UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Exploring Harry Gwala District Further Education & Training mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during the Corona virus pandemic lockdowns

by

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Submitted in partial fulfilment of the academic requirements for the degree of

MASTER OF EDUCATION (Mathematics Education)

in the School of Education

Mathematics & Computer Science Education Cluster

University of KwaZulu-Natal

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February 2024

DECLARATION

I, Thulisile Happiness Mbanjwa, declare that:

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- This thesis has not been submitted for any degree or examination at any other university.
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07/02/2024

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Student Name Date

Ms BB Goba

07/02/2024

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Name of Supervisor Date

DEDICATION

I dedicate this work to my son, Prince Lukhanyo Yamkelindumiso Rivaldo.

ACKNOWLEDGEMENTS

Had it not been for the LORD who was on my side: then I would not have made it. Blessed be the LORD, who has been with me throughout this journey, granting me wisdom, knowledge, and understanding. I want to express my gratitude to God for giving me a friend—the Holy Spirit—who consistently guided, comforted, and provided strength in moments when I felt like giving up.

I extend my sincere gratitude to the following individuals for their significant roles in this study:

- Ms Busisiwe Goba, my supervisor, who provided proper and professional support throughout the writing of this thesis.
- My family and friends, I thank you all for the words of encouragement that played a crucial role in ensuring the completion of my degree qualifications.
- To my son, Prince LYR, thank you for your patience during times when I was absent in our relationship.
- A special thanks to the teachers who generously gave their time to participate in this study, knowing that there are no direct benefits. Your contribution is invaluable, and I appreciate your commitment to making this study possible.

ABSTRACT

The 21st century is characterised by substantial societal, economic, and technological changes, fostering an era of continual evolution and innovation. These transformations pose acknowledged challenges, all of which were emphasised by the disruptions triggered by the COVID-19 pandemic and subsequent lockdowns. This phenomenological case study investigated teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns, a period when face-to-face workshops were prohibited.

Data was collected through semi-structured questionnaires administered to 35 mathematics teachers across 15 schools in Harry Gwala District, KwaZulu-Natal. Additionally, three Further Education and Training (FET) mathematics teachers underwent in-depth interviews during the data collection process. Employing a mixed-method approach, teachers were purposively selected from four circuits within the Harry Gwala District, aligning with the interpretive paradigm. Quantitative data was organised using the technological pedagogical and content knowledge (TPACK) framework, while qualitative data underwent interpretative phenomenological analysis.

The study found significant challenges in online teaching, particularly in deep rural areas, due to factors such as poor network coverage, limited data availability, scarce resources, low socio-economic status of learners, and negative learner attitudes. Despite these challenges, teachers utilised various digital tools and platforms, including WhatsApp, YouTube, virtual workshops, Google Classroom, Sketchpad, GeoGebra, and smartboard softwares. These tools played a crucial role in enhancing teachers' understanding of teaching Euclidean geometry proofs during COVID-19 lockdowns, improving communication skills and technological pedagogical knowledge. Overall, the strategic use of these digital resources elevated teaching competencies despite uncertainties during the lockdown period.

The findings of this study offer practical, empirically based guidelines for education stakeholders and educators seeking to enhance teachers' competencies in online teaching. Understanding how teachers navigated the challenges of online teaching within the context of geometry education during these unique circumstances offers invaluable insights into effective strategies and practices for teaching in similar scenarios.

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CHAPTER 1: INTRODUCTION TO THE STUDY

1.1 OVERVIEW OF THE CHAPTER

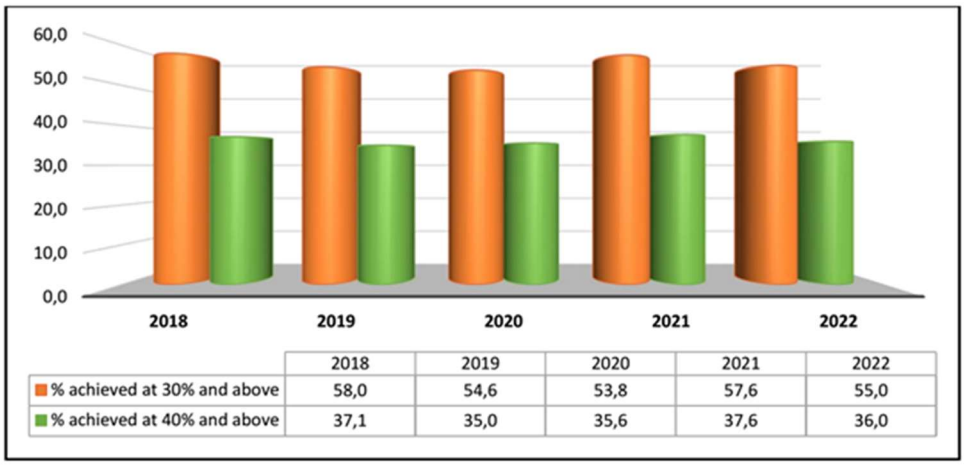
This research study aimed to explore the experiences of mathematics teachers in Further Education and Training (FET) within the Harry Gwala District, KwaZulu-Natal. The focus was on their efforts to enhance their competencies of teaching Euclidean geometry proofs during the lockdowns imposed during the coronavirus pandemic. This chapter offers an overview of the background, problem statement, and the rationale that underpins the study. Additionally, it delves into the study's significance, outlines the research objectives, and presents essential research questions. In conclusion, the chapter provides clarification of key terms used in the study and a preview of each chapter of the dissertation.

1.2 INTRODUCTION AND BACKGROUND

Mathematics is widely recognised as a fundamental subject due to its substantial contribution to national prosperity and future development. The role of mathematics education is pivotal in shaping individuals' cognitive abilities, problem-solving skills, and logical reasoning (Suurtamm et al., 2020). Proficiency in mathematics is not only crucial for various academic and professional pursuits but also contributes significantly to broader societal and technological advancements (Suurtamm et al., 2020). Therefore, the importance of mathematics cannot be overstated.

Moreover, mathematics is acknowledged as a gateway subject (World Economic Forum, 2020), providing essential tools for understanding other fields like science, technology, engineering, and economics. Despite the critical importance of mathematics in South Africa, learners persist in facing challenges leading to bad performance in the subject. This is evident in the results of national benchmark tests (ANA & matric) and international assessments (TIMSS & PISA) (Department of Basic Education [DBE], 2020) which reveal a concerning negative trend in the academic performance of South African learners in mathematics.

Additionally, diagnostic reports from the mathematics matric examinations for the years 2018, 2019, 2020, 2021 and 2022 reveal consistently poor performance among learners in the subject (Figure 1.1).



	2018	2019	2020	2021	2022
% achieved at 30% and above	58,0	54,6	53,8	57,6	55,0
% achieved at 40% and above	37,1	35,0	35,6	37,6	36,0

Figure 1.1: Overall achievement rate in Mathematics (2018 – 2022)
Source: Retrieved from Diagnostic report 2022, part 1

Figure 1.1. illustrates a decline in the pass rate from 2018 to 2020. As per the depicted results, the performance in Mathematics was notably poor in the year 2020. However, a positive shift was observed in 2021, with an improvement in overall performance. The percentage of candidates achieving a score of 30% and above increased from 53.8% in 2020 to 57.6% in 2021.

In 2020, the already existing challenges in learners' performance in mathematics were compounded by the disruptions triggered by the COVID-19 pandemic lockdowns. The diagnostic report for that year highlighted a notable observation: not all topics were equally covered in preparation for examinations. This disparity was particularly evident in examination centres where learners had limited or no access to schooling during the lockdown and experienced extended school holidays in 2020. The diagnostic report emphasised the need for mathematics teachers to be strategic and skilful in realigning their teaching with the annual teaching plan to compensate for the lost time. Consequently, the researcher of this study undertook an investigation exploring FET mathematics teachers' experiences of enhancing their competencies for teaching Euclidean geometry during the COVID-19 pandemic lockdown.

Drawing from personal teaching experience, I have encountered challenges in covering topics within the allocated time, with the Euclidean geometry section posing a specific difficulty. Tachie (2020) corroborates this, finding that many teachers in South Africa face challenges in instructing Euclidean geometry concepts due to insufficient subject content knowledge (CK) and cognitive skills. This suggests that teachers stand to gain significantly from targeted professional development initiatives designed to improve their subject CK and cognitive skills, especially in complex areas such as Euclidean geometry. Therefore, this study is crucial for South African teachers, as it delves into their experiences of improving their competencies of teaching Euclidean geometry proofs. Through this research, teachers can glean insights from the experiences of others and develop effective strategies for tackling challenging topics.

Before 2020, changes in the South African curriculum presented challenges to teachers' competencies in teaching Euclidean geometry. Historically, the assessment of Euclidean geometry was optional until the implementation of the Curriculum Assessment and Policy Statement (CAPS) in 2014, where its assessment became mandatory. Placing Euclidean geometry on an optional paper (Paper 3) had repercussions on teachers' CK, as many educators had not extensively studied Euclidean geometry during both their secondary and tertiary education. Tachie (2020) contends that the fundamental issue contributing to poor geometry teaching lies in the misalignment between teacher education courses and the actual needs of learners in schools. Consequently, these teachers often discover themselves insufficiently equipped to teach Euclidean geometry as expected, lacking familiarity with the necessary skills and strategies (Adolphus, 2011). In Tachie's (2020) research, it was discovered that teachers not only lack subject CK but also struggle with understanding various strategies to effectively teach Euclidean geometry, especially given its practical nature.

Studies have demonstrated the significant role of geometry in mathematics education. Notably, it aids learners in making sense of various mathematical areas such as arithmetic, algebra, and statistics, along with understanding the relationships between function graphs, as highlighted by Binti et al. (2004). Euclidean geometry constitutes about one-third of the total marks in mathematics Paper 2 during the Further Education and Training (FET) phase.

Furthermore, approximately 80% of the Euclidean geometry section in Paper 2 requires learners to prove theorems and riders. This underscores the importance of effectively teaching Euclidean geometry proofs, as it can positively impact not only learners' performance in this specific area but also their overall proficiency in mathematics.

Given these considerations, it is crucial for FET mathematics teachers to proactively enhance their competencies in teaching Euclidean geometry proofs, allowing for the effective implementation of creative teaching methods. Consequently, this study explored how FET mathematics teachers improve their competencies in teaching Euclidean geometry proofs, particularly in the context of the challenges presented by the COVID-19 pandemic lockdown. Considering the current surge in the number of children hospitalised in China due to *Mycoplasma pneumoniae* as of December 2023 (Yan et al., 2024), there is a crucial need to assess whether South African teachers and learners are adequately prepared for e-learning in the event of a future pandemic resulting in similar lockdowns to those experienced during the COVID-19 pandemic.

1.3 PROBLEM STATEMENT

While mathematics teachers in South Africa generally experience problems with teaching Euclidean geometry, the impact of these challenges was further intensified by the reduced teaching time resulting from the lockdowns imposed by COVID-19. According to the research conducted by Chen et al. (2017), increased interaction between teachers and learners during in-person classes, along with extended periods of both learners and teachers being present at school, positively influences academic performance. The COVID-19 pandemic, however, brought about a complete shutdown of schools, resulting in a lack of contact between teachers and learners. In South African schools, the designated instructional time for mathematics in the FET phase is typically four to five hours (240-300 minutes) per week. Contrary to this, Luneta's study in 2021 revealed that, among the schools they examined, only 110 minutes per week were allocated to mathematics. Essentially, this indicates that teachers lost approximately a minimum of two hours and 10 minutes of mathematics instruction each week. Luneta (2021) argued that this loss is substantial on a weekly, termly, and yearly basis, leading to the conclusion that the consistent and systemic reduction of instructional time significantly impacts performance in mathematics. The

situation became even more dire during the COVID-19 pandemic lockdowns, as the global shutdown resulted in the suspension of face-to-face lessons.

While some schools made efforts to sustain teaching through technological platforms, others faced insurmountable challenges, driven by the combination of social, economic, and technological constraints prevalent in rural and poor township areas. In the specific locale of this study, a majority of learners hailed from economically disadvantaged backgrounds, raising concerns about their access to online learning. The reality was that many learners possibly lacked the necessary resources for online education. Research by Hašková et al. (2021) corroborated these challenges, revealing that the shift to online education during the COVID-19 lockdowns presented difficulties for both teachers and learners. The lack of essential facilities, digital skills, and expertise hindered effective implementation of online teaching and learning. Furthermore, the geographical context of the study exacerbated the situation, with limited internet connectivity prevalent in the deep rural areas where most schools in this study were located. The overarching objective of this study was to investigate how teachers adapted to the constraints imposed by the prohibition of face-to-face teaching during the COVID-19 pandemic lockdowns, shedding light on their efforts to develop the necessary skills for online instruction and their competency in geometry proofs.

1.4 THE RATIONALE OF THE STUDY

A substantial body of literature has emerged that focuses on the instruction and acquisition of Euclidean geometry in South Africa, notably since its shift from optional assessment in previous years (e.g., Dhlamini, 2016; Sibiya, 2020; Tachie, 2020, etc.). These studies delve into various aspects, such as effective teaching tools for Euclidean geometry (Sibiya, 2020), essential strategies for teachers when instructing Euclidean geometry (Tachie, 2020), and the competencies required by mathematics teachers to successfully teach this subject (Dhlamini, 2016). Chirinda et al. (2021) spotlight the challenges faced by teachers and learners, emphasising the necessity for digital resources and internet connectivity. Despite these challenges, Mutambara (2022) suggests that social media pedagogies can be employed for mathematics instruction, although these potentially reduce teacher-learner interactions. Sujadi et al. (2023) further underscore the importance of enhanced technological and pedagogical knowledge among teachers to improve online learning.

However, a discernible gap exists in the literature concerning how teachers enhance their competencies in teaching Euclidean geometry when access to workshops organised by the DBE is limited or unavailable. Furthermore, there is a scarcity of literature that delves into teachers' experiences in enhancing their competencies, particularly during the unprecedented circumstances of a global shutdown. Consequently, the researcher of this study was interested in gaining insight into how FET mathematics teachers navigated and enhanced their competencies of teaching Euclidean geometry proofs amid the challenges presented by the lockdowns enforced during the COVID-19 pandemic.

Numerous studies have underscored the advantages of integrating technology into the teaching of Euclidean geometry. For instance, Mudaly (2021) highlighted that technology provides learners with the opportunity to experience mathematics and science dynamically, allowing for the manipulation of diagrams through simple actions such as dragging or implementing code. Furthermore, Mudaly and Mahlaba (2017) found that learners benefit from teacher guidance when utilising sketch pads to solve problems related to cyclic quadrilateral theorems. Additionally, Jones and Tzekaki (2016) pointed out the impact of technological tools on teachers' geometric CK and professional development in geometry education.

However, there remains a gap in the understanding of how mathematics teachers acquire the skills to effectively use these technological tools, especially given that Euclidean geometry was previously assessed optionally. Moreover, the question arises of how teachers continue to enhance their teaching skills, particularly during the COVID-19 pandemic when social distancing is promoted. This aspect, which involves adapting teaching methods to a remote or socially distanced context, is an area that warrants further exploration in the existing literature.

The backdrop of this study is the COVID-19 pandemic, during which schools, training centres, and higher education facilities globally were closed in compliance with regulatory measures, lockdowns, and social distancing protocols. Teachers faced significant challenges in accessing traditional avenues for professional development, such as workshops organised by the DBE or conferences organised by the Association of Mathematics Education for

South Africa (AMESA). These areas are crucial for teachers to advance their understanding of teaching mathematics, including specific areas like Euclidean geometry. While companies like SHARP and Answer Series organise webinars for mathematics teaching (Dwivedi et al., 2020), their effectiveness is hindered by the limited data access for many teachers.

This abrupt transition from conventional face-to-face to online learning necessitated a comprehensive revision of teaching and learning approaches, pedagogical techniques, subject content areas, communication models, and assessments. Teachers found themselves under pressure to implement digital educational curricula while addressing the social, academic, emotional, and mental health needs of learners (Barron Rodriguez et al., 2021). In the current literature, a conspicuous lack of documented exemplary online teaching approaches and research papers presenting strategies for enhancing competencies in utilizing technological tools is evident. Furthermore, literature focusing on teachers' preparedness to integrate technology into their pedagogical practices is limited. These gaps underscore the importance of exploring teachers' experiences of enhancing their competencies of integrating technology into their teaching during COVID-19 pandemic lockdowns.

Examining how teachers adjusted to the new requirement of mandatory online teaching during the COVID-19 pandemic lockdowns becomes crucial, considering this was an unprecedented experience for many educators. Unfortunately, there's a scarcity of literature specifically addressing how teachers enhance their competencies in online teaching within the FET phase, especially in rural South African schools. This gap in understanding the experiences and perspectives of FET teachers regarding online teaching competencies is particularly acute, considering that effective online teaching demands the successful integration of technology, pedagogy, and content knowledge, known as TPACK (technological pedagogical and content knowledge) as highlighted by Mishra and Kohler (2006).

Hence, this research aimed to delve into the experiences and perspectives of FET Mathematics teachers in Harry Gwala district schools, specifically focusing on how they improved their competencies in teaching Euclidean geometry proofs amidst the lockdowns imposed by the COVID-19 pandemic. Comprehending how teachers navigated the difficulties of online teaching within the context of geometry education during these unique

circumstances could offer invaluable insights into effective strategies and practices for teaching in similar scenarios. Amid the recent increase in hospitalised children in China due to *Mycoplasma pneumoniae* as of December 2023 (Yan et al., 2024), it is imperative to evaluate the readiness of South African teachers and learners for online learning. This assessment is crucial, particularly in anticipation of potential pandemics that may necessitate lockdowns similar to those experienced amidst the lockdowns imposed by the COVID-19 pandemic.

1.5 SIGNIFICANCE AND SCOPE OF THE STUDY

The 21st century has witnessed profound social, economic, and technological transformations, shaping an era marked by constant change and innovation. The challenges stemming from these shifts have been widely recognised in academic circles and underscored by the disruptions caused by the COVID-19 pandemic and subsequent lockdowns. Consequently, there has been a continual and at times radical evolution of school curricula. Within this dynamic environment of change and innovation, educational institutions globally have grappled with the imperative to adapt teaching approaches, ensuring that both educators and learners stay abreast of the transformations. Mathematics education, far from being exempt, finds itself strategically positioned to actively engage with these changes and innovations.

It is within this overarching context that the researcher conducted a study aimed at providing a practical exploration for mathematics teachers, academics, researchers, policymakers, and administrators. The research aims to illuminate changes, innovations, and challenges embedded in the teaching and learning of mathematics in the digital age. This endeavour contributes to the ongoing discussion on the continually evolving landscape of education in the 21st century.

In an effort to make a meaningful contribution to the advancement of mathematics education, this study concentrated on exploring the experiences of mathematics teachers as they sought to improve their competencies in teaching Euclidean geometry proofs. The aim was to gain insights into the specific challenges, strategies, and learning processes these educators encountered and utilised in their pursuit of enhancing their teaching abilities in this

mathematical domain. By examining the lived experiences of mathematics teachers, the study aimed to provide valuable insights that can inform and enhance pedagogical practices in the realm of Euclidean geometry proofs within the broader context of mathematics education. These insights have the potential to contribute significantly to a thorough understanding of the changing dynamics in mathematics education. This is particularly relevant in the context of the challenges brought about by remote learning and the ongoing digital transformation of education.

The study was conducted across 15 schools located in the Harry Gwala District of KwaZulu-Natal, South Africa. The focus of this research encompasses mathematics teachers within the Harry Gwala District instructing in the FET phase. The majority of schools in the Harry Gwala District are situated in rural areas, catering to a population with diverse socio-economic backgrounds. These schools face challenges related to limited resources, lacking amenities such as libraries, laboratories, computer rooms, and internet services. The difficulties were further exacerbated by the lockdowns imposed by the COVID-19 pandemic, intensifying the pre-existing challenges faced by the schools in the Harry Gwala District.

1.6 OBJECTIVES OF THE STUDY

The objectives of this study were:

1) To examine how the Harry Gwala District FET mathematics teachers responded to the need for e-learning to teach Euclidean geometry proofs during the COVID-19 pandemic lockdowns.
2) To investigate ways in which Harry Gwala District FET mathematics teachers enhanced their skills of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns.
3) To explore the Harry Gwala District FET mathematics teachers' experiences of enhancing their competencies for teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns.

1.7 RESEARCH QUESTIONS

This study sought to address the following questions:

1) How did FET mathematics teachers from Harry Gwala District respond to the need for e-learning to teach Euclidean geometry proofs during the COVID-19 pandemic lockdowns?
2) In what ways are the FET mathematics teachers from Harry Gwala District enhancing their skills of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns?
3) What are the Harry Gwala District FET mathematics teachers' experiences of improving their competencies for teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns?

1.8 DEFINITION OF TERMS

In this section, the researcher elucidates the meanings of some of the terms utilised in this thesis.

1.8.1 Teachers' experiences

Teachers' experiences refer to the collective range of perceptions, feelings, and insights gained by educators during their professional careers, encompassing the challenges, successes, and evolving perspectives they encounter in various aspects of teaching and learning (Gillis & Mitton-Kükner, 2019). The challenges and support they encounter in these experiences, as well as the role of feeling safe in fostering honest dialogue, are also significant (Gillis & Mitton-Kükner, 2019).

1.8.2 Teachers' competencies

Teachers' competencies encompass a range of knowledge, skills, attitudes, and personal characteristics that enable effective teaching (Cilic et al., 2015). The importance of teacher training and the need for a modern discourse on teacher competencies is emphasised, particularly in the context of changing paradigms in education (Şişman, 2009). The

development of competencies required for teaching, including the ability to use technology, foster transversal competencies, and support individual learner development, is crucial (Augškalne, 2019).

