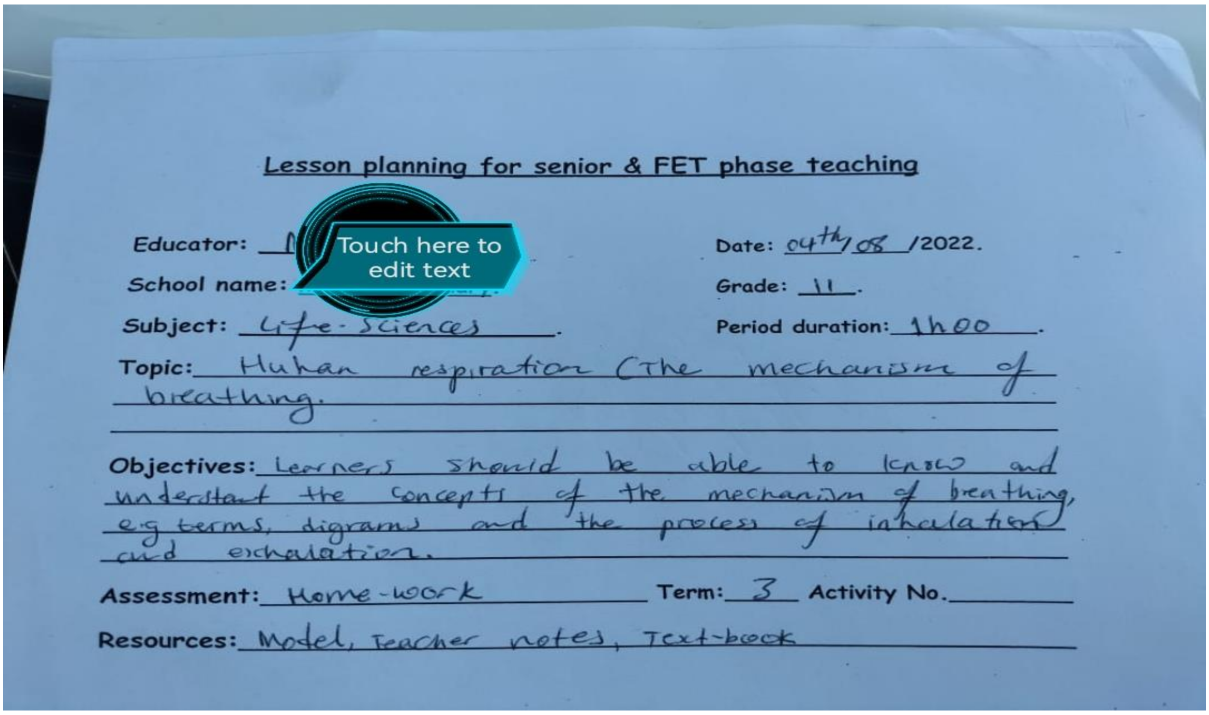
LST 2: ‘’*I believe that STEM initiatives are programs that could immensely benefit learners both theoretically and practically, particularly if they would engage learners more in problem-solving yet requiring them to apply two or more discipline knowledge at a time to conclude a model\project. In this manner, they are being equipped with a set of skills*’’

Teachers also highlighted that initiatives that treats STEM learning includes acquiring problem-solving skills, and critical and analytical thinking.

LST 3: ‘’*STEM initiatives are essential because they would develop learners mentally to succeed in any field of their choice. Also, these initiatives could require learners to be more practical, to challenge them to think critically with the goal of coming up with solutions to real-world problems*’’

LST 1’s lesson plan

The lesson plan in Figure 4.2 belongs to LST 1, who presented the lesson of the day. Looking at the lesson plan, it was clear that the objectives set for the lesson in question were vague. However, it was thrilling to see the teacher using materials in the classroom which was written in the plan.



Lesson planning for senior & FET phase teaching

Educator: Touch here to edit text

School name:

Date: 04th/08/2022.

Grade: 11.

Subject: Life Sciences.

Period duration: 1h00.

Topic: Huhan respiration (The mechanism of breathing.

Objectives: Learners should be able to know and understand the concepts of the mechanism of breathing, e.g terms, digrams and the process of inhalation and exhalation.

Assessment: Home-work

Term: 3

Activity No.

Resources: Model, Teacher notes, Text-book

Figure 4-2: LST 1’s lesson plan

LST 1 was teaching human respiration and brought to class the human torso to show learners the organs responsible for breathing (Figure 4.3).

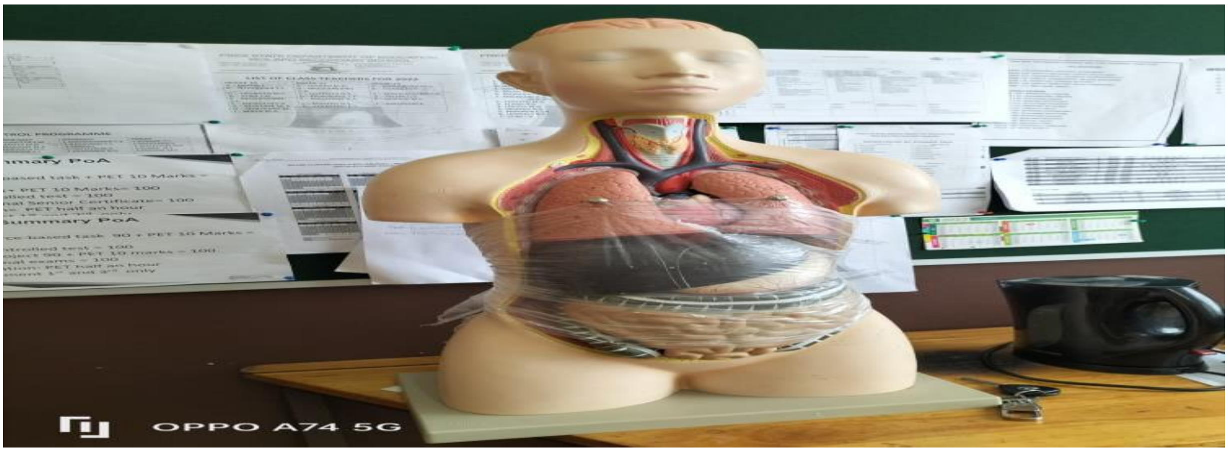
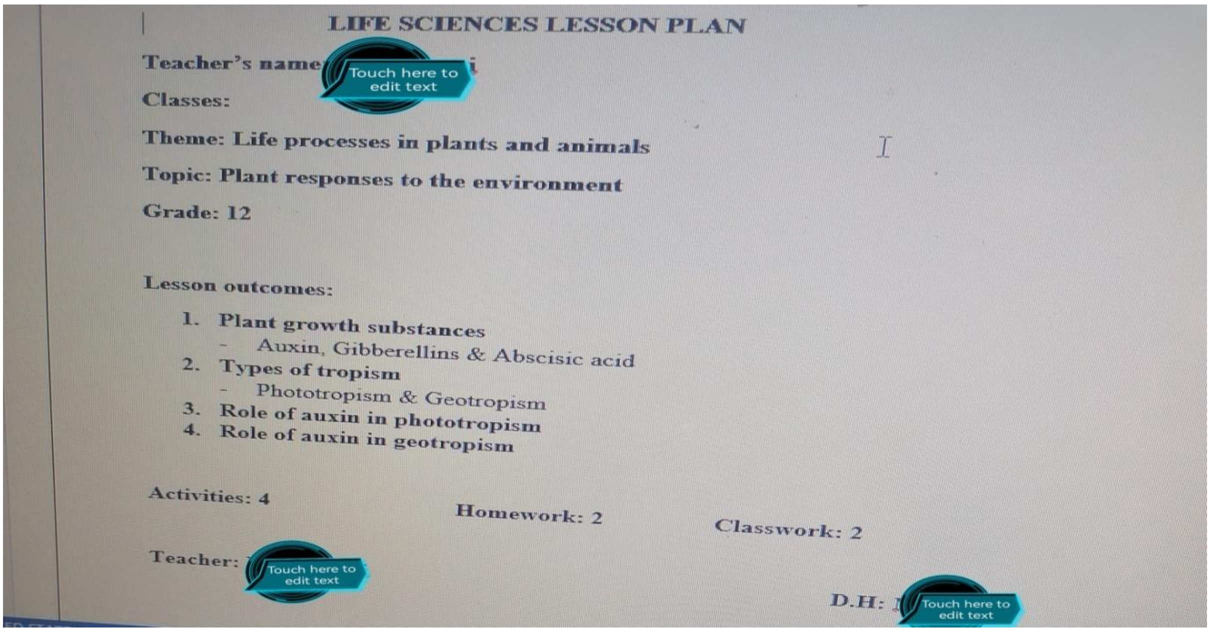


Figure 4-3: LST 1's teaching model

LST 2's lesson plan was well-constructed and the objectives were well-constructed (Figure 4.4). However, the teacher did not have any materials to teach the topic, such as a plant to show various structures of the plant and how the plant responds to environmental stimuli.



LIFE SCIENCES LESSON PLAN

Teacher's name:

Classes:

Theme: Life processes in plants and animals

Topic: Plant responses to the environment

Grade: 12

Lesson outcomes:

1. Plant growth substances
   - Auxin, Gibberellins & Abscisic acid
2. Types of tropism
   - Phototropism & Geotropism
3. Role of auxin in phototropism
4. Role of auxin in geotropism

Activities: 4 Homework: 2 Classwork: 2

Teacher:

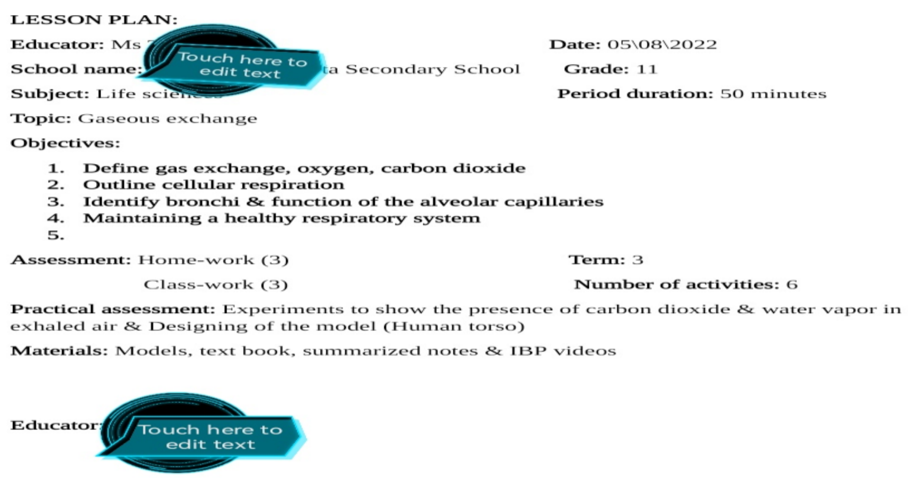
D.H:

Figure 4-4: LST 2's lesson plan

Below is a project a learner designed to demonstrate how a double-stranded DNA molecule looked like and how nitrogenous bases paired with each other in a DNA molecule (Figure 4-5).

Figure 4-5: LST 2's project designed by learners

The lesson plan constructed by LST 3 was well-planned and clearly showed set objectives and a sufficient number of activities with relevant materials (Figure 4.6). However, the use of integrated business planning videos was not done during the lesson despite the indication of it being incorporated.



LESSON PLAN:

Educator: Ms
Date: 05\08\2022

School name: ta Secondary School
Grade: 11

Subject: Life scie
Period duration: 50 minutes

Topic: Gaseous exchange

Objectives:

1. **Define gas exchange, oxygen, carbon dioxide**
2. **Outline cellular respiration**
3. **Identify bronchi & function of the alveolar capillaries**
4. **Maintaining a healthy respiratory system**
5.

Assessment: Home-work (3)
Class-work (3)

Term: 3

Number of activities: 6

Practical assessment: Experiments to show the presence of carbon dioxide & water vapor in exhaled air & Designing of the model (Human torso)

Materials: Models, text book, summarized notes & IBP videos

Educator:

Figure 4-6: LST 3's lesson plan

4.4.2 Sub-theme 2: Preparation of STEM classrooms

The environment should be set up in a manner that caters for effective and successful learning of STEM disciplines. All three teachers were asked how the STEM classroom and school environment should be prepared to be stimulating. The following were their responses to the question.

4.4.2.1 Diversity-accommodating environment

> LST 1: '*'Preparation of STEM classrooms should be in a manner that caters for all learners in terms of various learning styles*''

The teacher lacks the knowledge of how the STEM education environment should be prepared in terms of how the set-up should be in the classroom in terms of activities or the conduction of the teaching and learning process. They understood the aspects that should be looked at when delivering the content; that is, STEM-based, together with the types of activities that should be included but he did not mention how learners should be seated in a STEM classroom and the materials that should be present to induce STEM activities, as well as the overall presentation of the classroom set up. It was observed that learners were seated individually in the classroom and did not help each other in any way. As a matter of fact, the teacher instructed learners not to help each other tackle questions that he posed to them, despite group\teamwork being crucial in STEM classrooms.

> LST 2: *"I think a conducive environment is key for proper instruction of STEM education. An environment that allows diversity of learning in one classroom.*''

The two teachers' understanding of how a stimulating environment should be prepared was the same. Like LST 1, LST 2 also made mention of the teaching and learning aspects of STEM but not of how the whole classroom set-up should be in terms of preparing for a STEM education conducive environment. It was noted by the researcher that the teacher had more than 40 learners in his class, which made it impossible for groups to be formed for learners to help each other to brainstorm various solutions to the problems posed by the teacher. Instead, learners talked directly with the teacher regarding solutions to problems, which teachers declined or accepted on the spot as they were seated individually.

LST 3: *"For me, I think well-prepared STEM classrooms constitute diversity whereby diverse learners are allowed to learn STEM concepts differently according to their different cognitive levels with the teacher scaffolding them here and there*''

4.4.2.2 Practical aspect of STEM classroom preparation

LST 1: *"STEM classrooms should be prepared in terms of practical activities with the surrounding environment full of carious charts from each topic together with materials that will enable learners to successfully carry out designs*''

LST 2: *"STEM classroom should mostly consist of models that learners can use to familiarise themselves with some structures like how and where lungs are situated, models that help them learn easier so that it becomes easier for them to design their own projects knowing exactly how certain structures actually looks like*''

LST 3: *"First and foremost, learners need to engage heavily in practical activities in the laboratory where they are able to make mistakes and rectify them at the same time. In this way, learners are taught to be independent citizens who are fully equipped with the 21st-century skills*''

4.4.2.3 LST 1's seating plan

The manner in which learners was seated didnot allow them to hold mini-discussions; brainstorming, comingup with their own possible solutions, and concluding on the best idea\solution learning from each other (Figure 4.7).

Figure 4-7: LST 1's seating plan

LST 2's seating arrangements

Learners were seated individually, each doing their own thing, against the principle of a constructivist classroom (Figure 4.8).

Figure 4-8: LST 2's seating arrangements

LST 3's seating arrangements

Like LST 1, LST 3 has her learners seated in pairs, indicating that learners do not construct knowledge among themselves as peers and through socialisation (Figure 4.9).

Figure 4-9: LST 3's seating arrangements

4.5 Theme 2: The practice of STEM education in Life-sciences classrooms

The researcher explored teachers' practices of STEM education in life sciences classrooms, whereby five sub-themes emerged. The theme had sub-themes, which had further sub-headings. The first sub-theme: conducive STEM learning had two categories: (i) seating arrangements and social interaction, and (ii) knowledge construction. The second sub-theme, curriculum had two categories: (i) chapters that are inclusive of STEM education, and (ii) STEM activities. The third sub-theme, promotion of creativity in life sciences classrooms, had two categories: (i) designing models\projects, and (ii) project-based activities and application of scientific concepts. The fourth sub-theme, STEM approaches yielded two types: (i) adoption of STEM approaches, and (ii) importance of STEM approaches. Finally, the last sub-theme, STEM instructional methods, had one category: employment of STEM methods. Below is a table that summarises the contents of theme 2(Table 4.4).

Table 4-4: Emerging categories on the integration of STEM education

Sub-theme 1: Conducive STEM learning	**Sub-theme 2:** Curriculum coverage	**Sub-theme 3:** Promotion of creativity in life sciences classrooms	**Sub-theme 4:** STEM approaches	**Sub-theme 5:** STEM instructional methods
This sub-theme explorestwotenetsof constructivism learning theory	This sub-theme is based on curriculum coverage in terms of chapter that accommodates STEM disciplines and their activities.	This sub-theme explores how creativity is catered for in the classroom	This sub-theme explores approaches that teachers employ during their lessons and the importance of adopting these approaches	This sub-theme explores methods of teaching employed by teachers
Category 1: Seating arrangements & social interaction	**Category 1:** Chapters that are inclusive of STEM disciplines	**Category 1:** Designing of models\projects	**Category 1:** Adoption of STEM approaches	**Category 1:** Employment of STEM methods
Category 2: Knowledge construction	**Category 2:** STEM activities	**Category 2:** Project-based activities & application of scientific	**Category 2:** Importance of STEM approaches	

		concepts		

4.5.1 Sub-theme 1: Conducive STEM learning

The three life-sciences teachers were able to make provision for STEM disciplines, although vaguely so. When constructing assessment activities, they were able to make instructions in a way that enabled learners to tackle a little bit of science and mathematics or science and technology in one activity. The environment should be conducive for proper instruction in science, technology, engineering and mathematics. For the latter to occur, the seating arrangement should inform how learners will construct knowledge.

4.5.1.1 Seating arrangements and social interaction

Participants asked how they cater for STEM learning, and this is how they responded:

> LST 1: *"Life sciences itself is an interdisciplinary subject because it includes a variety of disciplines ranging from, mathematics, science and so on. When I plan my activities for assessment, I ensure that I structure my questions in a way that makes provision for other disciplines*''

The researcher further asked the teacher to provide an example of how he planned his assessment in a way that made provision for other disciplines.

> LST 1: *"When I assess my learners on gaseous exchange, my assessment activities include drawing the different muscles that are involved in breathing and to try design that structure to present those muscles to the rest of the class which constitutes the engineering design*''.

LST 1 mentioned that he plannedhis activities in a manner that afforded learners the opportunity to have knowledge ranging from various disciplines. The researcher observed that LST 1 usedmodels in the classroom to demonstrate what he wastrying to disseminate to learners, which is a good STEM practice.

> LST 2: "*As a life sciences teacher, as I prepare my lessons, I see to it that I include models, charts are incorporated as well as the use of IBP videos which is also important to enrich the critical thinking of learners during a lesson*''

Use of various materials and display ofstructures allowedvarious types of learning to take place while implementing STEM education. The teacher hadan overhead projector where he displayedsome structures such as the structure of the ear and the eye for learners to see them and relate them to the processes that they carriedout.

> LST 3: "*Í use various resources in my lessons which accommodate different styles of learning. There are also charts and assessment activities, include projects or practical activities.*''

It was observed by the researcher that learners' seating arrangement was not inclusive of STEM learning. Learners were not grouped to exchange and brainstorm ideas amongst themselves. The lessons were teacher-centred and learners were not given a chance to be active in their learning and to learn through peers socially.

As a result of having learners seated haphazardly in the class, very little to no social interaction took place. Based on the premise that learners construct their knowledge, they should be arranged in a way that allows them to socialise. This method of seating observed in the classes by the researcher inhibited social interaction among learners, and ultimately inhibited effective knowledge construction.

4.5.1.2 Knowledge construction

In addition to the above, learning is an active process constructed and not disseminated to learners. Having observed the environment that learners were exposed to, it is safe to conclude that learners were passive recipient of knowledge instead of active creators. Having small groups in a class induces\arouses interest in learners to construct their own knowledge with the facilitation of the teacher. In this regard, the process of teaching and learning becomes learner-centred. However, the researcher observed a great deal of obstruction regarding proper construction of knowledge based on the seating arrangement and lack of social interaction among learners. In addition, the classroom arrangement did not allow social interaction to take place, which is one of the main tenets of social constructivism. In this regard, the teaching and learning process was teacher-centred instead of learner centred, as STEM requires.