1.8.3 Technological pedagogical and content knowledge

Technological pedagogical and content knowledge (TPACK) is a framework that describes the knowledge base required for effective teaching with technology (Yeh et al., 2014). It encompasses a range of knowledge dimensions, including the use of technology to enhance professionalism and conceptual comprehension (Yeh et al., 2014).

1.9 ORGANISATION OF CHAPTERS

This section highlights the structure of the thesis by presenting a concise overview of each chapter. This thesis is organised into six chapters as follows:

Chapter 1 – Introduction

This chapter serves as an introductory section to the study, providing the reader with essential background information and outlining the reasons for conducting the research. The rationale behind the study is articulated, emphasising the importance and relevance of the chosen topic. Additionally, the chapter highlights the significance of the study, delineates specific research objectives, and poses critical research questions to guide the inquiry. To facilitate understanding, a brief description of the key terms used in this study is also provided.

Chapter 2 – Literature Review

This chapter presents an extensive review of literature concerning teachers' experiences in bolstering their competencies amid the COVID-19 pandemic lockdowns. The researcher presents a comprehensive overview sourced from both local and international references. The context of the COVID-19 lockdowns is introduced, setting the stage for the discussions

to follow. The literature review encompasses an examination of teaching competencies in a broader sense, followed by a specific focus on competencies required for teaching mathematics and, more precisely, teaching Euclidean geometry. The researcher thoroughly explores these competencies, providing a detailed discussion to contextualise their relevance within the study's scope. Finally, the chapter encompasses a review of teachers' experiences to gain understanding into the specific phenomenon under investigation.

Chapter 3 – Theoretical Framework

In this chapter, an in-depth exploration of the theoretical frameworks that form the foundation of this study is presented. The study draws on two primary theoretical frameworks, namely phenomenology and the TPACK framework.

Phenomenology, as a philosophical approach, offers a framework for in-depth exploration of the lived experiences of individuals, particularly teachers in this context, can be thoroughly examined. This framework enables the researcher to explore the essence of teachers' experiences, perceptions, and understandings related to enhancing their competencies, particularly in the unique context of COVID-19 pandemic lockdowns. Concurrently, the TPACK framework offers a structured perspective on the integration of technology, pedagogy, and content knowledge. This framework is particularly relevant in the study's exploration of how teachers navigated the challenges posed by the abrupt transition to online teaching during the pandemic. The TPACK framework serves as a guiding structure to comprehend how teachers amalgamated technological tools, pedagogical approaches, and CK in the specific domain of Euclidean geometry instruction. The synthesis of phenomenology and the TPACK framework provided a robust theoretical foundation, allowing for a nuanced understanding of teachers' experiences and competencies in the dynamically evolving landscape of education during the COVID-19 pandemic lockdowns.

Chapter 4 – Research Methodology

In this chapter, the research methodology utilised to address the research questions of this study is thoroughly expounded. The reader is provided with a detailed description of the

research design, research paradigm, research approach, sample, and sampling strategies. The chapter delves into the specifics of data generation and data analysis techniques employed in the research. Furthermore, the chapter addresses the assurance of trustworthiness in the study, discussing concepts such as transferability, dependability, credibility, and confirmability. These concepts ensure the rigour and reliability of the research findings, providing transparency regarding the methods used to enhance the quality of the study. Ethical considerations in conducting the research are also elucidated, emphasising the ethical principles adhered to throughout the research process. Lastly, the chapter acknowledges and discusses the limitations inherent in the study, providing a comprehensive understanding of the scope and potential constraints of the research.

Chapter 5 – Research findings and Data Analysis

Chapter 5 presents the research findings which are analysed through an interpretative phenomenological approach. The chapter commences with a comprehensive demographic description of the 35 participants involved in the study. The research findings are presented organised according to the three overarching themes that surfaced during data analysis. The chapter systematically addresses the critical research questions by demonstrating how each question is answered through the analysed data and the integration of literature from Chapter 3. The insights gained from participants' responses are compared and contrasted with existing literature, enriching the understanding of the research findings. This approach ensures a comprehensive and coherent response to each research question while strengthening the study's validity and relevance.

Chapter 6 – Discussion of Research Findings, Recommendations, Conclusions

In this concluding chapter, the main findings of the study are summarised, and their implications and contributions are discussed. The chapter concludes with recommendations stemming from the study's findings.

1.10 CONCLUSION

This chapter introduced the study by presenting the background, rationale, and significance of the study. It further outlined the research objectives, research questions, and definitions of terms utilised in this study. Lastly, it highlighted the structure of this thesis by providing a brief synopsis of each chapter of this thesis. The following chapter reviews the relevant literature related to FET mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the researcher conducts a comprehensive review of the available literature related to FET mathematics teachers' experiences in enhancing their competencies for teaching Euclidean geometry during the COVID-19 pandemic. The literature is organised and discussed under the five sections as illustrated in Figure 2.1.

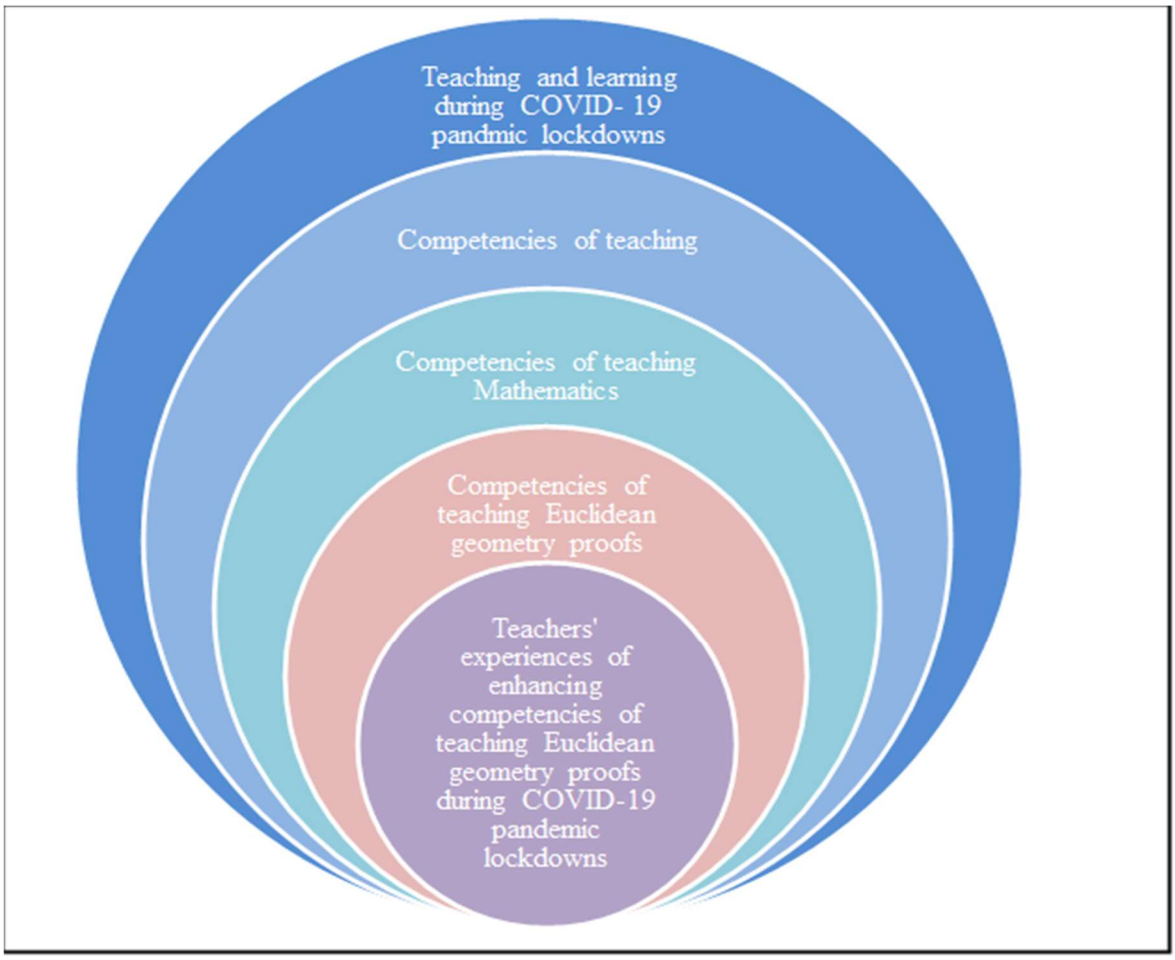


Figure 2.1: Outline of the topics to be discussed in the literature review.

Teaching and learning during COVID-19 pandemic lockdowns: This first section explores the broader context of education amidst the COVID-19 pandemic, particularly the challenges and transformations in teaching and learning practices.

Competencies of teaching: In this section the literature is examined with a focus on the general competencies required for effective teaching. This provides a foundational understanding of the skills and knowledge necessary for successful teaching practices.

Competencies of teaching mathematics: This section narrows the focus to the specific competencies required for teaching mathematics. It delves into the unique challenges and set of skills needed within the context of mathematics education.

Competencies of teaching Euclidean geometry: Here, the literature is reviewed to understand the specialised competencies required for teaching Euclidean geometry. This section provides insights into the distinct challenges and considerations associated with this specific area of mathematics.

Teachers' experiences of teaching Euclidean geometry proofs before COVID-19 lockdowns: This section focuses on mathematics teachers' experiences with teaching Euclidean geometry, specifically proofs and theorems, prior to the COVID-19 pandemic lockdowns.

Teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during COVID-19 pandemic lockdowns: The final section zooms in on the main focus of the study, examining existing literature to understand how teachers have navigated and improved their competencies in teaching Euclidean geometry specifically during the challenges posed by the COVID-19 pandemic lockdowns.

2.2 TEACHING AND LEARNING DURING COVID-19 PANDEMIC LOCKDOWNS

The global teaching and learning process underwent substantial changes due to the COVID-19 pandemic lockdowns. The United Nations Educational, Scientific and Cultural Organization (UNESCO) (2020) notes that many countries suspended face-to-face learning as a response to the pandemic's challenges. Consequently, teachers and learners had to adjust to novel teaching and learning strategies, shifting to remote work from home (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2020). Over 1.5 billion

learners worldwide, spanning from primary school to university levels, were compelled to participate in remote learning, heavily depending on digital educational platforms for this purpose (UNESCO, 2020).

In the United States, face-to-face classes were either cancelled or moved to online learning to cope with the pandemic's impact (Smalley, 2021). China also experienced disruptions, with the Ministry of Education postponing the spring semester in 2020 (Ministry of Education, PRC, 2020). In African countries around 297 million learners faced school closures due to the pandemic lockdowns (UNESCO, 2020). These abrupt shifts from traditional to online teaching methods had both positive and negative impacts on teacher competencies.

2.2.1 Problems associated with pandemic-regulated teaching strategies

The transition to teaching strategies influenced by the pandemic introduced various challenges, as noted by several researchers. Prasetyo (2022) identified key issues such as limited internet and device access, cost constraints, incomplete material delivery, communication limitations, and concerns related to teacher competence. Medellin et al. (2021) emphasised the necessity for innovative teaching strategies to maintain instructional quality in the face of these challenges. Honra (2022) underscored the importance of providing mental and emotional support for teachers during this period of adaptation. Dávila et al. (2022) highlighted the crucial role of pedagogical strategies in addressing these challenges, cautioning that while technology-based solutions can be beneficial, they may also introduce new problems. The collective insights from these researchers contribute to a comprehensive understanding of the multifaceted challenges encountered by educators in the pandemic-influenced teaching environment.

The unexpected onset of the COVID-19 pandemic in 2020 hastened the exposure of difficulties associated with e-learning. Huber and Helm (2020) note that during school lockdowns, teachers, learners, and parents were thrust into an entirely new educational landscape, compelling the exploration of alternative methods to continue teaching and learning. Drossel et al. (2020) highlighted that teachers' primary concerns during lockdowns were maintaining social connections with learners and parents. To address the challenge of

limited interaction, teachers provided various tasks for learners to complete at home (König et al., 2020), and online assessment became a necessity.

Online teaching, often facilitated through video conference systems, became a cornerstone for educational interaction, especially when whole-class assignments were given during COVID-19 closures (Eickelmann and Gerick, 2020). However, many teachers were unfamiliar with online platforms (Fraillon et al., 2020), and their limited experience with information and communication technology (ICT) raised the need for research on how teachers can effectively apply ICT (Fraillon et al., 2020). Baker et al. (2021) emphasized the question of how teachers incorporate technology into pedagogical contexts, supporting the need for understanding the effective use of technology in teaching.

Koning et al. (2020) posed the inquiry regarding the implementation of opportunities for acquiring digital competence, aiming to enhance teachers' skills in digitalization within school. Consequently, this study aimed to explore how mathematics teachers enhanced their skills in teaching Euclidean geometry using digital resources during the COVID-19 pandemic lockdowns. This inquiry is particularly relevant in the context of the broader challenges and opportunities posed by the sudden shift to online and digital teaching methods.

The transition from traditional face-to-face learning to digital learning, necessitated by the COVID-19 pandemic, exacerbated the challenges of poor performance in mathematics. The difficulties faced in 2020 included the failure to cover all topics, an inability to effectively use e-learning, and a lack of necessary skills to teach (DBE, 2020; Tachie, 2020). This review focuses on the essential skills required for teaching mathematics and delves into the experiences of FET mathematics teachers in enhancing their competencies, specifically in teaching Euclidean geometry.

The study explored how teachers addressed the academic losses incurred during the pandemic and sought to improve their teaching abilities, especially in the context of potential shifts from face-to-face to online teaching. The following section of the review examines teachers' competencies in teaching, providing a foundational understanding for the

exploration of the specific challenges and experiences related to teaching Euclidean geometry.

2.3 COMPETENCIES OF TEACHING

The concept of competency has gained prominence in recent literature, particularly in economic, education and societal contexts. In 2006, the European Parliament and the Council of the European Union defined competence as a combination of knowledge, skills, and attitudes relevant to a given context (Halász & Michel, 2011). Ferrari and Punie (2013) expanded on this definition, characterizing competence as the demonstrated capability to apply knowledge, skills, and personal, social, or methodological abilities in various work or study situations, as well as in professional and personal development.

Competency has become a central construct in the educational paradigm, especially in recent years (Stacey & Turner, 2014). The challenges posed by the COVID-19 pandemic lockdowns compelled teachers to reassess and refine their teaching competencies. Scholars such as Bhengu and Blose (2022) argue that teachers must continually develop their competencies to meet the evolving demands of teaching. Additionally, Nessipbayeva (2012) emphasises that the essential requirement for modern educators is to have a repertoire of instructional skills aligned with the demands of the 21st century. Continuous professional development has been identified as a solution to address teachers' lack of skills and to improve examination results (Knox et al., 2015)

This study specifically investigated how FET mathematics teachers enhanced their competencies in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns. The focus on a specialized area within mathematics teaching provided a nuanced exploration of the strategies employed by teachers to navigate the challenges posed by the pandemic in their instructional practices.

Researchers have explored both cognitive and affective motivational dimensions of professional competence in various studies (e.g., Blömeke & Kaiser, 2017). In the upcoming section, the researcher delves into these dimensions.

2.3.1 Cognitive aspects of professional competencies

2.3.1.1 Pedagogical Content Knowledge

In the cognitive realm, researchers make distinctions among teachers' CK, pedagogical content knowledge (PCK), and general pedagogical knowledge (GPK), aligning with Shulman's framework for classifying teacher knowledge (Guerriero, 2017). Proficiency in addressing the fundamental challenges of teaching requires educators to leverage this spectrum of professional knowledge (Shulman, 1987). In a qualitative inquiry into the influence of teachers' subject CK on learner performance in South Africa, Shepherd (2015) concluded that possessing a deep understanding of the subject matter was crucial, and that the teacher's ability to effectively convey this information to learners held great significance. Similarly, Shulman (1987) asserted that possessing CK alone is insufficient; teachers must also have the capacity to present content in a manner that is comprehensible to learners. The discourse above suggests that teachers should continuously enhance their teaching competencies.

Numerous studies have delved into strategies for teachers to develop the teaching competencies. For instance, Burgess (2010) recommended that teachers enhance their knowledge through personal reflection and engaging in discussions with colleagues on specific topics. Zhang et al. (2017) highlighted the significance of teachers' peer support groups which offer opportunities for the improvement of CK. Furthermore, Wessels and Nieuwoudt (2011) outlined various methods for developing CK, including workshops, discussion forums, participation in professional communities, and involvement in peer support groups.

However, the advent of COVID-19 pandemic lockdowns posed unique challenges, with training centers closed and social gatherings restricted to maintain social distancing. Little is known about how teachers enhanced their teaching competencies during this unprecedented era, as teaching in the absence of physical school settings became a novel situation. This study aimed to fill this gap by exploring the experiences of FET mathematics teachers in enhancing their competencies, specifically in teaching Euclidean geometry proofs, during the COVID-19 pandemic lockdowns.

2.3.1.2 Technological knowledge

Given the increasing significance of the ICT transformation in the educational system (Selwyn, 2012), Shulman's categories of teacher knowledge have been expanded to include the expertise required to navigate challenges associated with the use of ICT, termed technological knowledge (TK). Consequently, teachers are expected to possess the capacity to integrate technologies into pedagogical concepts and teaching practices, irrespective of their subject specialisation (Mishra & Kohler, 2006). Digital competency encompassing skills, concepts, approaches, and attitudes, has become a necessity for all teachers engaged in digital learning implementation.

Examining the concept of competency, Jasute and Dagiene (2012) underscored the necessity of digital competency in the teaching and learning of geometry, with a specific focus on teachers' effectiveness in performing tasks in a digital environment. In a report on the project concerning digital competency in Europe, Ferrari and Punie (2013, p. 43) defined digital competency as "the confident, critical, and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion, and/or participation in society." Ferrari and Punie also highlighted that digital competence enables teachers to acquire other competencies such as language, mathematics, learning to learn, and cultural awareness, skills that every citizen in the 21st-century must possess to actively participate in society.

The integration of technological tools in classrooms began as early as the 1980s (Sun and Chen, 2016), with further encouragement propelled by the fourth industrial revolution (4IR). Although online teaching methodologies had been in place for several years already, the COVID-19 pandemic accelerated its widespread adoption. The pandemic necessitated the use of technology for all teachers, as many educational institutions shifted to online learning due to the suspension of face-to-face classes in lockdown situations (UNESCO, 2020). Consequently, TPACK emerged as one of the most crucial competencies for educators.

However, recent studies indicate that a significant portion of teachers have not fully embraced technology in the classroom, citing various reasons such as inadequate time and support, apprehension towards change, and a lack of resources (Fraillon et al., 2020). Despite

the prominence of technological tools, some educators still encounter barriers that hinder their effective utilisation of these resources in their teaching practices.

Moloi and Mhlanga (2021) conducted a study assessing the availability of resources essential for advancing the 4IR in South Africa's basic education system. The study's findings revealed that South Africa is ill-equipped for the challenges posed by the 4IR. Moreover, the results indicated a significant disparity in the competence of teachers between urban and rural areas when it comes to utilising online tools for teaching. Teachers in urban areas demonstrated higher proficiency in using online platforms such as WhatsApp/Google Apps, YouTube, Office 365, MS Teams, and Zoom. In contrast, teachers in rural areas predominantly relied on traditional teaching strategies, such as the chalkboard (Moloi & Mhlanga, 2021). This highlights a digital divide in terms of technological readiness and competencies among educators in different geographical settings.

2.3.2 Affective motivational aspects

2.3.2.1 Self-efficacy

In addition to knowledge and skills, confidence plays a crucial role in effectively implementing teaching strategies. This study focuses on teacher self-efficacy as a vital construct for assessing teacher competence from the perspective of affective motivational factors. According to Bandura (1997), self-efficacy is the belief that teachers hold regarding their abilities to succeed in a specific situation. Teachers' perceptions of efficacy can influence their engagement in an activity, the effort they invest in it, and their ability to overcome more challenging tasks (Tschannen-Moran & Hoy, 2001). Therefore, teachers' self-efficacy serves as a key resource for adapting to new teaching strategies, a particularly pertinent aspect in the context of the challenges posed by the COVID-19 pandemic and associated lockdowns.

Bandura (1977) posits that self-efficacy beliefs influence how individuals feel, think, motivate themselves, and behave. According to Bandura (1977), people regulate their behaviour based on their beliefs, particularly within the domains of outcome expectancy (the ability to produce desired outcomes through commitment and prevent undesirable ones) and

personal efficacy (confidence in one's ability to achieve a goal). Bandura (1977, p. 191) distinguishes these two beliefs, stating, "an efficacy expectation can be defined as a person's conviction that one can successfully execute the behaviour required to produce certain outcomes, whereas an outcome expectation is the estimate that a given behaviour will lead to the outcomes." For instance, individuals may refrain from performing a task either because they doubt that they will achieve the desired outcomes or because they lack confidence in their ability to complete the task.

Both competencies – outcome expectancy, and personal efficacy – are pivotal factors in how individuals construct and navigate their lives to achieve their goals (Bandura, 1977). The landscape of mathematics education is evolving, with teachers expected to adopt new teaching methods such as inquiry-based learning, open-ended teaching, lesson-study models, and e-learning (Anderson et al., 2020). The COVID-19 pandemic and associated lockdowns further prompted a shift from face-to-face learning to online learning, requiring teachers to adapt their approaches. During this period, teachers' behaviour was contingent on their beliefs. Those who believed in their capability to teach using technological tools were more likely to succeed, while those who lacked such belief were prone to challenges. Confidence in utilising online tools became crucial for teachers to effectively achieve the goals of teaching and learning. This study delved into the experiences of FET mathematics teachers as they sought to enhance their competencies in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns.