4.5.2 Sub-theme 2: Curriculum coverage

4.5.2.1 Chapters that are inclusive of STEM disciplines

The teachers all responded that life sciences was an interdisciplinary subject because it consisted of knowledge from other disciplines such as mathematics, science, technology and engineering design. LST 1 and LST 2 vaguely explained why they were saying that life sciences consisted of knowledge from other disciplines when they were asked about topics that are inclusive of STEM education.

> LST 1: ‘’*Majority of the chapters have a little bit of content from other disciplines. The curriculum is structured in a way that caters for the knowledge of science, technology and engineering*’’

> LST 2: ‘’*In life sciences, we are dealing with structures and functions most of the times so all the chapters are inclusive of the STEM disciplines here and there*’’

In contrast, LST 3 mentioned a topic that she deems fit for catering for STEM learning in Life sciences. She further went on to elaborate why she thought the topic catered for STEM learning by saying:

> LST 3: “*Gaseous exchange: learner can perform experiments in class to demonstrate exchange of gases or familiarise themselves with the structure of the lung and draw all its’ aspects and use arrows to indicate the movement of gases’’*

4.5.2.2 STEM activities

The researcher understood the different perceptions held by the teachers regarding curriculum coverage in life sciences and the chapters that accommodated STEM disciplines and those which did not. The researcher then asked them to provide activities that they have engaged in which they believe implement two or more STEM disciplines.

> LST 1: “*STEM activities are rather practical, and we are integrating STEM when learners come with their own designed phases of mitosis in a box to show how the cell looks like during different phases of mitotic division such as prophase, metaphase, anaphase and telophase*’’

> LST 2: *“I think activities such ones where they come with made-up brains to demonstrate different parts of the brain and the function that each performs. Also, at the beginning of the year, they made structures of how a DNA molecule looks like for them to grasp how DNA nitrogenous bases pairs in a double-stranded DNA molecule*’’

LST 3: *"There are activities that require learners to design projects which constitute as STEM activity like*

4.5.3 Sub-theme 3: Promotion of creativity in Life sciences classrooms

LST 1 does not really create a learning environment that is creative judging from his classroom set-up. He further provided details on how he promotes creativity during his lessons. Creativity is crucial in STEM classrooms because learners need to feel motivated and fulfilled to carry out STEM-informed assessments. LST 1 explained how he creates creativity in his classroom as follows:

> LST 1: "*Uhm, creativity… firstly, I liberate learners and make them feel free in because they tend to respond positively to creativity when they are free and in terms of answering questions. The set up in my classroom triggers learners in a positive way. I normally have my own strategies in place which I always align with the topic of the day in order to deepen learners' understanding*''

LST 2 had sufficient knowledge to promote creativity in his classroom. His classroom consisted of some charts on the wall, and this is how he promoted creativity in his classroom:

> LST 2: "*So, the main thing is to create or design a learners-centred classroom in a manner that you want to promote and stimulate the cognitive ability and critical thinking of learners. I employ various learning styles in one lesson which is inclusive of models, charts and some videos in order to make learners interested*''

LST 3 elaborated that she promoted creativity in her classrooms by making sure that she switched among various learning styles, which she believed always keeps learners attentive.

''By making use of teaching aids and ensuring that I accommodate all the learning styles''

4.5.3.1 Designing of models\projects

The inclusion of the 'technology' and the 'engineering' part of the STEM is as important as the 'science' and 'mathematics' part of it. The four subjects were said to equip learners with the skills necessary for them to successfully compete the 21st century workforce. Teachers were asked if they allowed learners to design models in the classroom and if learners got to do these designs in groups or individually. They were also asked to provide the topics that they normally used to ask learners to design. This is how they responded:

> LST 1: "*under the topic 'the skeleton', I wanted learners to grasp the different names of the bones. As a result, I asked them to draw the skeletons with labels of the bones and to also design models of the skeleton which they will come to present the operation of a skeleton with reference to the bones*''

> LST 2: "*I'll provide one example in plant hormones; I ask learners to investigate the presence and effectiveness of abscisic acid in sprouting or growth of a plant by looking at various organs of the plant. Learners are divided into two groups, and two plants of the same height are given with abscisic acid concentration. They then work with the plants and tell if abscisic acid promotes or inhibits the growth of a plant as well as to tell if the plant in question is positively phototropic or geotropic with reference to the stem and roots in the absence of unilateral light*''

> LST 3: "*Yes, under the topic of gaseous exchange. I group them so that they discuss and brainstorm possible solutions to the problem and to agree upon the best possible solution fit for the problem*''

Furthermore, they were probed whether learners asked questions that sought clarity, and this is how each teacher responded:

> LST 1: "*Yes, they hold some mini debates amongst themselves. However, they struggle to direct questions to me as their teacher unless I force them to ask something. Then their questions are weak because they then ask for the sake of asking*''

> LST 2: "*Yes, there are some groups where you will find that they actually came with a number of plants following the example that I gave and then they discuss amongst themselves as to which plant they should work with in order to maximise the reliability of the results. They most often ask me if they can use all the various plants they have in order for them to conclude successfully on the effect that the hormone in question has on the growth of plants*''

> LST 3: "*Yes, they do debate on some aspects pertaining the experiment when they face challenges and then often refer to me for clarity*''

4.5.3.2 Project-based activities and application of scientific concepts

Teachers were fully aware that their activities should be structured to cater for STEM education. LST 1 was asked which activities he deemed fit in supporting the learning of science, technology, engineering and mathematics, and allowing learners to apply scientific concepts. He responded by saying:

> LST 1: "*Specifically, I choose activities that make learners to be hands-on. A good example is administration of practical activities in the laboratory*''

LST 1 could not mention the specific activities that he deems fit in supporting the learning of STEM disciplines and requires learners to be hands-on and adopt scientific concepts.

On the same note, LST 2 also responded just with no clear stipulation of those activities.

> LST 2: "*I deem all the chapters fit because they have activities that enables learners to learn all STEM disciplines*''

LST 3 explained that there were activities that ensured that STEM education waspractised through the designing of projects by responding:

> LST 3: '*' There are activities in life sciences that requires learners to design projects. An example that I have is that of the electric circuit. My learners designed electric circuits recently*''

4.5.4 Sub-theme 4: STEM approaches

There are various approaches that teachers can employ in their implementation of STEM education integration. The approaches are disciplinary, interdisciplinary, multidisciplinary and transdisciplinary. Firstly, disciplinary approach includes concepts and skills learned separately in each discipline. Secondly, the multidisciplinary approach includes concepts and skills learned separately in each discipline but within a common theme. Thirdly, an interdisciplinary approach includes closely linked concepts and skills learned from two or more disciplines to deepen knowledge and skills. Lastly, the transdisciplinary approach includes knowledge and skills learned from two or more disciplines applied to real-world problems and projects, helping to shape the learning experience.

4.5.4.1.1 Adoption of STEM approaches

The teachers wereasked which approach they employed during their lessons, and they responded differently to the question. LST 1 and LST 3 explained that they normally used an interdisciplinary approach during their lessons for different reasons, as stipulated below. However, LST 1 mentioned that he switchedbetween the approaches depending on the topic. As a result, he also used thetransdisciplinary approach to deliver the content successfully. With the focal point being Life sciences, it was concluded that implementation strategies for STEM education variedfrom one teacher to the other, judging from the various methods used by each teacher involved regardless of the teaching the same subject. However, the researcher picked some discrepancies regarding the approaches mentioned by the teachers and the ones the researcher observed the teachers employing in their lessons.

LST 1: *"I employ interdisciplinary and transdisciplinary approach in my lessons. One normally switches depending on the topic*''

LST 2: *"I employ transdisciplinary approach in my lessons*''

LST 3: "*According to the way I structure my lessons, I think I mostly employ interdisciplinary approach during my lessons*''

It is worth noting that teachers were unfamiliar with the terms which led to the researcher having to explain in depth what each approach entailed. In addition, the researcher observed that teachers were not switching between approaches as explained during interviews, which constitutes the 'discrepancies' in what was mentioned above by each teacher.

The findings reveal that teachers are more focussed on their subject area during their lessons. Additionally, they do not transition between approaches as stipulated in the interviews.

4.5.4.2 Importance of STEM approaches

Having observed and elicited teachers' perceptions on the approaches of STEM education integration, teachers were asked to provide their stance on the importance of these approaches.

LST 1: *"STEM approaches are necessary because one gets to see how content from one subject connects with content from other subjects. This connection helps learners learn multiple subjects at a time*''

LST 2: *"The approaches are all crucial in making learners draw connection from what they learn and their side or dailyexperience*''

LST 3: '*'These approaches enable* learners to think more deeply about key ideas *instead of just memorizing facts. They learn by doing*''

4.5.5 Sub-theme 5: STEM instructional methods

There are four methods of teaching that inform STEM education. These are project-based, inquiry-based, problem-based teaching together with the engineering design.

4.5.5.1 Employment of STEM methods

All the teachers responded uniquely to the question of the type of STEM method they usedfor delivering STEM-related lessons. LST 1 mentioned that he madeuse of those methods at one stage or another depending on the chapter or the topic he was dealing with at that particular time. He further alluded that he rarely used the engineering design method because learners do not always design models or projects in life sciences. LST 2 seemedunsure of the method he employedbecause he indicated that he usedproject-based teaching even though his learners didnot really make projects. Then LST 3 claimedthat she usedinquiry-based teaching. This is how each teacher responded to the question of the kind of method they used.

> LST 1: "*This also depends on the topic but it's rare for the engineering design because we do not always design models in Life sciences. One way or another depending on the topic, I do employ all those STEM methods but rarely that one of engineering design*''
>
> LST 2: *"I personally prefer project based teaching even though we don't always do projects in our school as regular*''
>
> LST 3: "*My method of teaching mostly dwells in the inquiry-based teaching*''

4.6 Theme 3: Challenges encountered during STEM integration

Challenges posed by STEM education integration were explored. Two sub-themes emerged.The first was motivation to follow problem\project-based approach,which had its own sub-themes; (i) lack of resources, and (ii) overcrowding. The second sub-theme,professional development had one category;teacher-training workshops. Table 4.5 belowsummarisesthe theme 3 and its sub-themes.