2.4 COMPETENCIES OF TEACHING MATHEMATICS

A range of studies have explored the competencies required for effective mathematics teaching. Wess et al. (2021) emphasise the importance of developing professional competencies in mathematical modelling for effective mathematics teaching, but there appears to be a gap in the literature regarding the practical implementation and impact of these competencies in online learning platforms. To address this gap, this research delved into ways in which mathematics teachers applied and integrated digital competencies in their instructional practices. This study contributes valuable insights into the practical implications of developing digital competencies for mathematics educators.

The current literature highlights the critical role of teachers' competencies in effectively teaching mathematics, with a specific emphasis on CK and its impact on instructional practices. Pillay et al. (2016) found that mathematics teachers' CK made a significant contribution to effective teaching. This concurs with Venkat and Spaull (2015) who specifically studied FET mathematics teachers in Limpopo and found that teachers lacking subject CK tended to resort to less effective instructional methods such as 'safe talk' supported by notes, constant referral to books, and repetition of examples and exercises.

Additionally, Setyaningrum and Mahmudi (2020) contributes to the literature by revealing that teachers who lack subject knowledge and PCK may deliver incorrect content to learners or skip content, ultimately exacerbating poor performance among learners. These studies collectively underscore the importance of teachers possessing strong CK for successful mathematics instruction. However, a noticeable gap in the literature exists regarding the integration of PCK and how teachers improve these competencies, especially in South African high schools. This study aimed to investigate the interplay between CK and PCK among FET mathematics teachers, seeking a comprehensive understanding of how teachers develop and enhance these competencies. Such insights could be invaluable for guiding targeted teacher training and professional development initiatives.

Teachers' competencies play a crucial role in shaping the quality of mathematics education and learners' performance. This assertion aligns with Spaull’s (2013) argument that the performance of South African learners in mathematics is closely tied to the quality of their teachers. A study by Setyaningrum and Mahmudi (2020) further emphasised the impact of teachers' professional development on learner outcomes. Setyaningrum and Mahmudi (2020) found that learners taught by teachers who did not participate in career professional development exhibited poorer performance in mathematics. The researchers attributed the learners' inferior performance to a lack of learning support for teachers, with principals expressing dissatisfaction with the in-career training of teachers in mathematics. That research underscores the importance of ongoing professional development for teachers in improving learner performance in mathematics. In the context of the COVID-19 pandemic lockdowns, this study aimed to investigate how teachers enhance their competencies in teaching Euclidean geometry. The objective was to address persistent challenges in

mathematics education and contribute to overcoming the ongoing issue of poor performance in mathematics among learners.

Danish education authorities conducted surveys to delineate the concept of mathematical competence in order to address issues related to the quality of mathematics education. The Danish KOM project, where "KOM" stands for "competencies and mathematics learning" in Danish, defined mathematical competence as having knowledge about as well as understanding of, exercising, applying, and relating to and judging mathematics and mathematical activity in various contexts that involve or potentially might involve mathematics (Niss and Højgaard, 2019). Furthermore, Niss and Højgaard (2019) defined mathematical competency as an individual's well-informed readiness to act appropriately in situations involving a certain type of mathematical challenge. The visual representation of the results of the KOM project analysis is presented in Figure 2.2.

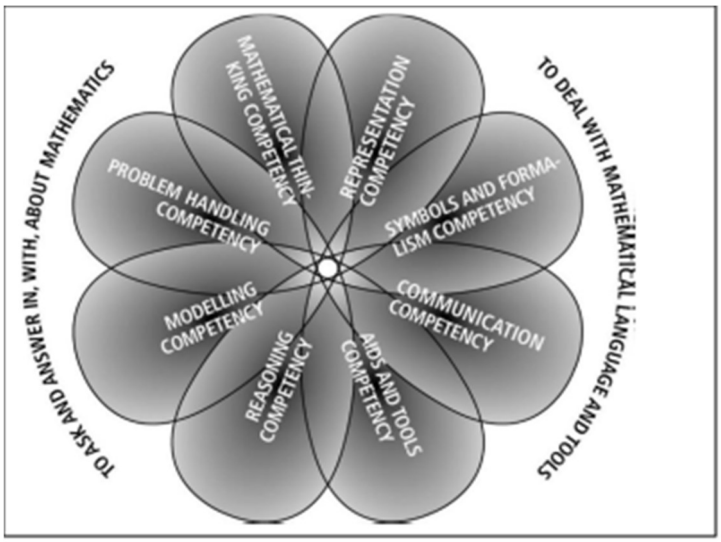


Figure 2.2: A visual representation – the "KOM flower"- of the eight mathematical competencies presented and exemplified in the KOM report
Source: Niss & Højgaard (2019, p. 19)

The Danish KOM project outlined eight mathematical competencies, as depicted in the above diagram. This study specifically aimed to explore how FET mathematics teachers in the Harry Gwala District enhanced their teaching skills in Euclidean geometry proofs during the COVID-19 pandemic lockdowns. Consequently, this review focused on two of the identified competencies from the KOM project: communication competency and aids and tools competency. This selection was motivated by the suspension of face-to-face lessons during the lockdowns, where technological tools played a crucial role in aiding

communication. The following sections offer a critical examination of communication competency and aids and tools competency.

2.4.1 Communication competency

Communication competency is intricately linked with aids and tools competency. According to Geraniou and Jankvist (2019), communication competency involves "the ability to study and interpret others' written, oral, or visual mathematical statements, explanations, or texts, as well as the ability to express oneself mathematically in such ways" (p. 36). In the aftermath of the COVID-19 pandemic ICT served as a pivotal tool for communication between teachers and learners, given the suspension of face-to-face lessons. UNESCO (2020) defines ICT as the combination of informatics technology with other related technologies, specifically communication technology. This encompasses technologies designed to process information and facilitate communication such as desktop and laptop computers, software, peripherals, and internet connections.

Effectively utilising these technological tools requires mathematics teachers to possess a mastery of digital skills (Colombo et al., 2020). This mastery extends to acquiring new skills in online lesson planning and implementation. Consequently, teachers are compelled to enhance their competencies in using digital tools. Regrettably, the existing literature is sparse in documenting teachers' experiences in enhancing their competencies with digital tools.

2.4.2 Aids and tools competency

Aids and tools competency encompasses the knowledge of pertinent tools, including digital tools, utilised in mathematics teaching, along with the ability to proficiently employ such teaching aids (Jankvist et al., 2018). According to Jankvist et al. (2018), mathematics has consistently employed a diverse array of technical aids, serving to represent and uphold mathematical entities and phenomena, as well as to manipulate them in activities like measurements and calculations. This extends beyond ICT encompassing tools such as calculators, computers (inclusive of arithmetic programs, graphic programs, computer algebra, and spreadsheets), as well as traditional aids like tables, slide rules, abacuses, rulers, compasses, protractors, logarithmic and normal distribution paper, among others. Aids and

tools competency pertains to the capacity to adeptly handle and engage with such aids (Jankvist et al., 2018, p. 69).

Several factors contribute to teachers' competencies in teaching mathematics using digital tools. Geraniou and Jankvist (2019) observed that many mathematics educators encounter difficulties in utilising digital tools, including free resources like GeoGebra and Scratch. These challenges stem from contextual and personal factors such as a lack of digital competencies and a diminished confidence in their technological pedagogical knowledge. Similarly, Das (2019) highlighted that teachers' struggles in incorporating maths software into their teaching are closely linked to their lack of confidence and understanding of available technologies.

The existing body of research has identified factors that hinder teachers' competency in using digital tools, underscoring the need for them to enhance their ability to teach through online modes. While numerous studies have explored the effectiveness of digital tools in teaching and learning mathematics (Mudaly, 2021), there remains a significant gap in the literature concerning strategies for teachers to improve their competencies in teaching mathematics using digital tools. This study aimed to address this gap by investigating how mathematics teachers can enhance their skills in teaching Euclidean geometry proofs, with a specific focus on the challenges and strategies employed during the COVID-19 pandemic.

2.5 COMPETENCIES OF TEACHING EUCLIDEAN GEOMETRY PROOFS

While there is a growing body of literature on teaching Euclidean geometry, there is a gap in exploring how teachers enhance their competencies, especially in the absence of traditional workshops and conferences. The COVID-19 pandemic amplified this challenge. Despite the growing literature on teaching Euclidean geometry, there is a gap in understanding how teachers enhance their competencies, especially during COVID-19 pandemic type of lockdowns. The researcher's objectives included exploring FET mathematics teachers' experiences, challenges, and strategies in improving their competencies in teaching Euclidean geometry proofs in this unique context.

Studies underscore the pivotal role of geometry, particularly Euclidean geometry, in the comprehensive teaching of mathematics. Kunimune et al. (2010) assert that Euclidean geometry is a critical area in mathematics education, playing a fundamental role in teaching mathematical argumentation and proof, fostering learners' deductive reasoning, and nurturing critical thinking skills. Additionally, Tanton (2016) highlights that the core skills of logic and reasoning acquired through Euclidean geometry are indispensable for success in academic pursuits, professional endeavours, and various aspects of life.

Considering the points above, it is concerning to note that the South African National Examination Diagnostic reports for 2019 and 2020 reveal a trend of matric learners leaving gaps in Euclidean geometry sections. The absence of in-person teaching due to COVID-19 pandemic lockdowns emerges as a major contributing factor, hindering learners' comprehension of geometric proof development (DBE, 2019 and 2020). Mishra et al. (2020) further emphasised that, during the pandemic, many teachers found themselves ill-equipped to effectively teach Euclidean geometry remotely. The shift from traditional pedagogical approaches to modern methods, such as transitioning from classrooms to virtual platforms like Zoom, and from in-person to virtual interactions, including webinars, posed significant challenges to educators.

In South Africa, the deficiency in teachers' competencies for teaching Euclidean geometry is linked to curriculum reforms in recent years. Notably, the optional status of Euclidean geometry assessment from 2008 to 2013, specifically in paper 3, resulted in a significant gap in teachers' CK. Many teachers did not engage with Euclidean geometry during their schooling or university studies, exacerbating the challenge. With the introduction of the Curriculum Assessment and Policy Statement (CAPS), Euclidean geometry assessment became compulsory, compelling teachers to enhance their competencies in this area.

The researcher conducting this study shares a similar background, having never been exposed to Euclidean geometry in her studies at both the high school and university levels. This study holds particular importance for the researcher and other educators who share this experience, as it aimed to capture teachers' lived experiences in enhancing their competencies for teaching Euclidean geometry proofs.

Woldeab et al. (2023) emphasised the benefits of exploring the lived experiences of individuals in skills development and empowerment. Understanding how teachers overcome challenges in the realm of Euclidean geometry can offer valuable insights for effective strategies in professional growth. Expanding on this notion, Davidson (2015) highlights the significance of learning from the wisdom, strategies, challenges, and successes of others, proposing that such insights play a pivotal role in a journey of recovery or improvement.

The studies cited provide compelling evidence for the necessity of research that explores teachers' experiences in enhancing their competencies, especially in areas like Euclidean geometry that have undergone shifts in assessment and curricular emphasis. This study aimed to fill the identified gap by delving into the lived experiences of teachers facing similar challenges, ultimately contributing valuable insights to the broader field of mathematics education.

2.6 MATHEMATICS TEACHERS' EXPERIENCES OF TEACHING EUCLIDEAN GEOMETRY PROOFS BEFORE COVID-19 PANDEMIC LOCKDOWNS

According to research, mathematics teachers regard proofs as necessary for knowing mathematics and recognize the difficulties associated with teaching them. However, there is a scarcity of material on how teachers might enhance their skills in presenting Euclidean geometry proofs, especially in the absence of workshops. This study investigates teachers' experiences with improving their skills in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns.

Kolb (2014) emphasizes that both teaching and learning proofs and theorems present significant obstacles for educators and students. This issue is well-documented in mathematics education, where the ability to understand and construct proofs is essential yet difficult to master. Learners often struggle with geometric proofs, largely due to the persistent use of traditional, teacher-centered instructional methods (Abdullah & Zakaria, 2013). Despite numerous studies indicating that conventional teaching methods are ineffective for instructing Euclidean geometry (see for example, Mensah-Wonkyi & Adu, 2016; Yılmazer & Keklikci, 2015), many teachers continue to rely on them. In South Africa,

a significant number of teachers tasked with teaching Euclidean geometry under the CAPS curriculum did not study this topic in high school, college, or university (Govender, 2014). These teachers lack not just enough knowledge of Euclidean geometry, but also the pedagogical content knowledge (PCK) required for effective teaching (Mudaly, 2016). Olivier's (2019) survey indicated that many teachers were uncomfortable with the subject and considered their training was inadequate for classroom issues. Empowering these teachers with alternative instructional methods is crucial. Without such support, they are likely to persist with traditional teaching approaches. This study aims to make a significant contribution by showcasing how teachers can improve their competence in teaching Euclidean geometry proofs using digital tools.

2.7 FET MATHEMATICS TEACHERS' EXPERIENCES OF TEACHING EUCLIDEAN GEOMETRY PROOFS DURING COVID-19 PANDEMIC LOCKDOWNS

The COVID-19 pandemic has profoundly impacted education worldwide, forcing educators to navigate uncharted territories in the realm of remote teaching and learning. Among the subjects facing unique challenges, the teaching of Euclidean geometry proofs holds a special place, requiring interactive and visual engagement that is more complex task in virtual settings. This study delves into the experiences of FET mathematics teachers as they grappled with the intricacies of teaching Euclidean geometry proofs during the pandemic-induced lockdowns. The focus is on understanding the challenges faced, innovative strategies employed, and the overall impact on both educators and learners.

The significance of this study lies in the fact that Euclidean geometry, a pivotal aspect of mathematical education, requires a hands-on and visual approach, posing distinct challenges in remote teaching environments. By exploring the lived experiences of FET mathematics teachers, I aimed to unearth valuable insights that can inform future pedagogical practices and contribute to the ongoing discourse on effective mathematics education in times of crisis.

This study is particularly timely and relevant as it captures the unique circumstances brought about by the COVID-19 pandemic, shedding light on the resilience, adaptability, and

creativity demonstrated by mathematics educators in maintaining the quality of Euclidean geometry instruction amidst unprecedented challenges.

A qualitative study aims to explore a phenomenon through an individual's perception, with particular emphasis on the individual's subjective experience of the phenomena under investigation, thus enhancing our understanding of the phenomena (Creswell, 2009). In this study, the researcher sought to gain insight into mathematics teachers' experience of learning how to teach Euclidean geometry during the COVID-19 pandemic lockdowns improved their teaching competencies in this field.

2.7.1 CONCEPTUALISING TEACHERS' EXPERIENCES OF TEACHING

The concept of experience in education has been explored by numerous scholars, including Carl Rogers, Jean Piaget, John Dewey, Lev Vygotsky, Mary Parker Follet, and Paulo Freire (Kolb & Kolb, 2017). While these scholars approach the concept from diverse perspectives, they share a common thread in their agreement with John Dewey's notion of experience, which allows for an integrated approach to education.

John Dewey, a prominent philosopher, characterised experience as a 'natural' phenomenon inherent within the human species, an integral part of our evolutionary makeup (Dewey, 1938). Dewey's philosophy emphasises that experience is not an external entity but rather an internal aspect of human existence. This perspective aligns with the idea that learning is not a detached or isolated process but is deeply embedded within the context of human development and evolution.

Despite the varying perspectives among scholars, the agreement on Dewey's notion of experience suggests a shared recognition of the interconnectedness between learning and the broader human experience. This integrated approach implies that educational practices should acknowledge and leverage the natural and evolving aspects of human experience to enhance the learning process.

The integration of e-learning into teaching and learning practices during the COVID-19 pandemic lockdowns presented teachers with both affordances and challenges, collectively

constituting what we refer to as experiences. According to the National Research Council (2000), experience involves practical contact with and observation of facts or events, leaving a lasting impression on someone. Dewey (1938) extends this definition by emphasising that experience signifies how humans interact with their environment. In the context of this study, teachers' experiences relate to their efforts in enhancing competencies for teaching Euclidean geometry proofs using digital tools, ultimately influencing their success in the learning journey.

Building on this, Kolb and Kolb (2017) posited that knowledge is acquired through the transformation of experience. This implies that the experiences teachers underwent in adapting to digital tools for teaching Euclidean geometry proofs contributed significantly to their knowledge acquisition. Such transformative processes underscore the dynamic nature of learning through experience.

Additionally, Sahin and Yildirim (2016) delineated four stages that signify effective learning: (1) having a concrete experience, (2) observing and reflecting on that experience, (3) forming abstract concepts through analysis and drawing conclusions, and (4) applying these concepts and conclusions in future situations, thereby creating new experiences. These stages align with the cyclical nature of Kolb and Kolb's experiential learning theory, emphasising the importance of reflection, conceptualisation, and application in the learning process.

In essence, this study recognises the multifaceted nature of teachers' experiences in the realm of e-learning and digital tools for teaching Euclidean geometry proofs. By investigating how teachers navigate these experiences, the study aimed to contribute valuable insights into the transformative process of knowledge acquisition and effective learning during the challenging circumstances imposed by the pandemic.

2.8 CONCLUSION

This literature review delved into the multifaceted landscape of teaching mathematics, with a specific focus on Euclidean geometry, digital tools, and the challenges posed by the

COVID-19 pandemic. The integration of e-learning during lockdowns presented both affordances and challenges for educators, shaping what we define as their experiences.

CHAPTER 3: THEORETICAL FRAMEWORK

3.1 INTRODUCTION

In the previous chapter, the literature related to experiences of FET mathematics teachers of enhancing their competencies of teaching Euclidean geometry during COVID-19 pandemic was reviewed. This chapter introduces the theoretical framework that underpins the study. Grant and Osanloo (2014) assert that the theoretical framework in a dissertation encompasses the theoretical principles, constructs, concepts, and tenets of a theory.

Considering that the focal point of this study was teacher competencies in teaching, the researcher employed the TPACK theory to understand these competencies. Additionally, the researcher sought insight into teachers' experiences in enhancing their competencies of teaching Euclidean geometry during COVID-19 pandemic lockdowns, to which end the phenomenological approach was employed.

Technological pedagogical content knowledge extends Shulman's PCK by incorporating technology knowledge within the realms of content and pedagogical understanding. In contrast, phenomenology is rooted in the lived experiences of FET mathematics teachers.

Grant and Osanloo (2014) emphasise that the theoretical framework is where the epistemological perspective of the study, encompassing the problem, purpose, significance, research question, literature, and study analysis, is presented. Consequently, a theoretical framework serves as a valuable tool for the researcher. It facilitates a comprehensive review of core theories, philosophies, assumptions, and methodological techniques relevant to the study. Moreover, it forms the foundation for developing instruments for data collection.

Grant and Osanloo (2014) go on to assert that the theoretical framework represents the essence of the research, encompassing its philosophy, epistemology, methodology, and analytical approach. In a parallel vein, Bertram and Christiansen (2014) define research as a systematic procedure for collecting and analysing data to enhance our understanding of the focused phenomena. Thus, the theoretical framework is deemed essential for this study.

This study adopts a descriptive and interpretive qualitative case study approach, emphasising the necessity of incorporating a theoretical framework. According to Yin (2014), a case study is helpful in comprehending complex social phenomena and real-life events. Fischer (2010) further argues that the purpose of theory is to conceptualise and attribute meaning to intricate observations of phenomena and systematic behaviours.

In this study, the researcher endeavoured to explore the experiences of FET mathematics teachers in teaching Euclidean geometry proofs, and to understand the methods they employ to enhance their competencies in this domain. The TPACK framework serves as the foundational framework for this study, as it encapsulates the essential knowledge that teachers must possess to effectively instruct their students (Mishra and Koehler, 2006).

To guide the discussion of each theory—TPACK and phenomenology—the researcher utilised the following outline.

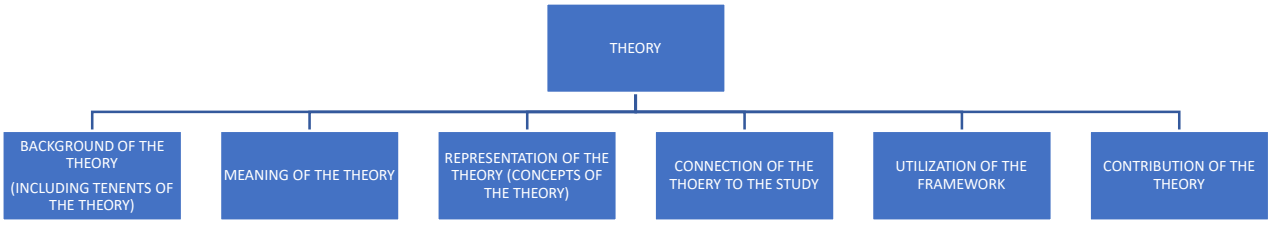


Figure 3.1: The outline of the theoretical framework chapter

3.2 BACKGROUND OF FRAMEWORK FOR TEACHER COMPETENCIES

In this section, the researcher traces the history of teacher competency frameworks. Teacher competencies include the relevant knowledge, skills, and values for the successful accomplishment of a task (Bakhru, 2017). According to Shulman (1986) teacher knowledge refers to the amount and organisation of knowledge in the mind of a teacher. Shulman (1987) suggested that teachers should have diverse types of knowledge which they can use to "explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions, both within the discipline and without, both in theory and practice" (p. 9). Shulman is supported by Jackson (1990) who stated that teachers must possess a variety of competencies to maximise learner learning in a complex environment where they must make hundreds of critical decisions each day. According to Shulman (1987), teachers draw upon seven sets of knowledge, namely: knowledge of subject matter, GPK, PCK, CK, knowledge of educational context, knowledge of learner thinking and learning, as well as knowledge of educational aims and goals.