Table 4-5: Challenges of STEM education integration

Sub-theme 1: Lack of motivation to follow problem\project-based approach	**Sub-theme 2:** Professional development
This sub-theme explores factors that inhibit proper instruction of STEM education	This sub-theme recommends professional help that could assist teachers to enhance their STEM implementation strategies
Category 1: Lack of resources	**Category 1:** Teacher-training workshops
Category 2: Overcrowding	

4.6.1 Sub-theme 1: Motivation to follow the problem\project-based approach

LST 1 and LST 2 hadsimilar challenges regarding the administration of project-based activities. They both mentioned lack of resources in their schools. LST 1 added that the time catered for a single period was not sufficient to conduct experiments properly and for learners to actually see projects to the end. Moreover, he mentioned that his classes were overcrowded,which hindered proper conduct of project-related activities. LST 2 added that on top of limitedresources, they experienced power outage and the IBP videos to compensate for shortage of material where learners observe how experiments are done. LST 3 stipulated that the only challenge she encountered that learners did not abide by the instructions of the laboratory as well as instructions of the experiments.

> LST 1: "*We deal with projects or practical activities, and we lack resources to administer. The time that is also provided does not cater for proper instruction of projects. Overcrowding also hinders proper administration of project-based activities*''
>
> LST 2: "*The difficulty in my institution is due to the lack of resources, electricity, various models and IBP content videos*''
>
> LST 3: "*Learners do not abide by the instructions of the laboratory as well as instructions of the experiment itself* ''

4.6.1.1 Lack of resources

Teachers were asked how they countered the challenges mentioned in the preceding question, and their responses differed depending on the challenge stipulatedby each teacher. LST 1 mentioned that he borrowedmaterials from neighbouring schools for learners to have sufficient resources. LST 2 noted that to counter the challenge of shortage of resources, lack of power and IBP content videos, he directed his learners to make use of their mobile phones and search for a particular experiment to observe how the experiment is carried out and then discuss the experiment as a class.He further added that their school allowedcell phones as toolsforlearning. Furthermore, he usedrelevant charts and the chalkboard to demonstrate how a certain experiment is conducted, given that they were short of materials for that particular experiment. Moving on to LST 3, who indicated that the major issue she facedduring project-based activities is that learnersdidnot abide by the instructions of the laboratory and mostly importantly, of the experiment to be administered. She highlightedthat she triedby all means to always explain the instructions pertaining the experiment in depth while still reminding them of the rules of the laboratory for a successful conduct of the experiment.

> LST 1:“*We normally go to neighbouring schools to borrow resources and we also group them to have a manageable lesson with materials adequate for all*’’

> LST 2:“*To mitigate that, I use charts and chalk board most of the time to demonstrate the investigation and allow them to use internet on their phones to have an insight of a certain practical*’’

> LST 3: “*I try to explain the instructions pertaining the experiment prior to the conduction of the experiment and I also remind them of the rules of the laboratory each time we enter the laboratory*’’

4.6.1.2 Overcrowding

It was common among teachers that they have a lot of learners which in a way inhibits the effective administration of project\practical based activities. This then induced the question of how they dealt with overcrowding in their classrooms\laboratory. They all provided similar answers indicating that they grouped learners in order for materials to accommodate them, as well as to have a more conducive and controllable set up.

> LST 1: “*The largest number I have is 61 so I divide them in groups of 20 in order for them to conduct practical in small numbers which is manageable and effective. However, this is time-consuming to do it in this manner*’’

> LST 2:“*They are grouped together in a way that the resources available are adequate and each group has a leader to call others to order while I facilitate other groups*’’

> LST 3:“*I also have a number that is intense which always leads to grouping learners in order to deal with a manageable groups and resources to be distributed among groups*’’

LST 1 had many learners in his classroom. The figure below shows his crowded classroom which also contributes to ineffective instruction of STEM education (Figure 4.10).

Figure 4-10: LST 1’s number of learners

LST 2 also has a high number of learners in his classroom which ultimately compromised proper and successful instruction of STEM education (Figure 4.11).

Figure 4-11: LST 2’s number of learners

Teacher LST 3 had the lowest number of learners in her classroom among the three teachers. However, the number of learners was still high considering the classroom's 30:1 learner: teacher ratio rule. She still had learners exceeding 30, which is believed to be the highest number a single teacher can have in their classroom (Figure 4.12).

Figure 4-12:LST 2's number of learners

4.6.2 Sub-theme 2: Professional development

4.6.2.1 Teacher-training workshops

The researcher elicited teachers' perceptions and observed their practices regarding STEM education implementation. The data extracted from the teachers showed some light with regard to the concept of STEM. However, it was observed in their lessons that they lacked the necessary knowledge pertaining to the integration of STEM education, as Mansour and EL-Deghaidy (2015) observed that teachers lacked pedagogical knowledge of STEM initiatives. Furthermore, the researcher deemed it fit to ask teachers if they thought they needed development in terms of STEM integration, and if they would be able to attend the training of such calibre.

> LST 1: "*We need to be provided with support of material. Workshops should be conducted that inducts teachers as to how to properly incorporate STEM disciplines in their lessons*''
>
> LST 2: "*Teachers' workshops could be vital in order to shape our knowledge of STEM with its' integrative nature in the classroom*''
>
> LST 3: "*Teachers can be assisted by conduction of workshops*''

Furthermore, they were asked if they would be interested to attend the training and workshops organised by the district officials to give them insight into effective way of incorporating STEM disciplines in their lessons.

> LST 1: "*I would appreciate it because it is going to enlighten me and do things in my lesson that I was not doing due to limited knowledge*''

LST 2: "*I will definitely attend the training, especially to understand the implementation of STEM in the classroom and to enhance my teaching strategies*''

LST 3: "*Yes, I would be interested to attend such workshops because I think they are informative and could possibly develop me on so many aspects of my career*''

4.7 Theme 4: Opportunities rendered by proper instruction of STEM education

Opportunities afforded by STEM education integration were explored and revealed two sub-themes. The first sub-theme: opportunities of STEM education had two categories; (i) skills, and (ii) careers. The second theme: perceived STEM education opportunities for academically challenged learners, also revealed two categories; (i) learning styles and (ii) a decrease in drop-out rates, respectively. Below is Table 4.6, which summarises the contents of theme 4.

Table 4-6: Opportunities created by STEM education

Sub-theme 1: Opportunities of STEM education	**Sub-theme 2:** Perceived opportunities of STEM education for academically challenged learners
This sub-theme explores multiple opportunities rendered by STEM education	This sub-theme explores possible opportunities offered STEM education for learners who are challenged academically
Category 1: Skills	**Category 1:** Learning styles
Category 2: Careers	**Category 2:** Decrease in drop-out rate

4.7.1 Sub-theme 1: Opportunities for STEM education

There are various opportunities offered by STEM disciplines. As such, teachers in the study were asked if there are any opportunities that come with having the skills of STEM disciplines and to provide some examples of those opportunities. Teachers were requested to provide possible opportunities that could be offered by the knowledge of STEM disciplines, and this is how they responded.

4.7.1.1 Skills

Teachers deem the STEM disciplines crucial in terms of acquiring new skills yet relevant to the current workforce. Similarly, they commonly depicteda few skills they thought could be benefited by learners from exposure to STEM initiatives.

> LST 1: "*STEM education affords and promotes scientific inquiry and the processes involved in the engineering design*''
>
> LST 2: "*STEM education could possibly qualify learners in professions such as architecture, engineer and web designers which are good in nature but requires a set of skills like ones provided by STEM education*''
>
> LST 3: "*Learners lack even the most mere skills such as argumentation, questioning and planning skills. I believe that STEM education programs could enhance learners' argumentation, questioning, planning and reasoning skills*''

The teachers added that these skills equipped learners with skills that qualified them to pursue careers that are in demand, and require a set of skills as a pre-requisite to the careers in question.

4.7.1.2 Careers

There are many careers that learners wish to pursue but fail to meet the requirements for admission into those careers. However, proper instruction in STEM education can eradicate this problem by developing various skills through STEM learning. As indicated by some teachers, they believed that learners could use their learning of STEM education programs for future careers.

LST 1 mentioned that the incorporation of STEM education in their lessons could benefit learners a great deal because they sometimes struggle to pick good careers as they either have one or two of the disciplines required in certain careers and never the whole set of disciplines required for such careers.

> LST 1: "*STEM exposes learners to various disciplines which afford them the knowledge necessary for their future careers*''

LST 2 also agreed that STEM education equipped learners with the necessary skills required in the workplace. As a result, learners would get a chance to fill the workforce requiring these skills.

> LST 2: ''*STEM will help learners acquire jobs that are dominant and requires*

workforce with the skills of the four disciplines''

LST 3 mentioned that STEM enhances the efficacy of practical activities. She claims that learners who are taught more integrated STEM disciplines are able to provide solutions to practical and real-world problems.

> LST 3: "*STEM education assists learners to think critically and help them to explore various practical activities which could ultimately help learners who choose practical-oriented careers.*''

The researcher probed the careers that teachers deemed fit to be occupied by STEM-literate individuals. They then provided a number of examples that they perceived fit to be pursued by learners who are skilled in STEM disciplines.

> LST 1:"*I personally feel that careers such as engineering are good but learners are not well equipped with pre-requisites for these careers as chemical engineer for one, requires mathematics, biology and some physics*''

> LST 2: "*There are a lot of computer-related careers that requires a set of skills like ones rendered by STEM education*''

> LST 3: "*Careers such as medical laboratory scientist and physicians demands not only physical sciences but other disciplines like mathematics and chemistry which could be afforded by STEM education*''

4.7.2 Sub-theme 2: Perceived STEM opportunities for academically challenged learners

From their knowledge of STEM education, they were asked to provide the opportunities that they perceived to be possible for academically challenged learners as a result of having skills rendered by STEM disciplines.