In this section, the researcher delves into the historical evolution of teacher competency frameworks, emphasising the integral role of knowledge, skills, and values in achieving successful teaching outcomes (Bakhru, 2017). Shulman's (1986) conceptualisation of teacher knowledge, defined as the quantity and organisation of information within a teacher's mind, serves as a foundational perspective. Shulman (1987) posits that teachers should possess diverse knowledge types, enabling them to elucidate the justification, significance, and interrelations of propositions across disciplines, both theoretically and practically.

Recent literature underscores the ongoing relevance of Shulman's insights. Contemporary scholars, such as Nielsen and Lund (2020), emphasise the need for educators to navigate complex learning environments by cultivating a spectrum of competencies, as advocated by Jackson (1990). In dynamic educational settings, teachers are confronted with hundreds of critical decisions daily, necessitating a comprehensive skill set for maximising learner learning outcomes.

Shulman's (1987) taxonomy of teacher knowledge remains influential, as confirmed by Nielsen and Lund (2020), for example.

As the field of education continually evolves, the synthesis of historical perspectives with contemporary literature provides a comprehensive understanding of the multifaceted nature of teacher competencies and knowledge frameworks. Future research may further explore emerging dimensions and refine existing frameworks in response to the ever-changing landscape of education.

The incorporation of Shulman's (1987) concept of teacher knowledge aligns seamlessly with the broader framework of teachers' competencies as articulated by Selvi (2010). Selvi's framework encompasses nine distinct dimensions, namely, field competencies, research competencies, curriculum competencies, life-long learning competencies, social-cultural competencies, emotional competencies, communication competencies, ICT competencies, and environmental competencies.

This study places specific emphasis on ICT competencies, a dimension described by Selvi (2010) as follows:

> ICT competencies are rooted in the utilisation of tools and technical equipment for the creation, distribution, and transfer of knowledge. This encompasses any technology facilitating the generation, manipulation, storage, communication, and/or dissemination of information. ICT competencies revolve around the adept use of technology in managing and processing information, encompassing all technologies involved in the manipulation and communication of information. (p. 6)

Selvi's delineation of ICT competencies underscores the evolving role of technology in the educational landscape and emphasises the multifaceted nature of teachers' skills in integrating ICT into their teaching practices. As technology plays an increasingly pivotal role in education, understanding and cultivating, ICT competencies among teachers is imperative for fostering effective and contemporary teaching methodologies. The intersection of Shulman's (1987) foundational ideas with Selvi's comprehensive framework further enriches our understanding of the diverse dimensions constituting teachers' competencies in the modern educational context.

Historically, the exploration of teacher knowledge predominantly centred on teachers' CK (Shulman, 1986). Over the past few decades, there has been a noteworthy shift in research focus, with scholars directing their attention towards pedagogy independent of CK (Ball & McDiarmid, 1990). This shift prompted Shulman (1987) to assert that teachers' subject matter knowledge and pedagogical expertise should not be regarded as mutually exclusive domains.

Shulman argued against the notion that possessing knowledge of subject matter and general pedagogical strategies alone was sufficient for effective teaching. Instead, the author contended that teachers must concurrently address issues related to both content and pedagogy to achieve success in their teaching endeavours. To address this dual requirement, Shulman proposed the concept of PCK, signifying an intersection between pedagogy and content (Shulman, 1986).

The introduction of PCK represented a significant advancement in the theory of teacher knowledge. Shulman's conceptualisation acknowledged the interdependence of pedagogy and CK, highlighting the nuanced ways in which teachers must navigate and integrate both aspects to optimise their instructional practices. This perspective has since become a cornerstone in understanding the complexities of effective teaching and has spurred further research and development in the field of teacher education and professional development.

Shulman's (1986, p. 9) seminal definition characterises PCK as the specialised knowledge that pertains to the teaching process, encompassing the methods of representing and articulating subject matter to render it comprehensible to others. This concept underscores the significance of not only possessing subject matter expertise but also the ability to effectively convey that knowledge through pedagogical strategies.

Building on Shulman's foundation, Mishra and Koehler (2006) further elaborate that PCK specifically involves how a teacher, in this instance, a mathematics teacher, presents mathematical content in a manner that is accessible and understandable to learners. PCK, according to Mishra and Koehler, empowers teachers to discern various forms of presenting content for meaningful learning experiences. This includes an awareness of the factors that

can make certain concepts challenging or straightforward, and the ability to formulate strategies that address learner difficulties and misconceptions (Shulman, 1986).

In essence, PCK equips educators with the insight and skills to navigate the intersection of pedagogy and CK. It goes beyond the mere possession of subject matter expertise by emphasising the crucial dimension of how that knowledge is translated and communicated effectively in the teaching and learning process. As an integral component of teacher knowledge, PCK enhances educators' ability to adapt their instructional methods to suit the diverse needs and understanding levels of their learners.

Shulman's (1987) conceptualisation of teacher competencies has served as a robust theoretical framework for this study, enriching the researchers' comprehension of the essential competencies required for effective teaching. However, it is noteworthy that Shulman's constructs of teacher knowledge have undergone redefinition, extension, and critique by various scholars (e.g., Ball et al., 2008; Cochran et al., 1993; Mishra & Koehler, 2006).

One significant extension of Shulman's work is evident in the contributions of Mishra and Koehler (2006), who broadened Shulman's notion of (PCK) to include the integration of technology. This augmentation led to the development of the TPACK framework. In the following section, the researcher delves into the TPACK theory, proposed by Mishra and Koehler, which extends Shulman's PCK by incorporating technology as an integral component. This evolution reflects the recognition of the changing educational landscape and the growing importance of technology in teaching practices.

3.2.1 The TPACK theory of teacher knowledge

The literature reflects ongoing discussions regarding the abbreviation for technological and pedagogical content knowledge theory. There is a divergence in practice, with some researchers opting for TPCK (Knolton, 2014) and others employing TPACK (Schmid et al., 2021). Ruthven (2014) has contributed to this conversation by distinguishing between TPCK and TPACK, stating that TPCK is sometimes utilised to denote the intersection of

technological, pedagogical, and CK areas in the Venn diagram, while TPACK refers to the entire framework.

The TPACK framework is visually represented through overlapping circles on a Venn diagram, illustrating the intersections of different teacher knowledge domains (see Figure 3.2). In this study, the researcher opts to use TPACK to refer to the entire framework, aligning with the holistic depiction of teacher knowledge integration. The choice to use the abbreviation TPACK provides clarity and consistency in terminology throughout the study. The ongoing discourse regarding the nomenclature highlights the dynamic nature of educational research and the importance of precision in communication within the scholarly community.

Given the specific focus of this study on FET mathematics teachers' experiences in enhancing their competencies for teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns, it is logical to adopt a theoretical framework that places a strong emphasis on technology. The context of the COVID-19 pandemic, marked by the suspension of face-to-face lessons and the necessity of online teaching, underscores the pivotal role of technology in the teaching and learning landscape.

During the pandemic technology shifted from being a supplementary tool to an essential component of effective teaching. In this challenging context, the knowledge of how to incorporate technology into teaching emerged as a critical aspect of teacher competence. The shift to online instruction compelled teachers to quickly acquire the skills and knowledge needed to navigate the digital realm and integrate technology seamlessly with content and teaching methodologies.

Therefore, the theoretical framework for this study should reflect the heightened importance of TK and skills in the wake of the COVID-19 pandemic. The TPACK theoretical lens captures this dynamic integration of technology, content, and pedagogy. The TPACK framework recognises the interconnected nature of these three domains so is relevant when exploring how teachers adapted and enhanced their competencies in the context of technology-mediated teaching during the COVID-19 lockdowns.

By adopting the TPACK framework, this study was able to capture the nuanced interactions between technology, pedagogy, and CK as FET mathematics teachers navigated the challenges posed by the pandemic by developing and integrating technological competencies into their teaching practices.

Mishra and Koehler (2006) introduced the TPACK model in response to the rapid evolution of ICT in the educational system. This model extends Shulman's constructs of PCK by incorporating technology, acknowledging the dynamic landscape of educational technologies. When Shulman initially proposed PCK, the available technologies, such as whiteboards, overhead projectors, and charts, were not as diverse as they are today (Mishra & Koehler, 2006).

The imperative for online learning during the pandemic shifted the focus to technologies conducive to remote instruction. In the contemporary educational context, prevalent technologies include computers, cell phones, educational games, simulations, smartboards, and the internet. This shift in technology usage necessitated new techniques and skills for effectively incorporating technology into teaching practices.

Mishra and Koehler (2006) concurred with Shulman that knowledge of technology should not be considered separate and independent from other forms of knowledge such as PK and CK. They argued against the isolation of TK, emphasising the interconnectedness of technology with pedagogy and content. This viewpoint has garnered support from various scholars who contend that effective teaching requires a comprehensive understanding of how technology correlates with pedagogy and content (Hughes, 2005).

Numerous studies have delved into the examination of TPACK skills across various teaching domains. For instance, research has explored TPACK skills among mathematics teachers (Akkoç, 2011), science teachers (Lin et al., 2013), and English teachers (Wang, 2022). In a similar vein, this study aimed to explore the FET mathematics competencies related to teaching Euclidean geometry proofs.

The TPACK model has been widely employed by scholars globally as a framework for understanding teacher competencies in effective teaching. For instance, Habibi et al (2020)

utilised TPACK as a data collection instrument in their study, exploring the relationships among TPACK components through the experiences of pre-service teachers. Similarly, Fuad et al. (2020) employed the TPACK framework to measure and evaluate teacher knowledge that fosters effective student learning. Their justification for using the TPACK model centred on its potential to serve as a foundation for enhancing teaching and training programs for both current and aspiring teachers.

In alignment with this global trend, the current study utilises the TPACK framework to assess how FET mathematics teachers improved their instruction of Euclidean geometry proofs, particularly in a context where traditional workshops were limited during the COVID-19 pandemic lockdowns. By adopting TPACK, this research study sought to provide a structured and comprehensive framework that addressed the unique challenges posed by the pandemic and facilitates the enhancement of teachers' competencies in integrating technology, pedagogy, and CK for effective online instruction in Euclidean geometry proofs.

Koehler et al. (2007) introduced TPACK training as a constructivist and project-based approach. They highlighted that the components of the TPACK model embrace constructivist and project-based methodologies, such as learning-by-doing, problem-based learning, collaborative learning frameworks, and design-based learning. This approach emphasises hands-on, experiential learning that actively engages educators in the integration of technology, pedagogy, and CK.

Building on this perspective, Chai et al. (2013) identified five dimensions of purposeful learning that can enhance teachers' TPACK skills. These dimensions include authenticity, deliberation, activeness, constructiveness, and collaboration in learning. Authenticity emphasises real-world relevance, ensuring that the learning experiences align with the practical challenges and contexts faced by educators. Deliberation involves thoughtful consideration and reflection, encouraging teachers to critically assess and refine their TPACK skills. Activeness underscores the importance of active participation and engagement in the learning process. Constructiveness centres on the creation of meaningful artefacts and applications, encouraging teachers to build tangible outcomes that demonstrate their understanding and application of TPACK. Collaboration in learning recognises the

value of shared knowledge and experiences, promoting collaborative efforts among educators to enhance their collective TPACK skills.

By integrating these purposeful learning dimensions into TPACK training, educators are provided with a comprehensive and effective framework for developing their technological, pedagogical, and CK in a meaningful and contextually relevant manner. This approach aligns with contemporary educational principles that emphasise active, collaborative, and project-based learning strategies.

Shu and Radio (2016) characterise TPACK as a theoretical framework aimed at understanding the teacher knowledge necessary for effective integration of technology into teaching (2016, p. 2). Similarly, Hechter et al. (2012) defined the TPACK model as a pedagogical construct that guides teachers in designing learning processes that consider prior experiences of both teachers and learners, including perceptions, attitudes, and beliefs, using various technologies.

Mishra and Koehler (2006) provided a comprehensive definition of TPACK, framing it as a technology integration framework that highlights the necessity for teachers to seamlessly combine three key types of knowledge: content, pedagogy, and technology. The intersection of these three knowledge sources creates four distinct knowledge bases, resulting in seven knowledge domains (as illustrated in Figure 3.2). The core components of TPACK theory can be summarised as follows:

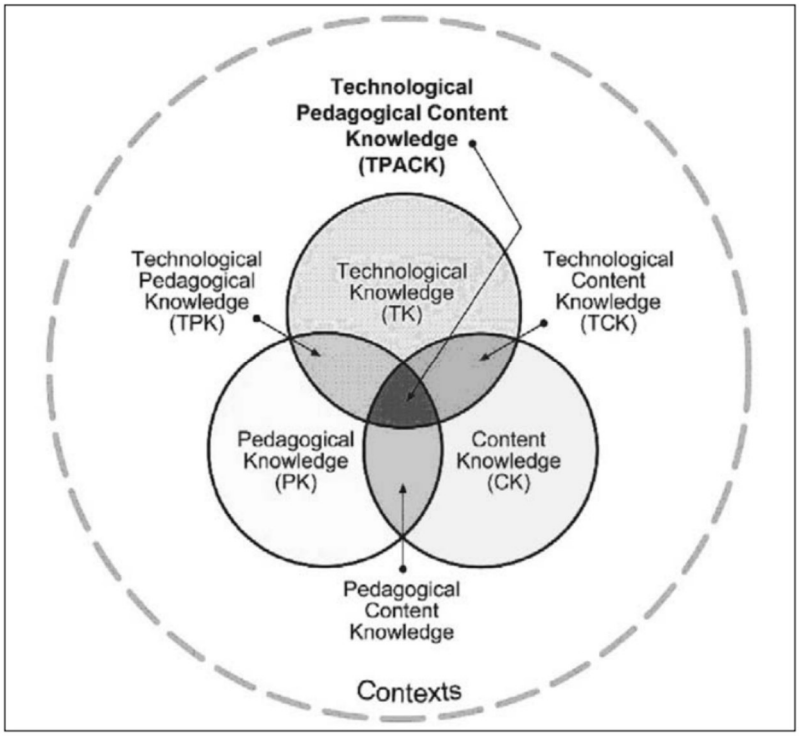


Figure 3.2: The components of the TPACK framework
Source: http://tpack.org.

1. Content knowledge

This aspect of the TPACK theory emphasises the importance of possessing in-depth knowledge of the specific subject matter to be taught. The content covered in Euclidean geometry differs significantly from that in other subjects, such as the physical sciences. Therefore, teachers need a profound understanding of the content within their domain. For example, mathematics teachers, when instructing Euclidean geometry, must possess a clear comprehension of central facts, theories, concepts, and procedures (Shulman, 1986).

Moreover, mathematics teachers are required to articulate, organise, and establish connections between ideas, demonstrating a comprehensive understanding of mathematical rules and proofs in the context of Euclidean geometry (Shulman, 1986). Tachie (2020) highlighted that a considerable number of teachers struggle with teaching geometry due to deficiencies in subject CK. This underscores the critical need for mathematics teachers to enhance their Euclidean geometry CK actively and continuously.

2. Pedagogical knowledge

Pedagogical knowledge constitutes the understanding of effective teaching strategies and instructional methods. This knowledge encompasses the discernment of when it is appropriate to employ various teaching techniques, such as collaborative learning, direct instruction, inquiry learning, and problem-solving (Schmidt et al., 2009). According to Carr and Skinner (2009), teachers should possess a repertoire of effective teaching approaches, techniques, and strategies to inform their teaching programmes and lessons.

PK extends to cover a broad spectrum of aspects related to learning, including lesson planning, lesson presentation, classroom management, and assessment of learners (Mishra and Koehler, 2006). Bibi and Khan (2017) align with Mishra and Koehler's perspective, emphasising that pedagogical knowledge involves the ability to capture learners' attention and deliver lessons effectively. Teachers endowed with strong PK comprehend how learners construct meaning and can adjust their teaching strategies to enhance learner learning outcomes (Mishra & Koehler, 2006).

In the context of mathematics teaching, particularly in Euclidean geometry, teachers with robust pedagogical knowledge understand both the social and cognitive theories of learning that pertain to this mathematical domain. This understanding allows them to apply appropriate teaching strategies that resonate with their learners, ensuring meaningful engagement and effective comprehension of Euclidean geometry concepts. Overall, the cultivation of PK is essential for effective teaching.

3. Technological knowledge

Technological knowledge encompasses teachers' skills in utilising a diverse array of technological tools during teaching. Specifically, TK reflects teachers' proficiency in employing computer hardware systems and software applications, such as spreadsheets, web browsers, emails, and other digital resources (Mishra and Koehler, 2006). The COVID-19 pandemic lockdowns necessitated a significant shift towards online learning, underscoring the indispensable role of TK in the TPACK framework. During this challenging period, teachers faced the imperative to adapt and use a variety of computing tools, including cell

phones, smartphones, laptops, iPods, iPads, and other devices, to effectively communicate with and instruct their learners in virtual settings.

In essence, TK became a critical component of TPACK as teachers had to leverage technology not only for instructional purposes but also for communication and engagement with learners in the online learning environment. The ability to navigate and integrate these technological tools into teaching practices became essential for educators to ensure continuity in education despite the disruptions caused by the pandemic.

4. Pedagogical content knowledge

Pedagogical content knowledge arises at the intersection of PK and CK, in accordance with Shulman's conceptualisation of teacher knowledge, as discussed earlier. In the context of this study, teachers were required to possess PCK to proficiently implement online learning.

PCK represents the nuanced understanding of how to teach specific content effectively. In the realm of online learning, teachers with strong PCK not only have a solid grasp of the subject matter (CK) but also possess the pedagogical expertise (PK) to convey that content in ways that engage and facilitate meaningful learning experiences for students. This includes knowing how to adapt instructional strategies, assessments, and learning activities to the online environment, considering the unique challenges and opportunities it presents.

As online learning became a predominant mode of instruction during the COVID-19 pandemic lockdowns, the importance of PCK became more pronounced. Teachers needed to navigate the digital landscape with a seamless integration of pedagogical and CK to deliver effective and engaging online lessons. The ability to translate traditional teaching practices into effective online instruction required a skilful blend of content expertise and pedagogical acumen, emphasising the significance of PCK in the dynamic educational landscape.

5. Technological content knowledge

Technological content knowledge refers to knowledge about technology that can be utilised to understand subject content (Fuad et al., 2020). Numerous scholars have reported on the positive impact of digital technologies on teaching and learning in the classroom. Pinto and Leite (2020) states that technologies, specifically learning management systems, encourage active engagement and participation in the learning process. This finding was corroborated by Johnson (2020), who affirms that the utilisation of digital tools improves learning outcomes and contributes to the overall effectiveness of the learning environment. Furthermore, Mudaly and Mahlaba (2017) emphasise that learners often require guidance from teachers when using sketch pads to solve problems, illustrating the importance of teachers possessing technological CK for effective classroom instruction.

In the present study, the researcher delved into how FET mathematics teachers enhanced their competencies in teaching Euclidean geometry proofs amid the challenges posed by the COVID-19 pandemic lockdowns. The exploration of TCK becomes particularly relevant in understanding how teachers integrate technology into the teaching of specific subject content, such as Euclidean geometry, in the context of online and remote learning environments.

6. Technological pedagogical knowledge

Technological pedagogical knowledge involves the understanding of how technology and pedagogy can be effectively integrated to enhance teaching and learning experiences (Mishra & Koehler, 2006). It signifies the capability to select appropriate technology to support optimal teaching approaches (Fuad et al., 2020). Teachers with strong TPK can choose technologies that enhance learner learning outcomes. In the realm of mathematics education, various technologies serve as valuable tools, such as GeoGebra, recognised for teaching functions (Mudaly & Uddin, 2016), and sketchpad, employed as a tool for learning Euclidean geometry (Mudaly & Mahlaba, 2017).

Moreover, Mishra and Koehler (2006) emphasised that TPK extends to the knowledge of tools for maintaining class records, tracking learner attendance, and managing learners'

grades. This aspect of TPK highlights the administrative and organisational uses of technology in education. Various resources, including Google Classrooms, WhatsApp, Zoom, and Microsoft Teams, enable teachers to collaborate effectively with their learners, fostering communication and interaction in virtual learning environments (Fuad et al., 2020). The ability to integrate these diverse technological tools into pedagogical practices is a hallmark of effective TPK, ensuring a seamless alignment of technology with instructional goals and strategies.

7. Technological pedagogical content knowledge

According to Mishra and Koehler (2006), technological pedagogical content knowledge (TPCK) underscores the interrelationship of content, pedagogy, and technology. Mishra and Koehler provide the following definition of TPCK:

> TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that learners face; knowledge of learners' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. (Mishra and Koehler, 2006, p. 1029)

This comprehensive definition encapsulates the multifaceted nature of TPCK, emphasising the need for teachers to integrate their understanding of content, pedagogy, and technology in a harmonious and effective manner. Technological pedagogical content knowledge serves as the foundation for effective teaching with technology, requiring a nuanced understanding of how to leverage technology to represent concepts, employ pedagogical techniques, address learning challenges, recognise students' prior knowledge, and strategically use technology to enhance and build on existing knowledge. This holistic perspective underscores the complexity and significance of TPCK in the educational landscape.

3.2.2 Connecting TPACK to the study

The integration of the TPACK model into this research is well-aligned with the research questions, following the principle of complementarity suggested by Grant and Osanloo (2014). They argue that research questions and the theoretical framework should exhibit a complementary relationship, where the theoretical framework points out existing knowledge, and the research questions act as a bridge between that existing knowledge and the problem addressed by the research.

In the case of this study, the TPACK theory, which focuses on how teachers can effectively integrate technology into their teaching practices, complemented the research questions. The TPACK model was particularly relevant in addressing the first research question, which explored how FET mathematics teachers from the Harry Gwala District responded to the call for e-learning to teach Euclidean geometry proofs during the COVID-19 pandemic.

By incorporating the TPACK framework, the research was guided in understanding how teachers navigated the integration of technology (TK) with effective pedagogical strategies (PK) to teach specific content (CK), which, in this context, was Euclidean geometry proofs. The TPACK model, therefore, served as a valuable lens for examining the intricacies of technology integration in the specific domain of mathematics teaching, especially during the unique challenges posed by the pandemic. The TPACK theory, in essence, enhanced the research questions by providing a theoretical underpinning that aligned with the focus on technology, pedagogy, and CK, offering insights into how teachers grapple with these interrelated components in the context of e-learning during the COVID-19 pandemic.

The TPACK theory served as the guiding framework for this study, providing a solid foundation that informed the construction of knowledge regarding mathematics teachers' experiences in enhancing their competencies of teaching Euclidean geometry proofs. Grant and Osanloo (2014) highlight the crucial role of theoretical frameworks in supporting the rationale for the study, framing the problem statement, clarifying the purpose, emphasising the significance, and aiding the researcher in addressing research questions. Theoretical frameworks are integral in grounding the literature review and, most importantly, shaping the methods and analysis employed in the study.

In the context of this study, the integration of the TPACK model with the problem statement, literature review, methodology, analysis, and findings, is pivotal. The study's problem statement is intricately connected to the TPACK framework, as it centres on the specific challenges and opportunities faced by mathematics teachers in enhancing their competencies amid the unique circumstances of the pandemic. The literature review is enriched by TPACK, offering a theoretical lens through which the existing body of knowledge on teacher competencies and technology integration in education is critically examined.

Methodologically, TPACK informed the choices made in designing the study, including the selection of research instruments, data collection methods, and analytical approaches. The analysis phase was guided by the TPACK framework, allowing for a nuanced interpretation of the findings in the context of the interplay between technological, pedagogical, and content knowledge.

In summary, the integration of the TPACK theory into the various facets of the study ensured a comprehensive and theoretically grounded exploration of mathematics teachers' experiences in enhancing their competencies of teaching Euclidean geometry proofs, particularly in the unprecedented circumstances brought about by the COVID-19 pandemic lockdowns.

3.3 THEORETICAL FRAMEWORK FOR TEACHER EXPERIENCES

The TPACK theory highlights the crucial role of technology in teaching and the development of constructivist pedagogical practices. Understanding teachers' experiences in enhancing their competencies in using technology, particularly in the absence of workshops or limited opportunities during the COVID-19 pandemic, is imperative. When social gatherings were restricted, traditional platforms for teacher development, such as workshops and seminars, were scarce. In response, teachers had to adopt self-developmental strategies to sustain their teaching practices during the lockdowns.

In light of these circumstances, the researcher adopted phenomenology as the most suitable theoretical framework and methodological approach for studying teachers' lived

experiences. Phenomenology, as a qualitative research method, allows for an in-depth exploration of individuals' experiences, providing valuable insights into how teachers adapted to using technology in the dynamically evolving landscape of education during the COVID-19 pandemic. The combination of phenomenology as a theoretical framework and the TPACK model offered a robust foundation for studying teachers' lived experiences in the context of them enhancing their competencies in teaching using technology during the COVID-19 pandemic lockdowns.

The main objective of phenomenology is to investigate and describe lived experiences directly from the participants' perspective, without preconceptions and casual theories (Husserl, 1970). In the context of the COVID-19 pandemic, which presented a novel and unprecedented phenomenon, there were insufficient theories to explain how teachers could enhance their competencies of teaching during unexpected disruptions, such as a global shutdown. Phenomenology is considered an appropriate approach when little is known about a phenomenon because it "seeks to describe the essence of a phenomenon by exploring it from the perspective of those who have experienced it" (Teherani et al., 2015).

Greckhamer and Koro-Ljungberg (2005) assert that every research study is an epistemological journey with philosophical underpinnings. Similarly, phenomenology has a philosophical background that aids in understanding the context of the study and ensures the researcher conducts sound and rigorous research. In the subsequent section, the researcher introduces phenomenology, elucidates its philosophical underpinnings, and delves into the phenomenological concepts, relating them to teachers' experiences.

3.4 BACKGROUND OF THEORETICAL FRAMEWORK FOR TEACHER EXPERIENCES

The philosophical underpinnings of phenomenology, rooted in the works of philosophers like Edmund Husserl and Martin Heidegger, emphasise the importance of understanding human consciousness and the subjective nature of lived experiences. Phenomenology seeks to uncover the essence of phenomena by capturing the unique meanings individuals attribute to their experiences. This aligns with the research objective of exploring how teachers, in

the absence of established frameworks, autonomously developed their competencies during the pandemic.

To date, diverse theories and research methodologies have been employed to study experiences. For instance, Verhagen et al. (2016) utilised the experience sampling method (ESM), which generally emphasises breadth rather than the depth of experience. In contrast, other researchers have opted for qualitative methods that delve into experiences in greater depth, such as grounded theory (Corbin and Strauss, 2008; Glaser and Strauss, 2017; Khan, 2014). Grounded theory generates theories from emerging ideas in collected data rather than relying on existing theories.

Other qualitative methods, including phenomenography and autoethnography, have been used to varying extents. Autoethnography aims to explore an individual's own experiences (Schwandt, 2014), while phenomenography investigates the different ways in which people experience a phenomenon, focusing on the variations in experiences rather than individual experiences (Marton, 1981). Each of these research methodologies has made significant contributions to educational research knowledge. However, phenomenology stands out as the only research method specifically designed for studying experience and its meaning.

Phenomenology, among various qualitative approaches, serves as a theoretical framework and method explicitly crafted to study lived experiences of phenomena from the perspective of those who live them (Giorgi, 1985; Moustakas, 1994; van Manen, 1990). Consequently, phenomenology is particularly suitable for studies aiming to gain a deeper understanding of various individuals' experiences of a phenomenon (Creswell, 2007). Its focus on exploring the essence of lived experiences aligns well with the objective of studying teachers' experiences and competencies during the unprecedented disruptions of the COVID-19 pandemic.

Phenomenology has found applications across various disciplines, including environmental studies, pedagogy, nursing, and psychology (Earl, 2010; Meyer & Carlson, 2010). Although phenomenology has been practised for centuries, it was explicitly articulated in the philosophical works of Edmund Husserl (Audi, 2022; Husserl, 1970; Moustakas, 1994). Edmund Husserl is recognised as the founder of phenomenology, having developed it as

both a theoretical framework and a methodological approach for studying individuals' lived experiences of phenomena (Audi, 2022; Husserl, 1970a; Moustakas, 1994). Gillis and Mitton-Kükner (2019) also note that phenomenology is both a philosophical movement and a group of qualitative research methodologies.

In alignment with this heritage, the current study employed phenomenology as both a theoretical framework and a methodological approach to explore the essence of individuals' lived experiences, specifically focusing on mathematics teachers' experiences of enhancing their competencies in teaching Euclidean geometry during the COVID-19 pandemic lockdowns. By adopting phenomenology, the study sought to uncover the underlying meanings and structures of these experiences, providing a deep and rich understanding of how teachers navigated the challenges and opportunities presented by the unique circumstances of the pandemic. Phenomenology's emphasis on exploring the subjective consciousness and perspectives of individuals made it particularly well-suited for unravelling the intricate layers of teachers' experiences in the context of evolving educational landscapes and disruptions.

3.4.1 What is phenomenology? Researcher's theoretical understanding of experiences

The term "phenomenology" was first used by eighteenth-century British thinkers, Hegel and Kant, and is derived from the Greek word *'phainein*,' meaning 'to appear.' Hegel, a German idealist, defined phenomenology as "a science in which we come to know the mind as it is through the study of the ways in which it appears to us" (Welch, 1999, p. 235). Kant defined phenomena as "objects and events as they appear in our experience or consciousness" (Welch, 1999, p. 235), aligning with the definition of experiences by Roth and Jornet (2017) as being events that profoundly develop a person. Consequently, phenomenology can be understood as the study of experiences, as stated by Smith et al., (2009): "phenomenology is a philosophical approach to the study of experience" (p. 11).

Larkin and Thompson (2011) view phenomenology as the philosophy or school of thought that explains being and consciousness based on the analysis of observable phenomena. Additionally, Finlay (2012) defines phenomenology as the study of the structures of

conscious experience from a subjective point of view and the ways in which the experience is directed towards a particular object. According to Finlay (2012), phenomenology aims to describe the meaning of an individual's experience, detailing how and what was experienced. The main goal and concern of phenomenology is to understand these meanings, focusing on freshly complex, richly described phenomena, from the participant's point of view (Finlay, 2012).

In the context of the current study, which aimed to explore FET mathematics teachers' experiences of enhancing their competencies in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns, phenomenology serves as a fitting approach. Phenomenology's emphasis on delving into the meaning of individual experiences aligns well with the objective of gaining a deeper understanding of teachers' lived experiences in the specific context of the pandemic.

3.4.2 Phenomenology as a philosophy

Phenomenology encompasses various philosophies, incorporating traditions such as transcendental, existential, and hermeneutic traditions (Audi, 2022; Schwandt, 2014). This diversity within phenomenology allows for different approaches and perspectives in studying lived experiences. Figure 3.3 illustrates the interconnectedness or distinctions between these traditions within the broader framework of phenomenology. Each tradition within phenomenology offers unique insights and methodologies for exploring and understanding the richness of human experiences from different angles. Researchers may choose the phenomenological tradition that aligns most closely with the goals and focus of their study, whether emphasising the transcendental structures of consciousness, delving into the existential aspects of lived experience, or employing a hermeneutic lens to interpret the meaning embedded in human phenomena.

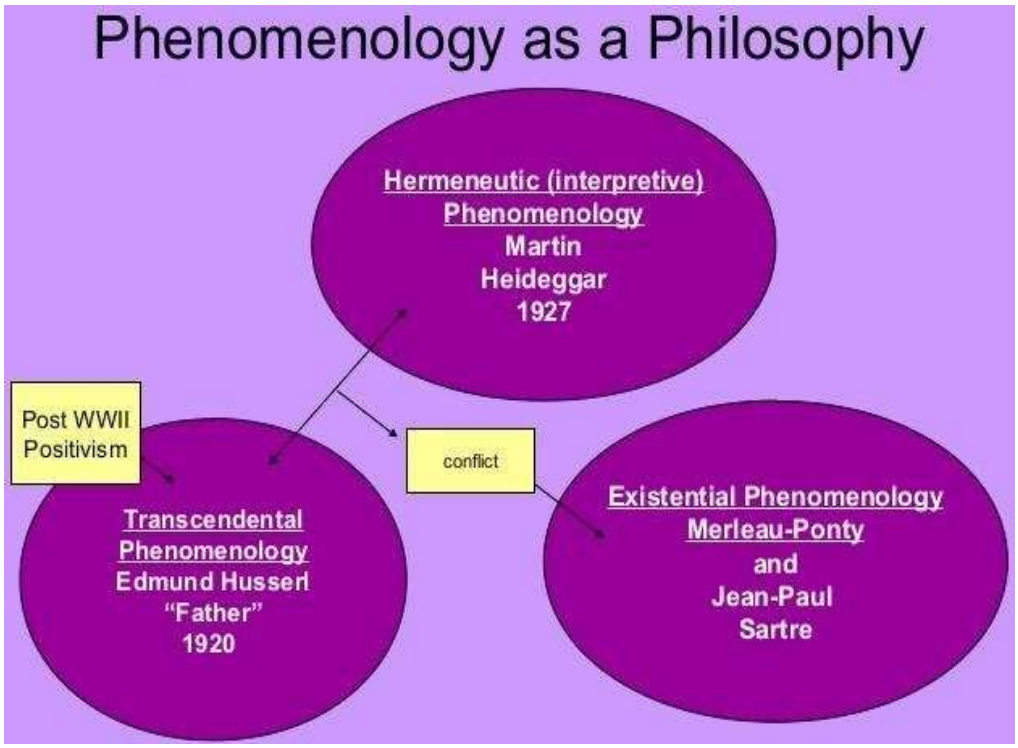


Figure 3.3: **The primary components and architecture of the phenomenology theory**
Source: https://images.app.goo.gl/sWTywBskAKuFHD8e

Researchers approaching phenomenology from a descriptive standpoint, such as in Husserl's original philosophy (1969), aim to uncover the essential structures of meaning within a phenomenon. Transcendental phenomenology, rooted in Husserl's philosophy, analyses the essences perceived by consciousness about individual experiences (Padilla-Diaz, 2015, p. 103). In contrast, philosophers in the hermeneutic tradition, such as Heidegger, Gadamer, and Ricoeur, argue that interpretation is a fundamental structure of our existence in the world. According to this perspective, interpretation is inevitable as we experience a phenomenon that has already been interpreted. Thus, hermeneutic phenomenology places emphasis on the interpretation of experience rather than mere description (Gadamer, 1990).

Existential phenomenology, developed by Heidegger (1962), a student of Husserl, emphasises an individual's uniqueness, one's social culture, and one's interaction with others in day-to-day life. Finlay (2012) posits that existential phenomenology appeals to universal consciousness. Although all phenomenology is descriptive in nature, as it seeks to describe rather than explain a phenomenon, scholars often differentiate between descriptive phenomenology (also known as transcendental phenomenology) and interpretive phenomenology (also known as hermeneutic).

For this study, the focus will be on both transcendental and hermeneutic traditions. This choice acknowledges the dual aspects of uncovering essential structures of meaning within experiences and understanding the interpretive nature of these experiences within a broader hermeneutic framework. This approach allows for a nuanced exploration of the lived experiences of FET mathematics teachers in the context of enhancing their competencies during the COVID-19 pandemic lockdowns. Table 3.1 provides a concise comparison between transcendental (descriptive) phenomenology and hermeneutic (interpretative) phenomenology across key philosophical, ontological and epistemological aspects.

Table 3.1: Comparison of transcendental (descriptive) and termeneutics (interpretative) phenomenology

	Transcendental phenomenology	Hermeneutics phenomenology
Philosophical origins	Husserl (1970)	Heidegger (1962) Gadamer(1997)
Ontological assumptions	Reality is internal to the knower; what appears in their consciousness	Lived experience is an interpretive process situated in an individual's lifeworld.
Epistemological assumptions	Observer must separate him/herself from the world including his/her own physical being to reach the state of the transcendental I; bias-free; understand phenomena by descriptive means.	Observer is part of the world and not bias free; understands phenomenon by interpretive means.

According to Williams (2021), phenomenology is characterised by four key aspects: intentionality, descriptiveness, reduction, and essence. These concepts interconnect to illuminate the nature of lived experiences. Cilesiz (2011) provides a diagram (Figure 3.4) that aids in understanding the connection between these phenomenological concepts, illustrating the concept of reality is grounded in the ideal-material duality, suggesting that every experience comprises both material and ideal components.

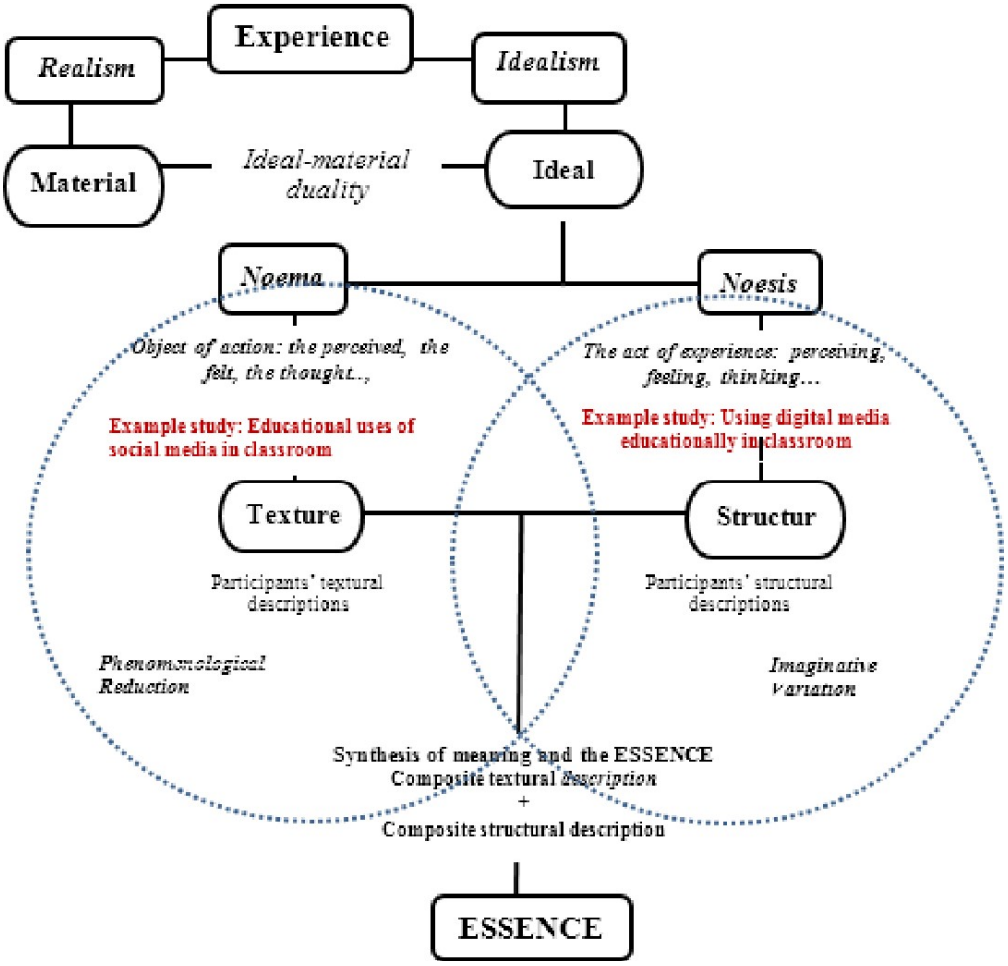


Figure 3.4: The phenomenological concept of experience
Source: Adapted from Cilesiz (2011)

The following section delves into the concepts of phenomenology, particularly from the perspective of transcendental phenomenology, and establishes their relevance to teachers' experiences. The four characteristics of phenomenology—intentionality, descriptiveness, reduction, and essence—are explored in the context of understanding the lived experiences of FET mathematics teachers during the COVID-19 pandemic lockdowns.

1. Intentionality

Eddle-Hirsch (2015) describes intentionality as a concept that incorporates both noema and noesis. In the context of this study, the experiences of enhancing competencies using technology were conceptualised as the object of the study, with mathematics teachers being the subjects. The objective was to explore this object from the point of view of the subjects. Therefore, in this study, mathematics teachers are referred to as noesis (e.g., perceiving,

feeling, thinking, remembering, or judging), while their experiences are referred to as noema (perceived, felt, thought, remembered, judged).

This intentional focus on the relationship between the experiencing subject (noesis) and the experienced object (noema) aligns with the phenomenological perspective, emphasising the intentional directedness of consciousness towards objects. In exploring the lived experiences of FET mathematics teachers, this intentional stance allows for a nuanced examination of how teachers engage with and make meaning of their experiences of enhancing teaching competencies during the COVID-19 pandemic lockdowns.

2. Description

The primary objective of this study was to generate in-depth descriptions of teachers' experiences based on the narratives of their experiences and feelings. Phenomenological inquiry aims to uncover and describe the meaning structures of experience, providing a profound exploration of the essence of a phenomenon (Audi 2022; Husserl 1970; Moustakas 1994). According to van Manen (1990), phenomenological research typically involves collecting data that consists of descriptions of lived experiences, which can be gathered through interviews, observations, or written self-descriptions. This aspect of phenomenology has guided the researcher in developing data collection instruments, such as interviews, that are inherently descriptive.

Moreover, the interviews created in this study serve the purpose of enabling the researcher to attain a deeper understanding of the meaning embedded in the mathematics teachers' experiences. Through engaging with the narratives and reflections of the participants, the study aimed to uncover the nuanced and contextual aspects of their experiences of enhancing teaching competencies during the unique circumstances of the COVID-19 pandemic lockdowns.

3. Reduction (also known as bracketing)

The purpose of bracketing in phenomenological research is to set aside preconceived judgements and biases related to the phenomenon being investigated. According to Husserl,

researchers engaged in phenomenological investigation must practice *epoché*, which involves suspending all assumptions. The goal is to allow the phenomenon under investigation to reveal itself fully. In applying *epoché*, the researcher of this study bracketed her own experiences of enhancing her competencies in teaching Euclidean geometry proofs during the data analysis process. This deliberate act of bracketing aims to enable the researcher to critically comprehend the participants' experiences without the interference of personal biases, fostering a more objective and accurate understanding of the participants' perspectives.

4. Essence

In the context of phenomenological research, essence refers to the intrinsic nature or meaning of individual experiences related to a particular phenomenon. Kafle (2011) defined essence as the inherent nature of an individual's experiences in relation to a specific phenomenon. Merleau-Ponty (as cited in Romdenh-Romluc, 2018, p. 454), described essence as the meaning inherent in a particular set of experiences. This study aimed to explore the essence of teachers' experiences in enhancing their competencies in teaching Euclidean geometry proofs. Through a focus on the essential aspects of these experiences, the researcher seeks to uncover the fundamental meanings and qualities that characterise the teachers' encounters with the phenomenon under investigation.