4.7.2.1 Learning styles

It is common among teachers that they deem the practical aspect of STEM as one that helps learners who are academically challenged to take part in something which could actually arouse interest in them. This would then spark an interest in learners to learn and give them hope and positivity towards learning.

> LST 1: "*It could be helpful because STEM forces one to adopt various learning styles and they do things practically which is what learners who are academically challenged enjoy and mostly probably good at.*''

LST 2: "*We have learners at different cognitive levels. Low achiever could possibly be accommodated by STEM lessons as it includes practical activities and projects which will help them improve their academic performance.*''

LST 3: "*STEM accommodates various learning styles and caters for academically challenged learners because they can applytheir knowledge rather than having knowledge being disseminated unto them.*''

4.7.2.2 Decrease in drop-out rate

Teachers believed thatthemajority of learners dropped out for different reasons, and one of them included learners those who thoughtthat they could not learn and ended up giving up on school. However, they believed that adoption of STEM classrooms could minimise the number of dropouts, as well as increase college enrolment, particularly colleges that have more to do with practical aspects of learning than theory.

LST 1: "*I have realised that learners who are struggling academically end up dropping out of school even before they reach matric level. Having practical programs that influence learning could probably keep such learners in school especially those who find themselves interested in practical activities*''

LST 2: "*There are a lot of learners I have taught who do not get to finish their matric, some of them are learners who have failed several times and end up excusing themselves from school so it is only fair to think that these are the learners who think that they are unable to progress and excuse themselves from school as a result. Perhaps, having such initiatives at school could spark an interest in them which will keep them in school until they complete their matric*''

LST 3: "[Uhm] *some learners are smart but they decide to drop put for whatever reason. Maybe they are struggling at home and do not see the point of being in school but if they are vested in something they like, they would probably find it difficult to just drop out.*''

4.8 Summary

This chapter analysed the data through descriptive and interpretive (thematic) analysis. The descriptive analysis entailed basic biographic information of the participants together with their years of experience in the education arena. The pseudonyms LST 1, LST 2 and LST 3 were used to describe Life science teacher 1, Life Science Teacher 2 and Life science 3 respectively. Table 4.1 presents a summary of the participants' ID, gender, qualification type, teaching experience & subjects and grades that they teach. Interpretive analysis mostly deals with the common themes that emerged from semi-structured interviews, lesson observations and document analysis. The themes that emerged were: teachers' perceptions of STEM education;the practice of STEM education in Life-sciences classrooms; challenges encountered during STEM integration; and opportunities rendered by proper instruction of STEM education. Among these common themes were sub-themes under each respective theme.

CHAPTER FIVE

KEY FINDINGS, DISCUSSIONS, RECOMMENDATIONS & CONCLUSIONS

5.1 Introduction

Findings, conclusions as well as summary of the study are discussed in this chapter. This qualitative exploratory case study explored teachers' perceptions and practices of science, technology, engineering and mathematics education in life sciences classrooms. This chapter outlines the summary of the research study, discusses the major findings, summarises findings with reference to thesub-research questions, provides limitations of the study, identifies conclusions of the study, and proffers recommendations forstaff development and future research.

It was deemed necessary to carry out this study for other researchers to expand on the strategies that are meaningful towards successful STEM education implementation. Additionally, the study was necessary to raise awareness about teachers' lack of knowledge with regard to STEM disciplines' integration. The interpretations as well as the discussion of findings of the study were linked to the literature review outlined in chapter 2. The techniques and methods used when data was collected were outlined in chapter 3. Finally, suggestions for future research and conclusions of the study are presented.

The objectives of the study were as follows:

- To elicit teachers' perceptions of STEM education integration in life sciences classrooms.
- To describe how teachers integrate STEM education in life sciences classrooms.
- To explore the challenges of STEM education integration.
- To determine the perceived opportunities for integrating STEM education in life sciences classrooms.

5.2 Summary of the study

The study explored teachers' perceptions and practices of science, technology, engineering and mathematics education integration in life sciences classrooms. The study pursued teachers' perceptions of STEM education, how teachers integrated STEM education, opportunities rendered by STEM education, and the challenges STEM education poses. The first chapter provided the structure of the study and the major components of the study. This was done with reference to the introduction and background, statement of the problem, outline of the main and sub-research questions, purpose of the study, research objectives, significance of the study, components pertaining research methodology, delimitation, definitions of terms, outline of chapters and summary of the chapter.

The second chapter explored and elaborated more on the theory underpinning the study, as well as the conceptual framework for the integration of the literature related to the two concepts. To achieve the above, the researcher introduced components that were explored in the chapter, explored the theoretical framework and its significance, reviewed the literature that related to the nature of the study, as well previous empirical studies, before providing a summary of the chapter.

The third chapter comprised the methods used in the study. The paradigm that aligns with the study, the interpretive paradigm, was discussed and employed due to its tenet that truth is socially constructed by an interaction between the researcher and the participants (Kivunja&Kuyini, 2017), the research approach that was employed was qualitative approach due to the study focusing on analysis of words. The case study design under the qualitative approach was deemed fit to be employed according to the nature of the study, because the study aimed to elicit teachers' perceptions. Regarding population and sampling procedures, purposive sampling was used as the researcher aimed to draw from information-rich sources. The researcher used triangulation of data to provide reliable and coherent data. Data collection procedures included semi-structured interviews, practical lesson observations, and analysis of documents. The researcher employed semi-structured interviews whereby teachers were interviewed by the researcher based on drafted questions aligned to sub-research questions. The study used practical observations of lessons, and reviewed each teachers' lesson plan as instruments to collect data. Moreover, the three data collection instruments were used to collect t data that supports itself.

Trustworthiness for the study was achieved through credibility, dependability, conformability and transferability. Descriptive and interpretive analyses were used to analyse the data. Descriptive analysis explored the biographic information of the participants while interpretive analysis entailed themes that emerged from the data. Ethical issues and a summary of the chapter were provided.

The second last chapter presented and analysed the data obtained. The analysis of data was done through descriptive and interpretive analysis, overview of themes, and diagrams presenting a summary of emerging themes, as well as the summary of sub-research questions, emerging themes and sub-themes. The current chapter outlines the summary of the study, discussion of major findings, summary of findings, limitations of the study, recommendations for staff development as well as future research, and conclusions of the study.

The study's aim was to respond to the research question: What are the teachers' perceptions and practices of science, technology, engineering and mathematics education in life sciences classrooms?

In order to successfully answer the main research question, four sub-research questions emerged. Each sub-research question provided in-depth responses which then contributed to answering the main research question. Table 5.1 presents the sub-research questions together with their relevant data collection instruments.

Table 5-1: Sub-research questions and collection instruments

Sub-research question	**Collection instruments**
1. What are the teachers' perceptions of STEM education integration in life sciences classrooms?	Semi-structured interviews
2. How do teachers integrate STEM education in life sciences classrooms?	Semi-structured interviews Lesson observation Document analysis
3. What are the challenges of STEM education integration?	Semi-structured interviews Lesson observation Document analysis
4. What are the perceived opportunities for integrating STEM education in life sciences classrooms?	Semi-structured interviews

5.3 Summary of findings

As indicated in the introduction, this section will comprise major findings and will be guided by the research objectives outlined in the introduction. The findings of this study clearly showed that there is limited understanding of what comprises STEM education and its identity for instructional purposes. Additionally, the findings reveal that teachers comprehend that STEM is integrative in nature and requires its implementation to be integrated. However, there is lack of pedagogical means to integrate in their classroom practices. Which then invokes the need for teachers to introduce team teaching and proper workshops to induct teachers accordingly regarding STEM education integration.

5.3.1 Sub-research question 1: What are the teachers' perceptions of STEM education integration in life sciences classroom?

Teachers view STEM education for instructional purposes as a difficult concept. Khuyen *et al*. (2020) assert that teachers feel that it is rather difficult to implement STEM education in their classroom practices. In addition, the manner in which the teachers provided STEM definitions proved their lack of knowledge of what STEM education entails and its purpose for instruction. The observation concurs with Bell's (2016) study, which also observes that teachers have a limited understanding of STEM education. Even though teachers are aware of the STEM initiative and the disciplines involved therein, they lack substantive knowledge of STEM, and the knowledge to incorporate it in their classrooms. This is supported by Mansour and EL-Deghaidy (2015), who posit that teachers lack pedagogical knowledge to integrate STEM education, which is one of the most significant issues. They perceive STEM education as an initiative that can be achieved if the four disciplines are to be taught in different classes. Sanders (2009)questions policymakers and all other stakeholders if STEM education is also achieved by teaching different STEM disciplines individually. Bybee (2013) observes that STEM education is perceived as a conglomerate term rather than an integrative one.

5.3.1.1 Sub-theme 1: Teachers' knowledge of STEM education

The findings of the study revealed that teachers were familiar with the term ''STEM'' and what it stands for. However, they were not well informed about the STEM-based instructional practices. The teachers lacked the pedagogical knowledge on how to integrate the STEM disciplines in a single lesson. Bell (2016) posits that teachers have a limited understanding of STEM, that results in them not knowing how to incorporate it in the classroom effectively.This is supported by Mansour and El-Deghaidy (2015), who assert that science and mathematics teachers lack the necessary pedagogical strategies to implement STEM education. It was observed by the researcher that those who managed to plan according to STEM education lack the necessary approaches to put their planning into practice successfully. Furthermore, it was discovered that teachers were willing to know more about STEM education following the interest in STEM disciplines shown by the teachers in question.