3.4.3 Contribution of the phenomenology in this study

The contribution of phenomenology in this study lies in its ability to serve as a guiding framework for uncovering the systematic patterns inherent in the lived experiences of FET mathematics teachers. Husserl's (1970) assertion about the primary purpose of phenomenological research aligns with the objectives of this study—to delve into the nature and meaning of FET mathematics teachers' experiences in enhancing their competencies for teaching Euclidean geometry during the challenging times of the COVID-19 pandemic lockdowns. The phenomenological theory was instrumental in creating the data collection instrument, specifically shaping interview questions that aimed to reveal the rich tapestry of mathematics teachers' lived experiences during this unprecedented period. Moreover, phenomenology plays a pivotal role in the analysis of the results, facilitating the

identification and exploration of common lived experiences among participants and the meaning attributed to those encounters.

3.5 UTILISATION OF THE FRAMEWORKS IN THE STUDY

The utilisation of theoretical frameworks in this study played a crucial role in providing guidance and structure at various stages of the research process. Specifically, the frameworks served the following purposes:

Formulation of research questions: The theoretical frameworks provided a foundation for crafting the research questions. By aligning the study with frameworks such as Shulman's constructs and Mishra and Koehler's TPACK model, and phenomenology, the researcher was able to shape questions that addressed specific dimensions of teachers' competencies and experiences during the COVID-19 pandemic.

Construction of themes/codes: The theoretical frameworks acted as a lens through which the data collected could be interpreted. Concepts and constructs from Shulman's ideas, the TPACK model and phenomenology influenced the identification and development of themes and codes during the analysis of teachers' experiences in enhancing their competencies for teaching Euclidean geometry.

Informing the focus of the study: The chosen frameworks directed the focus of the study by providing a theoretical lens through which the phenomena under investigation could be understood. Shulman's constructs and Mishra and Koehler's TPACK model offered a theoretical backdrop that helped to narrow down the scope and purpose of the research.

By employing these frameworks, the researcher ensured that the study was grounded in established theoretical perspectives, enhancing the rigour and coherence of the research design, data collection, and analysis.

CHAPTER 4: RESEARCH DESIGN, METHODOLOGY, ETHICAL CONSIDERATIONS, AND LIMITATIONS

4.1 INTRODUCTION

The previous chapter reflected on TPACK and phenomenology as theoretical frameworks underpinning this study. It critically examined the role of theory in gaining a profound understanding of teachers' experiences to enhance their competencies of teaching Euclidean geometry proofs. The current chapter focuses on the research design and methodology employed to address the research questions at hand. In accordance with Khoa et al.'s (2023) definition, research is viewed as a systematic process involving the collection and analysis of information, aimed at methodically addressing a research problem. This chapter scrutinises the strategies and techniques employed to explore teachers' experiences in enhancing their competencies of teaching Euclidean geometry proofs amidst the challenges posed by the COVID-19 pandemic lockdowns.

This chapter provides a comprehensive exploration of the intricate processes and methods chosen by the researcher to collect, organise, and analyse data obtained through the administration of questionnaires and semi-structured interviews. Before delving into the specific research processes and methods, the researcher offers a detailed explanation of the research design and methodology, aiming to familiarise the reader with the broader context of the study. Subsequently, the researcher substantiates the selection of the interpretive paradigm, framed within the lens of phenomenological strategies. This connection is then elucidated, demonstrating the alignment between the interpretive research paradigm and the qualitative and quantitative research approach employed in this study.

The researcher adopted a mixed research approach, employing purposive and convenience sampling to select participants for the study. A concise explanation of the chosen data generation methods, such as questionnaires and semi-structured interviews, is presented. Following this, the researcher elucidates and justifies the techniques employed for analysing the collected data. In addition, the chapter outlines the ethical considerations and principles of study quality, encompassing credibility, dependability, transferability, and confirmability,

to ensure the appropriateness of processes before, during, and after data generation. As a conclusion to the chapter, the researcher reflects on the discoveries made, with a brief mention of what is to follow in the next chapter.

4.2 RESEARCH DESIGN

Bertram and Christiansen (2014) define research design as a systematic plan for collecting and analysing data configured by the researcher to address the research questions. Similarly, Dawadi et al. (2021) characterise research design as a set of guidelines that a researcher follows to meet the research objectives and questions of the study. According to Denzin and Lincoln (2018), research design offers a series of guidelines and instructions that connect theoretical paradigms to inquiry strategies and data generation methods aimed at addressing the research problem. Creswell and Creswell (2017) assert that research design encompasses various research methodologies or approaches preferred by researchers. In terms of defining research methodology, Pillay et al. (2016) state that it can be viewed as a practical way of understanding how research is carried out, presenting underlying theories, and analysing how researchers gather information about human life. In simple terms, research design serves as the blueprint for the entire research study.

In this study, the focus was on exploring the experiences of FET mathematics teachers in their efforts to enhance their competencies in teaching Euclidean geometry during the COVID-19 pandemic lockdown. A phenomenological case study approach was employed, given the interpretive nature of the research. The interpretive paradigm favours case studies as a research style, as they enable vivid descriptions of what it is like to be in a particular situation (Bertram & Christiansen, 2014). Cohen et al. (2017) assert that case studies aim to capture the nuanced reality of participants' thoughts and feelings within a specific context. Similarly, according to Yin (2014) case studies are valuable for understanding complex social phenomena and real-life events.

The adoption of the case study research style in this study is advantageous as it enabled the researcher to gain a comprehensive understanding of FET mathematics teachers' experiences in enhancing their competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns. This study, framed as a phenomenological case study, specifically

focused on FET mathematics teachers who initially lacked technological skills for teaching geometry. The exploration centred on their reflections and experiences as they sought to improve their competencies in teaching Euclidean geometry proofs using technological tools during this challenging period.

4.3 RESEARCH PARADIGM

Kuhn (2012), a luminary in the realm of research paradigms, defined paradigm as a perspective for observing or investigating a phenomenon—a worldview encompassing accepted or correct scientific knowledge and methods, an established pattern. Similarly, Creswell and Creswell (2017) conceptualise a paradigm as the researcher's worldview, rooted in a broader philosophical orientation about the world and the nature of research. Leavy (2022) defines a paradigm as a framework of beliefs or worldviews that shape the values, methods, or boundaries for research. Guba and Lincoln (1989) echo these perspectives, affirming that a research paradigm comprises a set of assumptions, beliefs, and feelings that shape how the researcher perceives, interprets, and analyses the world.

Furthermore, Kivunja and Kuyini (2017) align with these shared perspectives, asserting that a research paradigm acts as a lens through which the researcher perceives the world. The aforementioned definitions collectively underscore the significance of a research paradigm in comprehending a researcher's interpretation of reality and the disciplinary context that informs their perspective. This understanding is crucial for constructing meaning from the collected data.

Kivunja and Kuyini (2017) emphasise that a paradigm constitutes the researcher's worldview, encompassing perspectives, thinking, schools of thought, or shared beliefs that elucidate the meaning or interpretation of gathered data. In the context of this study, an interpretive paradigm rooted in the phenomenological school of thought was employed. The researcher views the adoption of a research paradigm as crucial, serving as a guiding framework throughout the research process.

The chosen paradigm provides a lens through which a researcher examines methodological aspects. It influences decisions regarding what to study, how to conduct the study, the

methods of data analysis, and how meaning will be derived from the gathered data, all within the context of the researcher's lifeworld. The adoption of a specific research paradigm in the current study, in this case, an interpretive one, thus played a pivotal role in shaping and directing the entire research endeavour.

The preceding discussion makes it clear that this research was anchored in the beliefs, assumptions, norms, and values intrinsic to the chosen paradigm. Elements that shape a paradigm include the philosophical assumptions underpinning research paradigms such as epistemology, ontology, methodology, and axiology. Each of these components plays a crucial role in framing the researcher's perspective and approach throughout the research process.

Cohen et al. (2017) distinguish between ontology and epistemology, stating that ontology in research centres on "the nature of reality," while the focus of epistemology encompasses knowledge, its nature, and forms of inquiry. Similarly, Carter and Little (2007) assert that ontology is concerned with what constitutes knowledge, while epistemology deals with the theory of that knowledge.

In this study, the experiences of mathematics teachers were examined through the lens of phenomenology theory, where the meaning of a phenomenon is interpreted from the perspective of those who are involved in it. Phenomenology, as a theoretical framework, aims to explore and describe lived experiences directly from the participants' viewpoint, devoid of preconceptions and casual theories. The researcher firmly believes that mathematics teachers' experiences in enhancing their competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns were significantly shaped by the study's contextual backdrop.

As a result, this study adopted a relativist ontology, acknowledging the subjective nature of reality. The epistemological stance was subjective, emphasising the understanding that knowledge is shaped by individual experiences. The methodology aligned with naturalism, seeking to comprehend phenomena within their natural context. The axiological position was balanced, recognising the inherent value in diverse perspectives. Consequently, the

above-mentioned discussions about philosophical assumptions position this study firmly within the interpretative paradigm.

4.3.1 Interpretive paradigm

The interpretive paradigm is oriented towards constructing the meaning of a phenomenon based on subjective human experiences (Guba & Lincoln, 1989). At its core, this paradigm is centred on understanding the individual and how they interpret the world around them. Within the interpretive paradigm, a fundamental principle is that reality is socially constructed. The emphasis is placed on comprehending the subjective interpretation of the meaning of social contexts by individuals or groups. In this context, Creswell and Creswell (2017) characterise the interpretive paradigm as a social constructivist paradigm, wherein the researcher relies on the views of participants to understand the situation being studied. This approach recognises that reality is not an absolute entity but is shaped and understood through the perspectives of those involved in a given social context.

In this study, a relative ontology is assumed, reflecting the researcher's belief that teachers' experiences in enhancing their competencies of teaching encompass multiple realities. The recognition of diverse perspectives is integral to understanding the nuanced nature of these experiences. Furthermore, these multiple realities are examined and interpreted through human interactions between the researcher and the subjects of the research, as well as among the research participants, as outlined by Creswell and Creswell (2017).

The justification for assuming a subjective epistemology lies in the researcher's role in creating knowledge about teacher competencies based on participants' experiences within the real-life contexts investigated. The researcher acknowledges that knowledge is constructed subjectively and is influenced by the unique perspectives of those involved. Additionally, the researcher holds the belief that context is vital for the construction of meaningful knowledge, emphasising the importance of understanding the specific settings in which the research takes place.

The assumption of a naturalist methodology is grounded in the use of data collected through interviews, with the researcher also taking on the role of a participant observer. This

approach aligns with the naturalistic tradition of studying phenomena within their natural contexts, allowing for a rich and contextualised understanding of teachers' experiences.

Lastly, the assumption of a balanced axiology indicates that the end results of the research are believed to reflect the values of the researcher. This balanced approach acknowledges the importance of impartiality and fairness in the research process, ensuring that the outcomes are shaped by a comprehensive consideration of diverse perspectives and values.

4.4 RESEARCH APPROACH

Creswell (2014) defines a research approach as the plans and processes that encompass the steps taken in the research process, spanning from philosophical assumptions to methods of data collection, analysis, and interpretation. Additionally, Creswell and Creswell (2018) assert that a research approach serves as the link connecting the research proposal, research design, and research methods to a philosophical worldview, which may include postpositivist, constructivist, transformative, or pragmatic paradigms. Schwandt and Gates (2017) further argue that specific research approaches for constructing meaning in the social world are intricately connected to specific philosophical principles.

Creswell and Creswell (2018) emphasise that the researcher is guided by philosophical assumptions, research design, methods of data collection, analysis, and interpretation in selecting the research approach. In the field of social science methodology, three predominant research approaches are typically considered: qualitative, quantitative, and mixed methods (Creswell & Creswell, 2018). This study is situated within a mixed method research approach, signifying an integration of both qualitative and quantitative methods to provide a comprehensive understanding of the research questions and objectives.

4.4.1 Qualitative research approach

Even though this study adopts a mixed-method approach, the primary focus of the researcher is on the qualitative research approach, with an aim to deepen understanding of teachers' experiences in enhancing their competencies of teaching Euclidean geometry proofs. According to Creswell (2008), qualitative research inquiry is a process of comprehending a

social or human problem in a natural setting by gaining a holistic picture from the detailed perspectives of the informants. The qualitative research approach is closely associated with a constructive philosophical worldview, as it is concerned with constructing meaning from the participants' point of view (Creswell & Creswell, 2018).

Denzin and Lincoln (2018) support this perspective, stating that the qualitative approach facilitates understanding of a phenomenon by interpreting the meanings that people attach to it. Mohajan (2018) reinforces this view, suggesting that qualitative research emphasises the interpretation of how people create meaning from their own experiences to understand the social reality of individuals. Given that this study is situated within the interpretive paradigm, it aligns its philosophical assumptions with a constructive qualitative research framework. The emphasis on qualitative methods reflects the researcher's intent to delve into the rich and nuanced experiences of mathematics teachers during the COVID-19 pandemic lockdowns.

Drury et al. (2011) emphasise that qualitative research allows for a more open-ended and flexible approach to evaluating participants' views. Creswell and Creswell (2018) echo this sentiment, asserting that in qualitative research, the researcher relies on participants' perspectives, poses open-ended questions, collects data primarily in the form of narratives, and identifies themes from these narratives for data analysis. In alignment with these principles, the researcher in this study adopted a qualitative research approach. Through interactions with participants during interviews, the aim was to delve into their perspectives and gain insights into their experiences of enhancing their competencies in teaching Euclidean geometry proofs. This approach allowed for a nuanced exploration of the participants' viewpoints and a comprehensive understanding of their lived experiences.

4.4.1.1 Strengths of a qualitative research approach

Leedy and Omrod (2005) highlighted four main benefits of employing a qualitative research approach over a quantitative research approach, namely description, interpretation, verification, and evaluation. A qualitative research approach is inherently descriptive, providing the ability to vividly portray and articulate the characteristics of a phenomenon.

Moreover, it facilitates an in-depth analysis by exploring multiple realities as expressed by participants, a dimension often challenging to capture using quantitative methods alone.

In the context of this study, the qualitative research approach is particularly relevant. It aligns with the objective of deeply exploring, describing, and uncovering the meaning behind teachers' experiences in enhancing their competencies of teaching Euclidean geometry proofs. By embracing qualitative methods, the research can delve into the intricate details of the participants' perspectives, allowing for a rich and comprehensive understanding of their experiences during the COVID-19 pandemic lockdowns.

The interpretive nature of the qualitative research approach provides the researcher with the ability to gain insights into a phenomenon. Moreover, interpretive qualitative research empowers the researcher to construct new concepts or meanings about phenomena and identify existing problems (Creswell, 2014). In the realm of qualitative research, there is a focus on exploring the meanings of participants' interpretations of their lives and experiences.

Given that this study aimed to investigate the meanings of teachers' lived experiences from their own perspectives, the qualitative research approach is particularly suitable. It allows the researcher to engage deeply with the subjective experiences of the participants, providing a platform to uncover and understand the intricate nuances of how teachers perceive and navigate the challenges of enhancing their competencies in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns. The interpretive lens of qualitative research aligns well with the study's objective of exploring and constructing meanings from the teachers' point of view.

While qualitative research is often associated with exploration and interpretation, it can also serve as a valuable verification tool. This approach allows the researcher to check the validity of philosophical assumptions and theories in a real-world context. In the context of this study, the interaction between the researcher and participants during interview sessions served to gain deep insights. These insights were then used to verify and cross-reference different participants' views regarding their experiences of enhancing their competencies in teaching Euclidean geometry during the COVID-19 pandemic lockdowns.

Through this verification process, the qualitative research approach offered a robust mechanism to ensure that the findings align with the actual experiences and perspectives of the participants. It added a layer of credibility to the study by grounding the interpretations and meanings in the rich and authentic narratives shared by the teachers. This verification aspect contributed to the overall rigour and trustworthiness of the qualitative research findings.

The evaluative character of qualitative research played a crucial role in enabling the researcher to assess the influence of the context from which the participants originated. In the context of this study, which investigated the impacts of COVID-19 pandemic lockdowns on mathematics teachers' experiences of enhancing their pedagogical practices, the evaluative purpose was realised during interviews. The researcher systematically interrogated participants about their views on the specific impact of COVID-19 pandemic lockdowns on their experiences of enhancing their competencies in teaching Euclidean geometry proofs.

Through this evaluative lens, qualitative research allowed the researcher to gauge the effects of the external context, in this case, the pandemic and associated lockdowns, on the teachers' professional development. By directly engaging with the participants and eliciting their perspectives, the study not only explored the subjective experiences but also evaluated the broader influence of external factors on the participants' efforts to enhance their teaching competencies. This evaluative aspect contributed to a more comprehensive understanding of the complex interplay between contextual influences and the teachers' experiences.

4.4.1.2 Weaknesses of a qualitative research approach

Indeed, qualitative research, while valuable, comes with its own set of limitations. Choy (2014) rightly points out that both data collection and analysis in qualitative research can be time-consuming and expensive. This is primarily due to the wide array of procedures integrated into qualitative research methods, making it challenging to determine the most suitable approach to employ. Additionally, the involvement of a limited number of participants, as highlighted by Choy (2014), impacts the generalisability and transferability

of research findings to other studies and settings, thereby affecting the trustworthiness and credibility of the research.

Another weakness of qualitative research, mentioned by Daniel (2019), is the potential for multiple interpretations, which can influence the dependability of the findings. Despite these limitations, the researcher contends that the qualitative research approach remains the most appropriate for understanding teachers' lived experiences from their own perspectives.

In the following section, the researcher delineates an approach to mitigating these limitations when employing qualitative research techniques and tools to explore teachers' experiences of enhancing their competencies in teaching Euclidean geometry proofs. This strategic approach aims to enhance the robustness, validity, and reliability of the qualitative findings, addressing potential drawbacks associated with time, cost, limited participants, and potential for multiple interpretations.

4.4.1.3 Mitigation strategies against qualitative research approach weaknesses

To address the issues of trustworthiness and dependability in the qualitative research approach, the researcher opted for a case study investigation. Simons (2009) supports the use of case studies, noting that they enable researchers to explore phenomena from multiple perspectives within a real-life context. Additionally, Piekkari and Welch highlight that case studies provide an explicit context for a phenomenon, allowing for the development of new insights that can be transferred to other cases with similar conditions.

In the context of qualitative data collection, the depth of information obtained through in-depth interviews was invaluable. The use of semi-structured interview formats allowed participants to share their experiences comprehensively, contributing to a richer understanding of the phenomenon under investigation. This methodological choice aligns with the notion that case studies are well-suited for in-depth exploration and analysis.

Furthermore, the researcher employed a combination of data collection methods, including interviews and questionnaires. This methodological triangulation aimed at cross-verifying information, thereby enhancing the credibility and reliability of the findings. The

convergence of data from different sources adds robustness to the study, mitigating the risk of relying solely on one method.

The researcher employed purposeful sampling instead of aiming for a large number of participants, selecting individuals with rich and varied experiences related to the research topic. This strategic sampling approach was chosen to facilitate a more in-depth exploration of the phenomenon under investigation. By focusing on participants with diverse experiences, the researcher aimed to capture a comprehensive range of perspectives, contributing to the depth and richness of the qualitative findings.

Member checking was also implemented as a validation strategy. This involved returning the analysed data to participants for their feedback and validation. By incorporating member checking, the researcher ensured that interpretations and conclusions resonated with the lived experiences of the participants. This step adds an extra layer of credibility and trustworthiness to the study by directly involving participants in the verification process.

Furthermore, the researcher sought input and feedback from peers and experts in the field through external review. This external review process provided an additional perspective and helped identify potential blind spots or biases in the study. Peer review contributes to the rigour of the research by subjecting it to critical evaluation and ensuring that the methodology and findings withstand scrutiny from external experts.

In summary, the deliberate use of purposeful sampling, member checking, and external review demonstrates a commitment to enhancing the trustworthiness and rigour of the qualitative study. These methodological choices and validation strategies contribute to the overall quality and reliability of the research findings.

4.4.2 Quantitative research approach

Creswell (2009) defines the quantitative research approach as an investigative method that explores behaviour under controlled conditions, collecting data through precise measurements using validated instruments to answer research questions or test hypotheses.

This perspective is reinforced by Drury et al. (2011), who emphasise that the quantitative approach relies on measurement instruments and data analysis expressed in statistics.

In the context of this study, the quantitative research approach manifested itself through collecting and analysing statistical information related to teachers' profiles. The use of quantitative methods extended to the data analysis stage, where the researcher represented information by means of tables and graphs. This approach facilitated the systematic examination of multidimensional problems, informing the qualitative data analysis process and allowing for triangulation of findings within different sources of evidence (DeCuir-Gunby & Schutz, 2017).

The integration of quantitative methods in this study provided a complementary perspective to the qualitative findings, offering a quantitative lens to certain aspects of the research questions. This mixed-methods approach contributed to a more comprehensive understanding of the complex phenomenon under investigation, leveraging the strengths of both qualitative and quantitative research methodologies.

4.4.3 Mixed method research approach

The utilisation of both qualitative and quantitative research approaches in the study situates it within a mixed-methods approach. Creswell and Plano Clark (2018) define mixed-methods research as an approach that combines various elements of both qualitative and quantitative methodologies, encompassing perspectives, data collection, data analysis, and the nature of inferences made from the research.

Creswell and Plano Clark (2018) affirm that the goal of mixed-methods research is to provide a richer and deeper understanding of a phenomenon than what can be achieved through a single approach. Given that the researcher aimed to gain deep insights into teachers' experiences of enhancing their competencies in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns, the mixed-methods approach was deemed appropriate. This approach allowed for a more comprehensive exploration of the research questions by combining the strengths of both qualitative and quantitative methods.

The study's focus on understanding the influence of factors such as age, gender, level of study, and personal views of participants was well-suited to a mixed-methods approach. The collection and analysis of information through both interpretative phenomenological analysis (qualitative) and quantification into frequencies (quantitative) enabled a nuanced and holistic interpretation of the complex interplay of these factors on teachers' experiences.

In summary, the mixed-methods research approach was chosen for its capacity to provide a thorough and multifaceted understanding of the research questions, aligning with the study's objectives and the intricacies of the phenomenon under investigation.

4.5 SAMPLE AND SAMPLING STRATEGIES

Sample selection is a critical aspect of research design, and various scholars provide definitions and insights into this process. According to Singh and Masuku (2014), a sample is a subset of the study population used to represent the larger population in a research study. Selection is necessary due to limitations and delimitations influencing a study, making it impractical to include every member of the study population.

Etikan et al. (2016) offer a complementary definition, stating that sampling is the process of selecting subjects that will represent the entire population and provide information suitable for the study, aiding in answering research questions. McMillan and Schumacher (2010) suggest that during the sampling procedure researchers should consider participants who are conversant with and informed about the phenomena under study. This approach allows the researcher to create a composite picture of the phenomenon under scrutiny.

In the context of this study, FET mathematics teachers were selected as the sample. This decision was based on their expertise in Euclidean geometry proofs, as they are knowledgeable about the subject matter. Additionally, FET mathematics teachers were chosen because they generally seek to constantly enhance their competencies in teaching, which directly impacts the performance of learners in national examinations. The selection of this specific sample aligned with the research focus and ensured that participants possessed the necessary insights and experiences related to the study's objectives.

The sampling techniques employed in this study were purposive sampling and convenience sampling. Scholars often categorize sampling methods into two main groups: probability sampling and non-probability sampling (Saunders et al., 2023). Saunders et al. (2023) distinguish between these two techniques, stating that probability sampling includes every member of the population of interest, where all have an equal opportunity to be selected and become participants in the study. On the other hand, non-probability sampling allows the researcher to judge the population and generate the sample but does not provide every member of the population with an equal chance to be sampled and participate in the study (Saunders et al., 2023).

Non-probability sampling methods encompass a variety of relevant techniques, such as quota sampling, snowball sampling, accidental sampling, expert sampling, purposive sampling (or judgmental), and convenience sampling (Bertram & Christiansen, 2020). In this study, the researcher adopted a non-probability sampling method, specifically employing purposive sampling and convenient sampling techniques to understand teachers' experiences of enhancing their competencies in teaching Euclidean geometry proofs. These techniques were chosen strategically to ensure that participants had relevant insights into the research questions, aligning with the study's focus on gaining a deep understanding of teachers' experiences.

4.5.1 Purposive sampling

Creswell (2014) emphasises that purposive sampling, which involves deliberately selecting individuals and sites, is particularly effective for exploring and understanding the meanings of the research problem and the key phenomenon under study. This approach allows the researcher to intentionally choose settings, persons, or events that will provide crucial information for the study (Maxwell, 2012). Purposive sampling relies entirely on the researcher's judgement regarding who can supply the information needed to answer the research questions (Etikan and Bala, 2017). In this study, the researcher believed that FET mathematics teachers who taught during the COVID-19 pandemic lockdowns were the most informative and relevant participants.

Farrokhi et al. (2012) state that purposive sampling involves selecting participants who share common experiences related to the phenomena being studied. Abakpa et al. (2017) further argue that purposive sampling is geared towards understanding meaning rather than meeting statistical requirements. This suggests that purposive sampling is suitable for a study aiming to explore in-depth the experiences of individuals exposed to similar situations. In this study, all participants were purposively sampled since they taught FET mathematics during COVID-19 pandemic lockdowns. As a result, all selected participants had the experience of enhancing their competencies in teaching Euclidean geometry using technological tools during the COVID-19 pandemic lockdowns.

4.5.2 Convenience sampling

The researcher purposefully selected 35 FET mathematics teachers from 15 schools in the Harry Gwala District. These teachers were chosen to represent detailed and rich e-learning experiences in the teaching of Euclidean geometry proofs. The use of purposive and convenient sampling techniques in this study was intentional to focus on specific research sites and participants, avoiding generalisation about the wider population. The study specifically targeted mathematics teachers from rural schools who improved their competencies in teaching during the COVID-19 pandemic lockdowns.

The rationale for focusing on rural schools was influenced by previous scholarship (e.g., Mwapwele et al., 2019; du Plessis & Mestry, 2019), which indicated that teachers from rural areas may be less competent in technology integration. Therefore, the researcher aimed to explore the experiences of these teachers in enhancing their competencies in teaching Euclidean geometry proofs using technological tools. The choice of the Harry Gwala District as the research site was appropriate considering that it primarily comprises rural schools. Additionally, the Harry Gwala District was convenient for the researcher as she works within this district. This targeted sampling approach allowed for a focused and in-depth exploration of the experiences of a specific group of teachers in a particular context.

The 15 schools from which the sample was drawn are situated in four different circuits of the Harry Gwala District. Four rural schools were initially selected in each of the four circuits. However, one school from the Pholela Circuit withdrew from participating in the

study before data collection commenced. Consequently, four schools from each circuit participated in the study, except in the Pholela Circuit where three schools participated. The decision to select four schools in each circuit aimed at ensuring that manageable data could be collected.

According to Creswell and Plano Clark (2018) and Cohen et al. (2017), a sample size must be sizeable enough to provide the required information for estimating the parameters of the population. Cohen et al. (2017) emphasise that the sample size depends on the style of research being conducted. Creswell and Creswell (2018) recommend a range of 3 to 25 participants for a phenomenological case study. Therefore, the selection of 35 participants in this study aligns with the recommended sample size for a phenomenological case study, allowing for a comprehensive exploration of teachers' experiences in enhancing their competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns.

The sample for this study included all available participants in the Harry Gwala District who met the criteria for participation. Teachers were selected based on their first-hand experience in enhancing their competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns. The selection criteria were as follows: 1) participants must be teaching mathematics in the FET phase, 2) participants must have at least two years of teaching experience, and 3) participants must have enhanced their competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdown. Thirty-five participants who met these requirements were selected to participate in the study.

The researcher initially anticipated using a convenience sample of 60 FET mathematics teachers in the Harry Gwala District who had enhanced their competencies in teaching Euclidean geometry during the COVID-19 pandemic lockdowns. However, the researcher was aware that the sample size might not be exactly 60 due to ethical considerations. Participants were free to withdraw from the study at any time, and participation was voluntary. Additionally, Cohen et al. (2017) highlighted the importance of considering participants' willingness and availability when selecting participants for a study. Some teachers indicated that they were not willing to participate in the study, resulting in the final sample size of 35 participants.

4.6 DATA GENERATION

The researcher aimed to obtain a deep and rich array of data to thoroughly understand participants' lived experiences and perspectives. Atieno Okech and Rubel (2009) recommend that when the purpose of a study is to gain a profound understanding of phenomena, the researcher should employ methods that reveal themes and fundamental issues, such as the experiences of teachers in this case. Consequently, a questionnaire and semi-structured interviews were chosen as the methods for collecting data, and themes were derived from the responses of the participants. Table 4.1 summarises the data generation processes used in this study.

Table 4.1: Summary of research methods

Research questions	Who were the participants?	How will data be generated?	Data analysis
1. How did the FET mathematics teachers from Harry Gwala District respond to the need for e-learning to teach Euclidean geometry proofs during the COVID-19 pandemic?	Three FET mathematics educators	Interview	Transcribe and look for themes
2. In what ways are the FET mathematics teachers from Harry Gwala District enhancing their skills of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns?	Thirty-five FET mathematics educators	Questionnaire (Google form)	Tables, frequencies, and themes from open-ended questions
3. What are the Harry Gwala District FET mathematics teachers' experiences of improving their competencies for teaching Euclidean geometry during the COVID-19 pandemic lockdowns?	Thirty-five FET mathematics educators	Questionnaire (Google form)	Tables, frequencies, and themes from open-ended questions

4.6.1 Questionnaire

Questionnaires are widely accepted instruments for collecting demographic data and participants' views (Blandford, 2013). McLeod (2018) defines a questionnaire as a data generation instrument in which all participants are required to respond to the same set of questions pre-organised by the researcher. Both open-ended and closed-ended questions

were utilised as data generation techniques in this study. The primary purpose of employing a questionnaire in this research was to develop individual teacher profiles, providing an overview of teachers' qualities. Additionally, a questionnaire was employed to elicit teachers' perspectives on the strategies of teaching Euclidean geometry proofs, examining how these teaching strategies impact teaching practices and teachers' experiences in enhancing their classroom practices during the COVID-19 pandemic lockdowns.

A Google Form containing closed- and open-ended questions was electronically distributed to each participant in compliance with COVID-19 pandemic regulations on social distancing. The utilisation of an electronic format (Google Forms) facilitated easy access for the researcher to the participants. The use of open-ended questions allowed participants to express themselves freely and truthfully (Rule and John, 2011), thereby favouring qualitative research. Creswell (2014) highlighted several advantages of collecting data through online platforms such as cost and time efficiency, reduced travel expenses and reduced data transcription costs. Additionally, the author noted that online data collection provides participants with flexibility in terms of time and space (Creswell, 2014). Nicholas et al. (2010) further pointed out that gathering data online creates a nonthreatening and comfortable environment for participants, making it easier for them to express their feelings, including on sensitive issues.

4.6.2 Semi-structured interviews

Semi-structured interviews were used to address the first research question of this study. Bertram and Christiansen (2014) define interviews as being conversations between the researcher and the respondent. This definition is supported by Brinkmann and Friesen (2018) who state that interviews are purposeful conversations which aim to obtain concrete descriptions of participants' lifeworld experiences to develop understanding of multiple interpretations. Semi-structured interviews were used in addition to a questionnaire as a method of data generation in this study. Three FET mathematics teachers were interviewed. The overall purpose of interviewing participants was to gain and in-depth understanding of participants' experiences of enhancing their competencies in teaching Euclidean geometry proofs in their own words. Cohen et al. (2017) acknowledge the use of multiple methods of collecting data as it enriches the data collected. Additionally, Yin (2014) asserts that using

more than one method for generating data ensures accuracy for research findings and conclusions. As a result, interviews in this study were used to triangulate data collected through the questionnaire.

4.7 DATA ANALYSIS

According to Vithal and Jansen (2010), data analysis involves procedures through which the researcher prepares the raw data for analysis. Additionally, Cohen et al. (2017) state that data analysis involves organising, accounting for, and explaining the data generated in the study. In this section, the data analysis process employed by the researcher in organising and interpreting data collected is presented.

Data generated in this study comprised both qualitative and quantitative data. The primary source of data analysis was the transcribed recordings of interviews. The recordings from the interviews were transcribed verbatim into a format that allowed for analysis. During transcription, the researcher carefully and repeatedly listened to the tape recordings to extract all information, including the laughs and the probing questions. At this process of data analysis, the researcher read the transcripts several times to gain an understanding of the participants' perspectives and experiences regarding the phenomenon being studied. Reading the transcripts repeatedly also assisted the researcher to identify meaningful ideas on these transcripts, which was helpful in noting the meaning units. Transcription of interview recordings was conducted straight after the interview session to ensure that all participant's views were captured correctly. Responses of participants from questionnaires were also used to analyse data.

In analysing the qualitative data, the researcher adopted interpretive phenomenological analysis (IPA). Interpretative phenomenological analysis is a well-recognised qualitative approach that most researchers use to investigate individuals' lived experiences (Smith, 2011). The aim of IPA is to explore deeply particular experiences that individuals come across and ways in which they construct meaning arising from their personal and social world. This study sought to explore deeply the FET mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry during the COVID-19 pandemic lockdowns. Hence, IPA was the most appropriate data analysis tool for this study.

To date various scholars have developed numerous methods of interpretative phenomenological data analysis (for example: Giorgi, 1975; Moustakas, 1994; Creswell, 2014). After carefully studying these methods of phenomenological data analysis, the researcher decided to follow the steps proposed by Moustakas (1994) (Figure 4.1). Phenomenological data analysis methods are premised on the researcher 'bracketing' their subjectivity. This process is referred to as *epoché*, a Greek word meaning to 'refrain from judgements' (Moustakas, 1994, p. 33). In engaging in *epoché*, the researcher of this study attempted to set aside her prejudgments and predispositions towards the phenomenon. Even though it was difficult to suspend all the suppositions since the researcher shared common experiences with the participants, the researcher tried to avoid interjecting her experiences into the lived experience narratives of the participants. The researcher approached the analysis process with an open mind, understanding that all experiences and events that occurred prior to COVID-19 pandemic lockdowns would be set aside. The researcher sought to gain an understanding of how mathematics teachers responded to the need for a sudden shift to e-learning, particularly in the COVID-19 era. Figure 4.1 shows the steps taken to analyse the data.

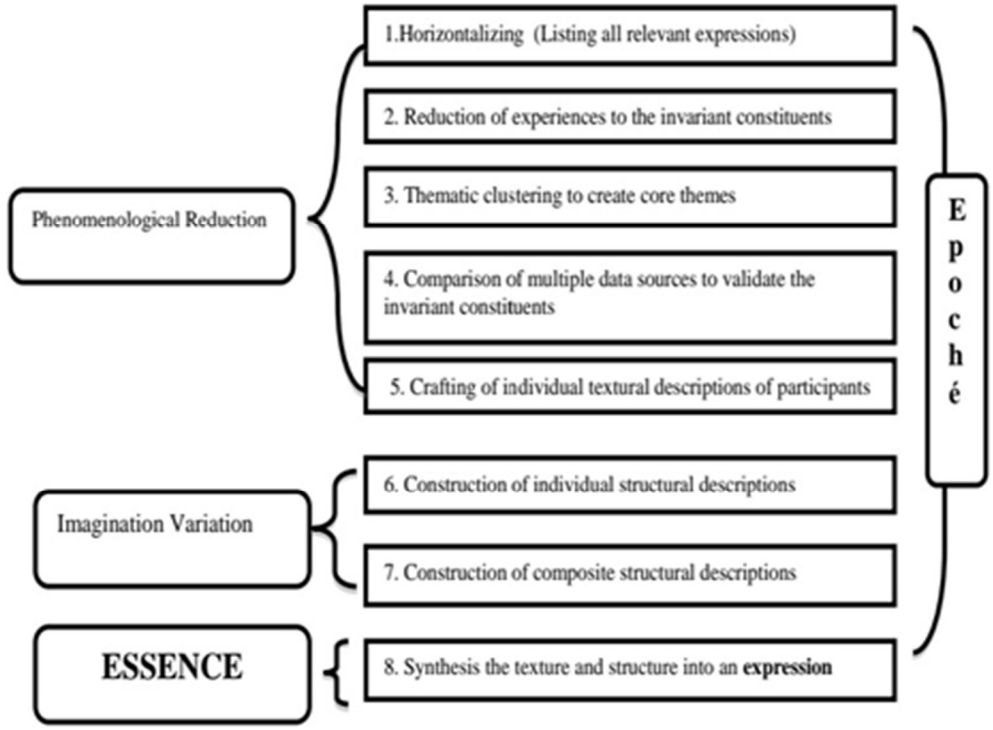


Figure 4.1: The steps of data analysis
Source: Adapted from Moustakas (1994)

1. **Horizontalising (listing relevant expressions)**

Moustakas's (1994) concept of horizontalising holds particular relevance in the examination of FET mathematics teachers' experiences in enhancing their competencies for teaching Euclidean geometry amid the COVID-19 pandemic lockdowns. In this analytical process, the researcher systematically sifts through the research data, discerning and retaining only those statements that directly address the study's research questions. By discarding repetitive and extraneous elements, this horizontalising approach aims to distil the essential textual meanings embedded in the participants' narratives.

2. **Reduction of experiences to the invariant constituents**

In phenomenological reduction, the researcher assumes the responsibility of articulating individual experiences using a nuanced, textural language. This crucial step in data analysis involves the meticulous reduction of the collected data, distilling it down to its invariant constituents.

Through a meticulous process, the researcher identifies and categorises statements that share similar meaning, subsequently clustering them into overarching themes. This thematic clustering unveils the underlying patterns and common threads woven into the rich tapestry of FET mathematics teachers' experiences. The resulting themes serve as key conduits through which the study explores the intricacies and nuances of how technology-mediated teaching unfolds in the context of Euclidean geometry during the challenges posed by the COVID-19 pandemic lockdowns.

3. **Thematic clustering to create core themes.**

At this stage of data analysis, the statements are organised into thematic clusters. There are two prominent approaches to theme development—inductive and deductive (Fereday and Muir-Cochrane, 2006). In this study, the researcher opted for the inductive approach. This method involves a meticulous reading of the collected data, undertaken multiple times, to discern inherent patterns and allow themes to organically surface from the data itself. The deductive approach relies on a predefined template of codes whereas the inductive method

prioritises the emergence of themes directly from the intricacies of the collected data. This nuanced approach ensured that the themes encapsulated the genuine and unfiltered essence of FET mathematics teachers' experiences, providing a robust foundation for the subsequent stages of analysis and interpretation.

4. Comparison of multiple data sources to validate the invariant constituents

To fortify the reliability and trustworthiness of the themes that emerged, a meticulous process of comparing themes from distinct data sources was undertaken. Themes gleaned from participants' rich perspectives, as articulated during interviews, were systematically juxtaposed with themes derived from their responses to the structured questionnaires. This methodological strategy aligned with the assertion made by Bertram and Christiansen (2014) that incorporating data from diverse sources serves as a robust mechanism for bolstering the trustworthiness of findings.

The comparison of themes across interview and questionnaire data not only validated the accuracy of the identified key themes and patterns, but also contributed to a comprehensive understanding of FET mathematics teachers' experiences. This triangulation of data ensures that the emergent themes resonated across different modes of participant expression, adding layers of authenticity to the study's outcomes.

5. Construction of individual textural descriptions of participants

To illuminate the detailed experiences of participants, individual textural descriptions were thoughtfully crafted. This process involved translating the identified themes into narrative formats, capturing the essence of what participants encountered during the phenomenon under investigation. The researcher employed a structured table format, aligning excerpts from both interviews and questionnaire responses with corresponding meaning units.

This textual journey created a vivid picture that delved into the depth of FET mathematics teachers' experiences, as expressed by the participants themselves. By presenting these individualised narratives, the study sought to authentically convey the essence of each participant's journey, fostering a holistic comprehension of the diverse ways in which

teachers navigated the challenges and opportunities presented by the COVID-19 pandemic lockdowns.

6. Construction of individual structural descriptions

In this step, the researcher employed textual descriptions formulated in the previous phase and applied imaginative variation to envision how the experiences unfolded. The objective of this process was to generate structural descriptions that shed light on the fundamental and contributing factors influencing the experiences. These structural descriptions aimed to elucidate the underlying conditions and triggers to explain the nature of the experience. When constructing the descriptions of the 'how', the researcher reflected on the contexts and situations that shaped the experiences encountered by FET mathematics teachers during their learning journey.

7. Construction of composite structural descriptions

This step involved a synthesis of steps five and six, where the researcher integrated textural descriptions into structures that explained how the experiences unfolded. This process proved invaluable for the researcher as it deepened the understanding of participants' perspectives and experiences in developing their competencies for teaching Euclidean geometry in a digital context.

8. Synthesising the texture and structure into an expression

This final step of data analysis marked the culmination of the study. In this phase, the researcher synthesised the composite of textural descriptions answering the 'what' with structural descriptions addressing the 'how'. This integration was aimed at deriving a shared meaning that encompassed the experiences of all the participants in the study, thereby forming the essence of the phenomenon under investigation.

The validation of data is crucial for ensuring the reliability and trustworthiness of the study findings. In the following section, the researcher elaborates on the methods employed to validate the data in this study.

4.8 TRUSTWORTHINESS OF THE FINDINGS

Having elucidated the data generation and analysis procedures, it is essential to assess the degree to which this research adheres to established criteria for validity. The validity of a study is paramount, as it determines the trustworthiness and effectiveness of the research endeavour (Cohen et al., 2017). A study lacking in validity holds little value and cannot be deemed reliable, as validity establishes the accuracy of research instruments in measuring the intended aspects of the phenomena under investigation. It is the responsibility of the researcher to persuade the reader that the research instruments employed in the study are as sound as possible.

In this section, the researcher expounds on the measures taken to ensure that the findings of this study are both valid and reliable. This entails a comprehensive examination of the steps undertaken to guarantee that the research instruments accurately capture and measure the targeted elements of the phenomena, instilling confidence in the robustness of the study's outcomes.

The principles of validity in qualitative methods diverge from those in quantitative approaches. Anney (2014) posited that while quantitative researchers emphasise reliability, objectivity, and validity, their qualitative counterparts prioritise dependability, credibility, transferability, and confirmability to establish the trustworthiness of their findings. Furthermore, the works of Lincoln and Guba (1985) as well as Loh (2013) have suggested that key criteria for validity in qualitative research encompass credibility, transferability, dependability, and confirmability.

In the subsequent discussion, the researcher elucidates how these elements were meticulously addressed to ensure the quality of the study. This involves a thorough exploration of the actions taken, the rationale behind them, and their appropriateness within the specific context of the research. By doing so, the reader is provided with the necessary information to make informed judgements about the quality of this study.

4.8.1 Credibility

The qualitative research approach often leads to the emergence of multiple realities, creating a challenge in determining whose perspectives are credible. Credibility, as defined by Guba (1981), pertains to how the researcher can instil confidence in the "truth" of the study findings, both for the participants involved and within the specific context of the research. It is imperative for the researcher to ensure that the presented results authentically reflect the lived experiences of the participants, establishing the credibility of the study (Anney, 2014).