5.3.1.2 Sub-theme 2: Preparation of STEM classroom

Social constructivism stipulates that learners are at the centre of their learning, and the latter can be done through prior experiences and being practical in the classroom, constructing knowledge through 'designing' and what they can see. This mirrors what Dennick (2016) says: that learning is achieved through relating new knowledge with previous experiences or knowledge. Additionally, Margot and Kettler (2019) allude that prior experience is a crucial aspect of STEM instruction. The study revealed that the setting of the classroom was not conducive enough to induce STEM learning. Powell and Kalina (2009) say learners build meaningful concepts through constant communication. This was concluded after the researcher realised that there were no charts or equipment that indicated that learners engaged in STEM disciplines during lessons. There was a lack of a conducive environment for mini discussions among learners. The theory underpinning the study notes that social interaction induces interest and instils knowledge. However, the class seating arrangement did not makes provision for interaction amongst learners to exchange ideasandconstruct knowledge.

One of the principles of constructivism learning theory stipulates that learners should engage in practical\project related activities, which in turn, informs conducive STEM learning. The findings of the study indicated that schools lacked resources which inhibited the practical aspect of STEM education. In addition to lack of resources, the classrooms did not have charts to show the ‘liveliness’ of life sciences in the classrooms. However, it was observed that the classrooms lacked necessary charts due to the crisis of resources.

5.3.2 Sub-research question 2: How do teachers integrate STEM education in life sciences classrooms?

Teachers had limited understanding of how a STEM environment should be prepared even though theyunderstood the aspects that should be incorporated in a STEM classroom. Teachers could respond positively to questions that entailed the set-up for STEM lessons and the integrative nature of STEM education. However, it was observed by the researcher that despite their knowledge, their classes were not prepared in that manner, and the manner they delivered the content did not compare with how the actual STEM lessons should be prepared. The content delivery methods and classroom environment of each teacher didnot address the integrative nature of STEM education. STEM education is informed by four approaches; disciplinary, interdisciplinary, multidisciplinary and transdisciplinary as explained by Vasquez *et al.* (2013), English (2016), and Aguilera, Lupianez *et al.* (2021). A senior academic in Life Sciences advises employment of these approaches even though he acknowledges the struggles they posed (Pollard, Hains-Wesson & Young, 2018). The researcher observed significant challenges, such as lack of resources to foster STEM activities. Alcena-Stiner and Markowitz (2020) claim that Life sciences learning centre (LSLC) is aimed at exposing learners to hands-on, experiential learning but has proven to be challenging on several occasions. Mansour and El-Deghaidy (2015) argue that teachers lack adequate knowledge to incorporate STEM disciplines into their lessons. Wood (2017) advises that the Department of Life Science should move towards inquiry-based teaching within learner learner-centred approach, informed by project-based activities in the classroom. This was not the case as observed by the researcher during practical lesson observations.

5.3.2.1 Sub-theme 1: Conducive STEM learning

A certain environment needs to be set up for proper instruction inSTEM education to take place. Teachers’ lesson plans indicate some incorporation of STEM education in terms of activities planned for learners on a certain topic. STEM activities need to be practical in nature. However, the manner in which learners was seated in all the classrooms did not align with STEM education. They were not placed in groups to brainstorm ideas for problems and agree on the best solution for a certain problem. Learners learn on their own, which the premise of constructivist classrooms that stipulate that learners construct their own knowledge by engaging with one another and drawing on past experiences to actively build knowledge. They were passive recipients of knowledge. The latter was concluded on the idea that some learners were seated individually and the teacher was dominant in the classroom, as observed by the researcher. STEM classrooms are dominated by learners, and the lessons are also learner-centred.

5.3.2.2 Sub-theme 2: Curriculum coverage

Having elicited teachers' perceptions of science, technology, engineering and mathematics education in life sciences classrooms, it was concluded that not all chapters in the life sciences curriculum incorporated all the STEM disciplines. To elaborate, there are some chapters that required integration of two or more disciplines. Other chapters did not allow forsuch integration of STEM disciplines through relevant pedagogical strategies, including scaffolding. Additionally, teachers can foster STEM education by encouraging multiple pathways to solving problems by means of scaffolding (Alanazi, 2017). This can be achieved through selection of various subjects that are related to the topic\project to afford learners the knowledge across two or more STEM disciplines (Arlinwibiwi, Refnawati&Cartowagiran, 2020). It is imperative for teachers to critically analyse the methods as well as approaches they employ when dealing with topics that allow connection and the integration of the STEM disciplines. Such connection forces teachers to be creative in terms of the various topics they come across, with the goal of introducing learners to skills embedded in STEM education.

5.3.2.3 Sub-theme 3: Promotion of creativity in life sciences classrooms

The teachers described life sciences as a fascinating subject. None of them struggled to elaborate how they managed to foster creativity in their lessons. In as much as the subject is theoretical, it is also practical teachers manage to trigger interest in learners through various experiments. Wells (2016) states that STEM-related activities should centre on creativity, such as the 'PIRPOSAL' model of STEM education that ensures that learners construct knowledge in a meaningful way while triggering learners' fancies.

5.3.2.4 Sub-theme 4: STEM approaches

There are a number of approaches that are deemed fit in supporting STEM education. Firstly, the disciplinary approach involves the learning skills and concepts separately in each discipline (Vasquez et *al.,* 2013). Secondly, interdisciplinary approach introduces closely related concepts and skills from two or more STEM disciplines. Thirdly, the multidisciplinary approach includes core concepts and skills being taught separately in each discipline but housed within a common theme(English, 2016:1). Aguilera*et al.* (2021) note that the transdisciplinary approach includes setting goals that transcend the curriculum as well as STEM disciplines by focusing on the problem that needs to be solved. It was concluded that teachers were not familiar with these approaches and most importantly, they thought they were mostly employing approaches that integrated all the four disciplines. In contrast, they mainly stuck to approaches that taught these disciplines individually (Disciplinary\Nested approach), as observed by the researcher during practical lesson observations. There was a need to distinguish among the four approaches and be able to employ relevant ones during STEM integration.

5.3.2.5 Sub-theme 5: STEM instructional methods

Like the approaches, STEM also comprises of various methods of teaching. The method varies from problem-based, project-based, and inquiry-based to engineering design type of teaching. Firstly, the problem-based approach is the type of teaching strategy that focuses on analysing the problem and the knowledge necessary to solve the problem in question (Aquilera*et al*., 2021). Secondly, project-based approach is a method that directs the teaching-learning process towards production of a device that serves as a solution to a particular problem. (Aquilera *et al*., 2021). Thirdly, the inquiry-based approach directs the process of teaching and learning towards identifying and analysing a problem, followed by various scientific steps to solve the problem by making hypotheses and carrying out scientific concepts (Aquilera et *al*., 2021). Lastly, engineering design centres on identifying a problem and establishing criteria that will successfully guide the possible designs to come up with a practical solution to the problem (Aquilera et *al*., 2021). A teacher may decide to employ one or two of the mentioned STEM teaching methods. Each teacher indicated the method relevant to them and their learners. However, upon lesson observations, it was observed that teachers only selected the methods that they deemed fit and appropriate as the researcher observed practices that contradicted the information that was provided by the teachers during interviews.

5.3.3 Sub-research question 3: What are the challenges of STEM education integration?

Lack of motivation, limited time to cover the syllabus, lack of skills, inadequate facilities, learners' poor involvement, and unresponsive environment are barriers several teachers faced when implementing STEM (Ramli & Talib, 2017). On the same note, the participants highlighted three challenges posed by STEM education integration. Firstly, there is a lack of motivation to follow the problem/project-based approach. Teachers noted that lack of motivation is induced by a lack of resources in their schools as well as power outage, which inhibited the effective use of Internet Broadcast Project(IBP) videos to display some experiments for learners to observe when there are insufficient resources. Secondly, overcrowding proves to be a challenge because their classes consist of about 45 learners, with the highest number being 61 among the teachers, which completely contradicts the normal pupil: teacher class ratio of 30:1, according to the Personnel Administrative Measures PAM document of South Africa. As a result, they claim that it was almost impossible to foster practical-based activities or project-based activities. Overcrowding inhibited proper instruction, including effective experiments and practical and project-based activities. Last was lack of staff development. Teachers also complained that they received neither support nor development from stakeholders to successfully equip learners with the necessary skills required for the 21st century. Hsu and fang (2019) note that there are only few research studies that have been conducted on teacher preparation for STEM teaching. As a result, they asked to be developed through workshops and training that informs them of proper ways of incorporating STEM disciplines and enforcing enforce the actual goal of STEM initiatives. Furthermore, they highlighted that it would be an honour to attend training to enrich themselves and their learners in turn.

5.3.3.1 Sub-theme 1: Motivation to follow problem\project-based approach

The findings of the study disclosed that there were many factors that hinder successful STEM learning. Factors such as shortage of materials, overcrowding and power outages contribute towards poor incorporation of STEM disciplines. Ramli and Talib (2017) agree that lack of motivation, poor syllabus interpretation skills, inadequate facilities, learners' poor involvement and an unresponsive environment are barriers encountered by several teachers in the implementation of STEM. In addition, Wang *et al.* (2011) highlight that teachers have varying difficulties regarding STEM implementation due to a lack of digital resources. The schools lacked resources that learners could use to design projects in the classroom. Classes consisted of over 40 learners(Tikly *et al*., 2018). The area that the schools are in was struggling from power outages. As a result, teachers could not use the necessary tools to enhance learners' knowledge, particularly in cases of shortage of materials where they resorted to displaying videos and experiments. The above-mentioned were contextual factors that tamper with the motivation to follow the project-based approach in the classrooms.

5.3.3.2 Sub-theme 2: Professional development

Having observed all the contextual factors as well as other factors that directly\indirectly prohibited the proper incorporation of STEM disciplines, it was importantto determine if the teachers were willing to receive internal and external help. They indicated their willingness to attend workshops that developed them in this aspect. Khuyen *et al.* (2020) state that their studyshowed that there was a need to design effective teacher development to sustain STEM instruction. Altan and Ercan (2016) agree that professional teacher programs are imperative as they greatly influence teachers' perceptions in their study. Furthermore, it was observed that novice teachers were more informed about STEM education than teachers who had more than fifteen years of practice (Altan & Ercan, 2016).

5.3.4 Sub-research question 4: What are the perceived opportunities for integrating STEM education in life sciences classrooms?

It was deduced that STEM education integration can benefit learners by affording them the necessary knowledge for their future careers. Learners equipped with STEM knowledge could be afforded the chance to qualify for multiple careers due to having skills that are in demand for the current workforce. Weis, Eisenhart, Cipollone, Stich, Nikischer, Hanson, Leibrandt, Allen and Dominguez (2015) attest toSTEM education presenting learners with varying skills that shape them into responsible citizens. Moreover, the project aspect of STEM education could benefit academically challenged learners as the lessons would be centred on learners, with the teacher being the facilitator of learning. This could also help struggling learners when they do projects and practical activities that are believed to trigger interest in them.

5.3.4.1 Sub-theme 1: Opportunities of STEM education

The findings of the study, like other studies of this nature, such as one compiled by Mansour and El-Deghaidy (2015),reveale d that teachers thought highly of STEM education. This was concluded after each teacher was asked if they thought STEM education could benefit learners. It was unanimous among all the teachers that STEM disciplines were paramount career-wise. They all indicated that there were learners who were slow but tended to be fast when doing experiments. They concluded that STEM education could benefit such learners by arousing interest in learning when projects were being designed. Weis *et al.* (2015) assert that STEM education affords learners various skills necessary for the current workforce (Weis *et al.*, 2015). Li (2014) states that the emerging fields of STEM education present opportunities crucial to a nation’s prosperity and security.

5.3.4.2 Sub-theme 2: Perceived STEM opportunities for academically challenged learners

STEM education poses various opportunities for learners, including those challenged academically. Proper instruction of STEM means that the teacher employs various learning styles to accommodate different learners who learn differently. Some learners are left behind because they are visual learners, and if they do not get the visual type of teaching, they fall under the ‘academically challenged learners’. However, with properly trained teachers for the integration of STEM disciplines, many learners can get a fair chance of learning. As a result, there will be a massive reduction in learners who are categorised as academically challenged, which, in turn, would positively affect the dropout rates by not having many learners who give up on school because nothing ‘interests’ them at school.

5.4 Limitations of the study

The study was only conducted at three public schools. As a result, the study’s findings are applicable only to the concerned schools and their contexts. The schools are all based in

Thabo Mofutsanyana district. The findings of the study are limited to term 3 curriculum coverage. The practical lesson observations could only be done once as the schools were busy preparing for the September examinations. As a result, the practical observations were done for the strand three which is diversity, change and continuity. A similar study could be carried out focusing on strands one, two and four. Furthermore, for the purpose of revealing the contexts of other schools in the future, a similar study could focus on public as well as private schools.

5.5 Conclusions of the study

The study explored teachers’ perceptions and practices of science, technology, engineering and mathematics education in life sciences classrooms. The study unveiled strategies that teachers employed in their classrooms, with the aim of accommodating STEM learning. Moreover, the study revealed teachers' perceptions of STEM education, how they integrated STEM education, challenges they encountered during STEM integration, and the opportunities STEM disciplines offered through its integrative nature. It was clear that teachers had knowledge of STEM education but lacked pedagogical means to incorporate it into their lessons. Additionally, the objectives of the study were to elicit teachers’ perceptions of STEM education integration in life sciences classrooms, to describe how teachers integrate STEM education in life sciences classrooms, to explore the challenges of STEM education integration, and to determine the perceived opportunities for integrating STEM education in life sciences classrooms.

Teachers’ perceptions were explored and elicited about STEM education. However, it was concluded that they were inadequately prepared to incorporate these disciplines into their lessons. Teachers struggled to integrate STEM disciplines into their classroom practices. Regardless of the comprehension that others showed with regard to STEM education, the classroom practices were far from what STEM integration demands. It emerged that there were many challenges that teachers encountered regarding STEM education. Other than individual challenges experienced by teachers, such as a lack of pedagogical strategies and being under-prepared to implement STEM education, there were also contextual factors which inhibited proper instruction of STEM education. The contextual factors in question included a lack of sufficient resources to carry out successful experiments and design projects, frequent power outages in the area, and overcrowding of learners, which inhibited facilitation of activities\experiments. Furthermore, there were various opportunities afforded by STEM education integration. Careers such as architecture and computer programming require individuals with a particular set of skills provided by STEM disciplines integration.

5.5.1 Recommendations for staff development

One of the findings of the study relates to the inadequacy of the teachers to integrate STEM disciplines in their lessons, which is a step in the right direction of having fully skilled citizens. Teachers need to be skilled first through workshops that inform them of the STEM concept, what its purpose is for instructional purposes, and the methods and strategies of incorporating these disciplines in their lessons.

5.5.2 Recommendations for future research

The study was a qualitative case study applicable to the participants and their contexts. Quantitative data acquired through a mixed methods approach could be combined with qualitative data to extract more data that could be applicable to a larger population.

Future research is recommended to determine how teachers can be assisted pedagogically regarding STEM education integration. Future research should also probe into how teachers deem the development fit without interfering with their daily work. It should also look into the aspects of STEM education that learners deem interesting in order for lessons to be centred around what triggers their fancy so that they enjoy what they do while learning these crucial skills. This can be achieved through comparative study that investigates learners' and teachers' views on STEM education integration. The district officials' views on STEM education integration should be explored, as well as how they can help acquire these set of skills. Moreover, more research should focus on private schools as the present study's findings are from public schools, and private schools may differ. Furthermore, future research should involve more than one district to compare the context of the findings from each section.

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LIST OF APPENDICES

APPENDIX A: SEMI-STRUCTURED INTERVIEW QUESTIONS

1

TITLE: Exploring teachers' perceptions and practices of science, technology, engineering and mathematics education in Life sciences classrooms

INTERVIEW PROTOCOL

MAIN RESEARCH QUESTION

What are the teachers' perceptions and practices of science, technology, engineering and mathematics education in Life sciences classrooms?

SUB-RESEARCH QUESTION 1

What are the teachers' perceptions of STEM education integration in Life sciences classrooms?

IQ1: What is STEM education?

IQ2: What is your perception related to STEM initiatives for instructional purposes?

IQ3: How do you think STEM stimulating learning environment should be prepared?

SUB-RESEARCH QUESTION 2

How do teachers integrate STEM education disciplines in Life sciences classrooms?

IQ1: How do you cater for STEM education in your lessons?

IQ2: Which chapters ensure the practice of STEM disciplines?

IQ3: STEM education is a project-based learning, which activities do you deem fit in supporting the learning of science, technology, engineering and mathematics disciplines and requires learners to apply scientific concepts?

IQ4: How do you promote creativity in life sciences classrooms?

IQ5: Provide detailed examples of how you promote creativity through the implementation of practical activities\ projects.

IQ6: Do you sometimes provide learners the opportunity to design practical activities or models? If so, under which topics do you ask learners to design? Is the design done individually or in groups? Also, do you provide the opportunity for learners to view different designs and suggest the best design out of different options?

IQ7: Are there any debates posed by learners on different designs? Or learner presentations followed by clarity seeking questions?

IQ8: Among the following four STEM approaches, which one(s) do you employ during your lessons?

Firstly, lessons centre around teaching concepts and skills separately (disciplinary\nested approach).

Secondly, concepts and skills are learned separately in each discipline but within a common theme. (Multidisciplinary approach).

Thirdly, closely linked concepts and skills are learned from two or more disciplines with the aim of deepening knowledge and skills (interdisciplinary approach).

Lastly, knowledge and skills learned from two or more disciplines are applied to real-world problems and projects, thus helping to shape the learning experience (transdisciplinary approach).

IQ9: Which method of teaching STEM disciplines do you employ among the following?

Firstly, identification and analysis of a problem, formulate questions that are explored by use of scientific experiments in order to later reject or accept hypotheses made (inquiry-based teaching).

Secondly, the identification of a problem and exploring the solution for that problem through designing products that serve as a resolution or solution for the problem identified (project-based teaching).

Thirdly, analysing the problem and focussing on necessary knowledge that could possibly resolve that problem (problem-based teaching).

Lastly, identifying the problem which is followed by possible designs to solve the problem which ultimately results in the problem being solved by an agreed upon practical solution (engineering design).

IQ10: Why do you think the activities you mentioned equip learners with the knowledge of STEM?

IQ11: Which chapters consist of content that provides less of STEM education learning?

<u>SUB-RESEARCH QUESTION 3</u>

What are the challenges experienced by teachers when integrating STEM education in Life sciences classrooms?

Motivation to follow the problem\project-based approach:

IQ1: What are the challenges you encounter during project-based activities in your lessons which caters for STEM learning?

IQ2: How do you counter these challenges in your lessons?

Resources:

IQ1: How do you improvise for STEM education learning in the case where you lack materials in your laboratory?

IQ2: How do you improvise in the case of shortage of materials where each and every can not have their own materials to work with for a particular project\design?

Overcrowding:

IQ1: In the case where you have a lot of learners in your lesson, how do you facilitate for effective and successful conduction of STEM education particularly during practical activities?

Staff development workshop to improve STEM instruction/ professional development focused on STEM education in your study

IQ1: How do you think teachers can be assisted regarding the proper instruction of STEM education?

IQ2: Will you be interested to attend development training where you are taught the effective methods of implementing STEM education in your classroom practices? If so, what would you mostly aim to benefit from the training of such?

SUB-RESEARCH QUESTION 4

What are the perceived opportunities for integrating STEM education in Life sciences classrooms?

IQ1: As a Life science teacher, what are the opportunities of incorporating STEM education in your lessons?

IQ2: What are your perceived opportunities for STEM education implementation in your lessons regarding academically challenged learners?

IQ3: What are the general opportunities rendered by STEM education incorporation for learners' future careers?

APPENDIX B: LESSON OBSERVATION GUIDE

LESSON OBSERVATION PROTOCOL

ITEM	CHECKLIST	NOTES	
STEM approaches: Disciplinary approach			
Multidisciplinary approach			
Interdisciplinary approach			
Transdisciplinary approach			
STEM methodologies: Inquiry-based teaching			
Project-based teaching			
Problem-based teaching			
Engineering design			
Stimulation of STEM learning environment: Prior knowledge			
Real-world context problems			
Collaborations and teamwork			
Learner-centred teaching			

Multiple pathways to solution			
Relevant connection among STEM disciplines			

APPENDIX C: DOCUMENT ANALYSIS GUIDE

DOCUMENT ANALYSIS PROTOCOL

DOCUMENTS	NOTES	CHECKLIST	√ \ ×
Lesson plans		Shows evidence of project-based activities. Shows evidence multiple pathways to solution. Shows evidence of learner-centred teaching. Shows evidence of collaborations and team work. Shows evidence of connection among disciplines of STEM.	
Assessment\Activity book		Shows evidence of project-based activities. Shows evidence multiple pathways to solution. Shows evidence of learner-centred teaching. Shows evidence of collaborations and team work. Shows evidence of connection among disciplines of STEM.	

APPENDIX D: LETTER TO THE PRINCIPALS

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Consent form: Master of Education student

Cell no: 078 674 5217 or Email address: enosancialethu@gmail.com

604 Slovo Park

Phuthaditjhaba

9866

Dear Principal

I am currently doing my research with UFS on ***''Exploring teachers' perceptions and practices of science, technology, engineering and mathematics education in Life sciences classrooms''***.I request permission to collect data at your school, by interviewing and observing one Life science educator. Participation is voluntarily and educators are allowed to withdraw from participation at any time prior to the signing of the consent forms. We will discuss the issues of confidentiality, anonymity and other legal issues about this study with the educators upon the invite which is prior to the interviews and observations. We will adhere to the Covid 19 regulations.

This study complies with the rules and regulations of conducting a research.

If you would like to know additional information,please feel free to contact me on 078 674 5217 or send an email at the following address enosancialethu@gmail.com

Details of my supervisor:

Name: Dr Mafugu T

Tel no: 058 718 5395

Email: MafuguT@ufs.ac.za

Please indicate by cancelling what is **NOT APPLICABLE** and sign below to give your consent.

Yours Sincerely,

Signature: Nzimande E.M

I agree/do not agree as the principal for my school to take part in the mentioned study

Name: ___________________________

Signature: _____________________________

Date: __________________________________

Contact details: _____________________________

APPENDIX E: LETTER TO TEACHERS

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Consent form: Master of Education student

Cell no: 078 674 5217 or Email address: enosancialethu@gmail.com

604 Slovo Park

Phuthaditjhaba

9866

Dear Participant

I am currently doing my research with UFS on ''***Exploring teachers' perceptions and practices of science, technology, engineering and mathematics education in Life sciences classrooms***''.I request you to take part in my study. Participation is voluntarily and you are allowed to withdraw from participation prior to the signing of the consent form. I will discuss the issues of confidentiality, anonymity and other legal issues about this study with you upon the invite which is prior to the interviews and observations. We will adhere to the Covid 19 regulations.

This study complies with the rules and regulations of conducting a research.

If you would like to know additional information,please feel free to contact me on 078 674 5217 or send an email at the following address enosancialethu@gmail.com

Details of my supervisor:

Name: Dr Mafugu T

Tel no: 058 718 5395

Email: MafuguT@ufs.ac.za

Please indicate by cancelling what is **NOT APPLICABLE** and sign below to give your consent.

Yours Sincerely,

Signature: Nzimande E.M

I agree/do not agree to take part in the mentioned study

Name: ____________________________

Signature: ______________________________

Date: ___________________________________

Contact details: ______________________________

APPENDIX F: PERMISSION LETTER FROM FREE STATE DEPARTMENT OF EDUCATION

1

Enquiries: M.Z. Thango
Ref: Research Permission for Extension: E.M. Nzimande
Tel. 051 404 8808
Email: MZ.Thango@fseducation.gov.za

education
Department of Education
FREE STATE PROVINCE

604 Slovo Park
Phuthaditjhaba
9866

Dear Ms. E.M. Nzimande

PERMISSION FOR EXTENSION TO CONDUCT RESEARCH IN THE FREE STATE DEPARTMENT OF EDUCATION: THABO MOFUTSANYANA DISTRICT

This letter serves to inform you that you have been granted permission for an extension to conduct research in the Free State Department of Education within the Thabo Mofutsanyana Education District. The details in relation to your research project with the University of the Free State are as follows:

Topic: Exploring teachers' perceptions and practices of Science, Technology, Engineering and Mathematics Education in Life Sciences classrooms.

1. **List of schools involved:** Beacon Secondary school, Bluegumbosch Secondary school and Mookodi Secondary school.
2. **Target Population:** Three teachers teaching Life Sciences in grade 10 and 11 at the selected schools.
3. **Period of research**: From the date of signature of this letter until 30 September 2023. Please note that the department does not allow any research to be conducted during the fourth term (quarter) of the academic year. Should you fall behind your schedule by three months to complete your research project in the approved period, you will need to apply for an extension. The researcher is expected to request permission from the school principals to conduct research at schools.
4. The approval is subject to the following conditions:
   4.1 The collection of data should not interfere with the normal tuition time or teaching process.
   4.2 A bound copy of the research document should be submitted to the Free State Department of Education, Room 101, 1st Floor, Thuto House, St. Andrew Street, Bloemfontein or can be emailed to the above-mentioned email address.
   4.3 You will be expected, on completion of your research study to make a presentation to the relevant stakeholders in the Department.
   4.4 The ethics documents must be adhered to in the discourse of your study in our department.
5. Please note that costs relating to all the conditions mentioned above are your own responsibility.

Yours Sincerely,

DATE: 04/05/2023

Mr. MZAMO W. JACOBS
DIRECTOR: QUALITY ASSURANCE, M&E AND STRATEGIC PLANNING

RESEARCH APPLICATION FOR EXTENSION BY E.M. NZIMANDE, PERMISSION LETTER 04 MAY 2023. THABO MOFUTSANYANA DISTRICT
Strategic Planning, Research & Policy Directorate Private Bag X20565, Bloemfontein, 9300 - Thuto House, Room 101, 1st Floor, St Andrew Street, Bloemfontein

Enquiries: M.Z. Thango
Ref: Notification of Research Extension: E.M. Nzimande
Tel. 051 404 8808
Email: MZ.Thango@fseducation.gov.za

education
Department of Education
FREE STATE PROVINCE

District Director
Thabo Mofutsanyana District

Dear Ms. Mabaso

NOTIFICATION OF RESEARCH EXTENSION: PERMISSION TO CONDUCT RESEARCH PROJECT IN THABO MOFUTSANYANA DISTRICT

This letter serves to inform you that Ms. E.M. Nzimande has been granted permission for extension to conduct research in the Thabo Mofutsanyana District under the auspices of the University of the Free State. The details in relation to the research project are as follows:

Topic: Exploring teachers' perceptions and practices of Science, Technology, Engineering and Mathematics Education in Life Sciences classrooms.

1. **List of schools involved:** Beacon Secondary school, Bluegumbosch Secondary school and Mookodi Secondary school.
2. **Target Population:** Three teachers teaching Life Sciences in grade 10 and 11 at the selected schools.
3. **Period of research**: From the date of signature of this letter until 30 September 2023. Please note the department does not allow any research to be conducted during the fourth term (quarter) of the academic year nor during normal school hours. The researcher is expected to request permission from the school principals to conduct research at schools.
4. **Research benefits:** The study will benefit the department of education as it will outline the perceived challenges experienced by teachers in the STEM education integration and the department can carry out relevant teacher development training to equip teachers with the necessary skills and assets to effectively integrate STEM disciplines. In turn, these will all benefit all learners as they go to different fields of careers that are STEM related.
5. Strategic Planning, Policy and Research Directorate will make the necessary arrangements for the researchers to present the findings and recommendations to the relevant officials in the Department.

Yours Sincerely,

Mr. MZAMO W. JACOBS
DIRECTOR: QUALITY ASSURANCE, M&E AND STRATEGIC PLANNING

DATE: 04/05/2023

NOTIFICATION OF RESEARCH EXTENSION. E.M. NZIMANDE. 04 MAY 2023. THABO MOFUTSANYANA DISTRICT
Strategic Planning, Research & Policy Directorate Private Bag X20565, Bloemfontein, 9300 - Thuto House, Room 101, 1st Floor, St Andrew Street, Bloemfontein

APPENDIX G: ETHICAL CLEARANCE CERTIFICATE

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

15-Jun-2022

Dear Ms Enosancia Nzimande

Application Approved

Research Project Title:
Exploring teachers' perceptions and practices of science, technology, engineering and mathematics education in life sciences classrooms

Ethical Clearance number:
UFS-HSD2022/0254/22

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
Chairperson: General/Human Research Ethics Committee

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APPENDIX H: EDITTING CERTIFICATE

Dr Jabulani Sibanda
Senior Lecturer: English Education
School of Education
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Email:Jabulani.Sibanda@spu.ac.za
Alternate e-mail: jabusbnd@gmail.com
Website: www.spu.ac.za
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10 July 2023

RE: CERTIFICATE OF LANGUAGE EDITING

To whom it may concern

I hereby confirm that I have proofread and edited the following **DISSERTATION** using Windows 'Tracking' System to reflect my comments and suggested corrections for the author(s) to action:

Teachers' perceptions and practices of science, technology, engineering and mathematics education in Life sciences classrooms

REFERENCE

- **Author(s):** Enosancia Morongwenyane Nzimande
- **Student No:** 2015107507
- **Affiliation:** University of the Free State

Although the greatest care was taken in the editing of this document, the final responsibility for the product rests with the author(s).

Sincerely

10.07.2023

SIGNATURE

This certificate confirms the language editing I have done in my personal capacity and not on behalf of SPU

APPENDIX I: ORIGINALITY REPORT

NZIMANDE E.M M.Ed1.docx

ORIGINALITY REPORT

10%	9%	8%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.researchgate.net Internet Source	2%
2	docplayer.net Internet Source	1%
3	doi.org Internet Source	1%
4	Submitted to University of the Free State Student Paper	<1%
5	apse-journal.springeropen.com Internet Source	<1%
6	link.springer.com Internet Source	<1%
7	orcid.org Internet Source	<1%
8	"Integrated Approaches to STEM Education", Springer Science and Business Media LLC, 2020 Publication	<1%