Anney (2014) suggests several strategies to enhance the credibility of a study, including field experience, triangulation, member checking, time sampling, interview techniques, and structural coherence. In this study, credibility was established through interviews with three participants from different schools. These interviews were meticulously conducted, audio recorded, and transcribed verbatim to guarantee that the generated data accurately represented the participants' perceptions. The interview questions were clear and concise, and participants were encouraged to seek clarification, contributing to the overall quality of responses.

Furthermore, triangulation was employed by using questionnaires to corroborate the data obtained through interviews. Bertram and Christiansen (2014) assert that triangulation enhances trustworthiness. Additionally, the researcher extended the duration of data collection from September 2022 to December 2022, spanning approximately three full months. This extended timeframe allowed participants ample opportunity to reflect on their feelings regarding the phenomenon under study and provided flexibility for reasonable adjustments before data analysis commenced.

4.8.2 Transferability

Transferability becomes attainable when the findings of a study are not only applicable within the study setting but also possess a degree of generalizability to other contexts (Lincoln & Guba, 1986). Johnson (1997) noted that qualitative research findings are often less generalisable due to their origin from a limited number of participants and specific

contexts. To address this limitation, the researcher adopted a phenomenological case study approach.

The phenomenological case study approach was chosen with the aim of delving deeply into the in-depth descriptions and meanings of participants' lived experiences within a specific situation. By focusing on the richness of these descriptions and meanings, the study aimed to enhance transferability. The insights derived from the participants' experiences in the particular context could then be considered for transfer to other settings sharing similar conditions. This approach acknowledges the contextual nature of qualitative research while striving to provide valuable insights that may have broader applicability beyond the immediate study setting.

4.8.3 Dependability

Dependability, as highlighted by Guba (1981, p. 80), is essential for determining whether the findings of a research study can be consistently replicated under similar conditions with similar participants. It underscores the consistency and reliability of research findings (Cohen et al., 2017). Moreover, dependability speaks to the extent to which research methods are documented, allowing readers to follow, audit, and critique the research process (Kumar et al., 2019). To ensure dependability in this study, the researcher meticulously documented a comprehensive description of the methodology and research methods employed. This documentation serves the purpose of enabling readers to assess the extent to which the research procedures were adhered to.

Guba (1981) suggested that reflexivity plays a crucial role in reducing bias and enhancing dependability. Reflexivity involves the researcher's ongoing self-assessment of bias and subjectivity throughout the research process and its potential impact on study findings (Berger, 2015). In this study, the researcher consistently engaged in reflexivity by bracketing out subjective experiences and preconceived notions related to ways of enhancing competencies in teaching Euclidean geometry proofs. The researcher practiced *epoché*, setting aside judgements and presuppositions to ensure that the findings genuinely reflected the truth and reality of participants' experiences. This commitment to reflexivity contributes to the overall dependability of the study.

4.8.4 Confirmability

Confirmability is intricately linked to the degree to which the outcomes of a study are exclusively rooted in the experiences and preferences of the research participants rather than those of the researcher. As emphasised by Miles and Huberman (1994), researchers can establish confirmability by openly addressing their predispositions, beliefs, and assumptions.

In this study, the researcher took deliberate steps to achieve confirmability. The philosophical and epistemological foundations of the study were thoroughly discussed in chapters 3 and 4. By articulating her philosophical position, the researcher conveyed to readers that she maintained detachment from the participants, with all presented information originating solely from the participants. Additionally, a detailed account of the procedures employed to collect, analyse, and manage data was provided, along with a reflection on how philosophical preferences influenced the research process. This transparency empowers readers to critically assess the research process, ensuring that the results are indeed reflective of the participants' experiences rather than being unduly influenced by the researcher's perspectives.

4.9 ETHICAL CONSIDERATIONS

This study employs a phenomenological case study approach guided by an interpretative and participant-oriented methodology. Given this framework, it was imperative and ethically crucial for the researcher to take every possible measure to safeguard the rights, privacy, and dignity of the participants. This section outlines the strategies adopted by the researcher to uphold participants' values, rights, and dignities in accordance with ethical considerations outlined by Cohen et al. (2017). It includes a discussion on how permission to conduct the study was obtained and outlines the researcher's commitment to the principles of autonomy, beneficence, confidentiality, and non-maleficence.

4.9.1 Obtaining permission to conduct the study

McMillan and Schumacher (2010) assert that obtaining approval is a fundamental step before commencing any research, a view supported by Creswell and Creswell (2018), who emphasise the necessity for researchers to seek permission from relevant institutions before data collection. Adhering to these principles, the researcher diligently sought permission from pertinent stakeholders.

Firstly, clearance to conduct research in the selected school was secured from the KwaZulu-Natal Department of Basic Education (KZN, DBE) (Appendix A). Subsequently, permission to collect data from FET mathematics teachers was obtained from the school principals of the selected institutions (Appendix B). Additionally, ethical clearance to conduct the study was granted by the University of KwaZulu-Natal (UKZN) Humanities and Social Sciences Research Ethics Committee (HSSREC) (Appendix D). Finally, research participants demonstrated their willingness to engage in the study by signing consent forms (Appendix C). These documented permissions and ethical clearances underscore the commitment to conducting the research in a manner that respects ethical standards and safeguards the rights of participants.

4.9.2 Autonomy

The ethical principle of autonomy upholds participants' rights to make independent choices regarding their involvement in the study (McDonald and Kidney, 2012). To align with this principle, participants were provided with an information sheet and consent forms (Appendix C). These documents detailed the study, including its purpose, methods, data generation instruments, and contact information for the researcher, adviser, and the UKZN research office.

The information sheet explicitly communicated that participation in the study was voluntary, and participants retained the freedom to withdraw from the study at any point without consequence. This commitment to autonomy ensured that participants had the necessary information to make informed decisions about their involvement in the research.

4.9.3 Beneficence

In adherence to the ethical principle of beneficence, participants were explicitly informed that there were no incentives or reimbursements offered for their participation in this study. This transparency ensured that participants were aware of the conditions surrounding their involvement and eliminated any potential expectations of compensation.

4.9.4 Confidentiality

According to McMillan and Schumacher (2010), preserving participants' confidentiality and safeguarding their privacy is paramount. In this study, participants were guaranteed that their confidentiality would be strictly maintained, ensuring their identities remained anonymous. To reinforce this assurance, codes such as P1, P2, and so forth were utilised instead of participants' actual names during data presentation, thereby preserving their anonymity.

Additionally, participants were informed about the secure storage of collected data in the researcher's computer for a period of five years. It was clarified that after this stipulated duration, the data would be permanently destroyed. This commitment to data security and confidentiality served to uphold participants' privacy and safeguard their information throughout and beyond the study period.

4.9.5 Non-maleficence

The ethical principle of non-maleficence, as advocated by Betram and Christiansen (2014), guides researchers to ensure that participants are not harmed during the course of the study. The information sheet provided to participants explicitly stated that this research would not cause any harm to them in any way. It was emphasised that their participation in the study was entirely independent of their academic records or their future prospects in the schools where they worked.

Additionally, participants were assured that any information they provided would remain confidential and would not be traceable back to them. This commitment to non-maleficence

aimed to alleviate any concerns participants might have had about potential negative consequences resulting from their involvement in the research.

4.9.6 Limitations and affordances

The study encountered limitations and affordances that warrant acknowledgement. Notably, most schools in Harry Gwala are located in deep rural areas. A significant obstacle emerged due to limited internet connectivity, impacting the prompt response of participants to the questionnaires. This constraint affected the overall efficiency of the study, prompting the need for additional considerations in the data collection process.

However, it is important to recognise that the rural setting also provided a distinctive opportunity to delve into education within a context that significantly differs from urban environments. This unique setting allowed for a more profound understanding of the intersection between technology and teaching practices in rural educational settings. Despite the challenges, the study's location brought about valuable insights that enriched the overall exploration of the research topic.

4.10 CONCLUSION

This chapter provided a comprehensive overview of the research design and methodology employed to fulfil the study's objectives. The rationale for selecting the interpretative paradigm as the research framework was elucidated, offering insights into the guiding research approach. Furthermore, the participant selection and sampling methods adopted in this study were justified. The chapter delved into the methods employed for data generation and analysis, offering a clear rationale for their selection. Additionally, principles ensuring the trustworthiness and validity of the study were highlighted, with a specific focus on adherence to the requirements of credibility, confirmability, dependability, and transferability.

In concluding this chapter, a succinct discussion on the ethical considerations adhered to throughout the study was provided. This encompassed a reflection on participant rights, confidentiality, and other ethical principles that were upheld to ensure the ethical integrity

of the research. Furthermore, the chapter candidly acknowledged the study's limitations and highlights its affordances, providing a comprehensive overview of the research endeavours.

CHAPTER 5: RESEARCH FINDINGS AND DATA ANALYSIS

5.1 INTRODUCTION

The primary objective of conducting this phenomenological case study was to delve into the experiences of FET mathematics teachers in the Harry Gwala District regarding the enhancement of their competencies in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns. The preceding chapter covered the methodology employed for this study. In this chapter, the researcher presents and analyses the data collected through both questionnaires and interviews, utilising the steps outlined in the Chapter 4.

This chapter is structured into three distinct sections. The initial section provides a comprehensive demographic overview of the study participants, detailing their profiles with a focus on information such as age, gender, educational background, and the number of years spent teaching in the FET band. The second section presents the data and research findings derived from interviews and questionnaire responses, specifically exploring teachers' experiences in enhancing their competencies. The collected data is analysed in relation to the research questions, noting connections and differences. The analysis of data was then juxtaposed with the literature reviewed in Chapter 2, highlighting both similarities and differences between this study and previous research.

5.2 DEMOGRAPHIC DESCRIPTION OF THE PARTICIPANTS

The participants' profiles for this study were derived from the initial section of the questionnaire, as detailed in Appendix E. This dataset played a crucial role in shedding light on the characteristics of the individuals involved in the research. Additionally, it served to contextualise the study, providing readers with a deeper understanding of the participants' lived experiences. The demographic information encompassed various factors, including age, gender, qualifications, and teaching experience.

To effectively convey this demographic data, quantitative presentation methods such as tables, graphs, and frequencies were employed. The Google Form utilised for the questionnaire efficiently captured participants' responses, translating them into visually accessible formats such as graphs and Excel spreadsheets. This method not only facilitated a comprehensive analysis of the participants' characteristics but also ensured a clear and visually engaging presentation of the demographic information for readers. The TPACK framework concepts were employed to analyse and interpret the demographic information of the participants.

5.2.1 Age distribution of the participants

The data analysis reveals a notable trend among FET mathematics teachers in the selected schools within the Harry Gwala District, with the majority falling below the age of 45. Figure 5.1 illustrates that the largest portion of participants falls within the age range of 35 to 45 years (42.9%), followed by those under 35 years (25.7%). Participants aged between 46 to 55 years constitute 28.6%, while those older than 55 years make up 2.8%.

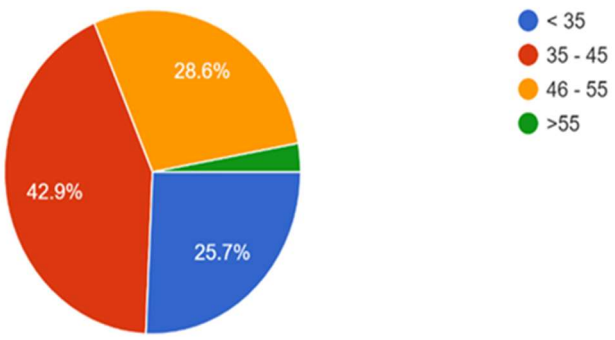


Figure 5.1: Age

The significance of this age distribution becomes apparent when considering the potential skills and knowledge gaps within these age groups. Teachers between the ages of 35 and 45 may possess technological skills but might lack proficiency in Euclidean geometry content. This cohort corresponds to individuals who attended school between 2008 and 2014 when Euclidean geometry was optional in the third paper of the matric mathematics exam.

Furthermore, those who pursued a Bachelor of Education (FET) at UKZN during this period may not have covered geometry content in the one module which was optional for the FET phase however, creating a potential knowledge gap. While these teachers may excel in technology, the absence of geometry content skills presents a challenge. However, their advantage lies in their ability to leverage technology for self-development in this regard.

Conversely, teachers under 35 years old, having completed the CAPS curriculum, likely possess comprehensive knowledge, including mandatory Euclidean geometry skills. At UKZN, the curriculum incorporates modules such as EDMA 160, EDMA 223, EDMA 225, and EDMA 414 which cover geometry PCK. This age group seems well-equipped with a holistic understanding of both technology and content.

On the other end of the spectrum, teachers above 45 years old may have a solid foundation in PCK but might lack proficiency in TK. This group may be further disadvantaged by being in a rural area such as the Harry Gwala District which face challenges associated with technology access.

5.2.2 Gender distribution of the participants

The study's participant composition was predominantly male, with a notable ratio of 3 males to 2 females, as depicted in Figure 5.2. The gender distribution reflects a population where 60% are males and 40% are females, showing the prevalent dominance of male teachers in the realm of mathematics education within the Harry Gwala District.

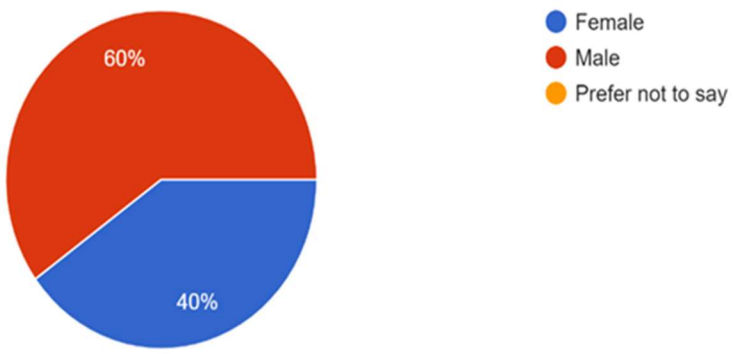


Figure 5.2: Gender

This data raises a concern regarding the underrepresentation of female teachers in the field of mathematics. The skewed gender distribution points to a broader issue of potential disparities in the pursuit of mathematics and science streams by female educators. Addressing this gender imbalance is crucial for fostering diversity in the teaching profession and encouraging more women to participate in STEM (science, technology, engineering, and mathematics) fields. Strategies aimed at promoting inclusivity and equal opportunities for male and female educators in mathematics should be explored to ensure a well-rounded and diverse teaching community.

5.2.3 Education

A noteworthy observation in the realm of education is that a significant majority of participants in the study hold at least two qualifications. This suggests a proactive approach among teachers in the Harry Gwala District towards developing their professional competencies through continued education. However, it's worth noting that a considerable portion of participants pursued courses that are not full-time education programmes, such as PGCE, ACE in maths, and secondary teachers' diploma (see Appendix F).

While these additional qualifications contribute to participants' CK, there may be a gap in pedagogical knowledge. Programmes such as the PGCE (Postgraduate Certificate in Education) and other non-full-time education courses may allocate less time to the methods of teaching. As a result, educators with these qualifications might excel in their subject matter but could benefit from additional training or professional development in pedagogical approaches and effective teaching methods. Addressing this balance between content and pedagogical knowledge is crucial for ensuring a comprehensive and well-rounded skill set among teachers. Efforts to provide ongoing professional development opportunities focused on effective teaching strategies could further enhance the overall quality of education in the district.

5.2.4 Number of years of teaching

All participants in the study possessed teaching experience exceeding two years, aligning with the study's criterion that teachers must have taught mathematics in the FET band for

over two years. The largest group of participants, constituting 31.4%, reported having 11-15 years of teaching experience, as illustrated in Figure 5.3.

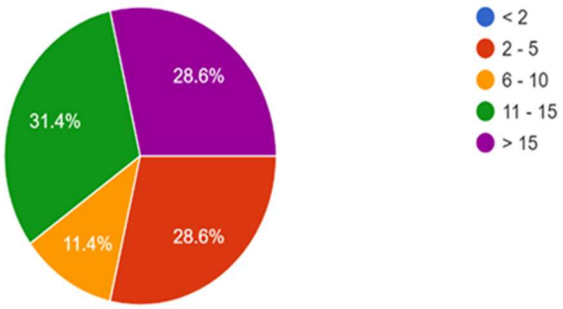


Figure 5.3: Number of years teaching in the FET band

This extended teaching experience raises noteworthy considerations, particularly for those with 11-15 years in the education system. Given the predominantly rural nature of schools in the Harry Gwala district, it is plausible that these teachers may not have had prior exposure to teaching geometry using technology. The lack of technological infrastructure in deep rural areas could mean that, despite their competence in using technology for personal purposes, these teachers might not have integrated technology into their teaching methodologies before the COVID-19 era.

The potential challenges these teachers faced during the COVID-19 lockdowns become evident. With schools closed for extended periods, the sudden shift to teaching through technology could have posed difficulties for educators unaccustomed to this mode of instruction. Furthermore, even if teachers were proficient in using technology, the accessibility barriers faced by learners in the district could have hindered the effectiveness of online learning. This highlights the broader issue of technological disparities and access limitations that impact both educators and learners in less affluent regions of South Africa.

The study reveals a balanced distribution of participants, with 28.8% having 2-5 years of teaching experience and an equivalent percentage having more than 15 years of teaching experience. This diversity in experience levels, spanning both the younger and older generations of educators, carries positive implications for knowledge exchange and professional development.

The presence of both younger and more seasoned educators in the study cohort establishes an encouraging dynamic. The younger generation, typically more adept with the latest technology, can contribute by informing and updating their older counterparts on technological advancements and innovative teaching methods. Simultaneously, the experienced senior educators bring valuable insights and mentorship to the novice educators, helping to enhance their overall skill set beyond technological aspects.

This intergenerational collaboration fosters a conducive environment for the exchange of ideas, knowledge transfer, and mutual capacity building. The coexistence of different experience levels within the teaching community bodes well for creating a well-rounded and adaptable educational landscape that benefits from the strengths of both the younger and older generations.

5.3 PRESENTATION AND ANALYSIS OF TEACHERS' EXPERIENCES IN ENHANCING THEIR COMPETENCIES OF TEACHING EUCLIDEAN GEOMETRY PROOFS DURING COVID-19 PANDEMIC LOCKDOWNS

In this section, the researcher elucidates the lived experiences of the participants. Utilising the process of IPA, three overarching themes and subthemes emerged from data gathered through both questionnaires and interviews. The ensuing table represents the themes that emerged during phenomenological reduction process.

Table 5.1: Summary of findings

Research questions	Themes	Subthemes/ Responses
1. How did FET mathematics teachers from Harry Gwala District respond to the need for e – learning to teach Euclidean geometry proofs during the COVID-19 pandemic?	Technological tools used by participants	- Communication tools - Technological pedagogical tools and aids
2. In what ways are the FET mathematics teachers from Harry Gwala District enhanced their skills of teaching Euclidean geometry proofs during the COVID-19 pandemic?	Developing technological pedagogical skills.	- Dependency on online workshops - Reliance on internet and YouTube videos - Reliance on other colleagues - Studying further
3. What are the Harry Gwala District FET mathematics teachers' experiences of improving their competencies for teaching Euclidean geometry proofs during the COVID-19 pandemic?	Teachers' experiences of enhancing competencies	- Teachers' positive experiences - Teachers' negative experiences - Mixed experiences - Underlying factors that influenced teachers' experiences ➢ Frustrations at poor network connectivity ➢ Frustrations due to data availability ➢ Lack of technological resources ➢ Learners' negative attitude towards online learning

The data within this section is systematically presented, addressing each research question individually.

The research questions were:

1. How did FET mathematics teachers from Harry Gwala District respond to the need for e-learning to teach Euclidean geometry proofs during the COVID-19 pandemic?
2. In what ways are the FET mathematics teachers from Harry Gwala District enhancing their skills of teaching Euclidean geometry proofs during the COVID-19 pandemic?

3. What are the Harry Gwala District FET mathematics teachers' experiences of improving their competencies for teaching Euclidean geometry proofs during the COVID-19 pandemic?

5.3.1 How did FET mathematics teachers from Harry Gwala District respond to the need for E – learning to teach Euclidean geometry proofs during the COVID-19 pandemic?

The first research question intended to capture mathematics teachers' reactions towards the inevitable need to transition from face-to-face teaching and learning to e-learning prompted by the COVID-19 pandemic lockdowns.

Participants were asked whether they were able to use online teaching platforms to teach mathematics in general or Euclidean geometry proofs during the COVID-19 pandemic lockdowns. Thirty-four of the 35 respondents provided responses to the open-ended question on this matter. Remarkably, all teachers affirmed their use of online teaching platforms, signalling a unanimous acknowledgement of the necessary shift from face-to-face to virtual instruction. Despite encountering initial challenges, the teachers exhibited adaptability by devising effective coping strategies. It is noteworthy that one teacher opted not to respond to the questions.

Participants' responses to the necessity for online learning were evident across various themes and subthemes explored in this study. However, Theme 1 focused specifically on teachers' reactions to the shift to e-learning for the instruction of Euclidean geometry proofs.

Theme 1: Technological tools used by participants

This theme summarises ways in which the participants responded to the necessity for e-learning. The results indicate that these teachers embraced e-learning. In response to the challenges posed by the COVID-19 pandemic, participants utilised social media pedagogies, incorporated cooperative learning strategies, and navigated obstacles associated with online learning platforms and technology. Teachers who utilised technological tools during the

COVID-19 pandemic lockdowns indicated a diverse array of such tools. Figure 5.4 illustrates the types of technological tools employed by the participants in this study.

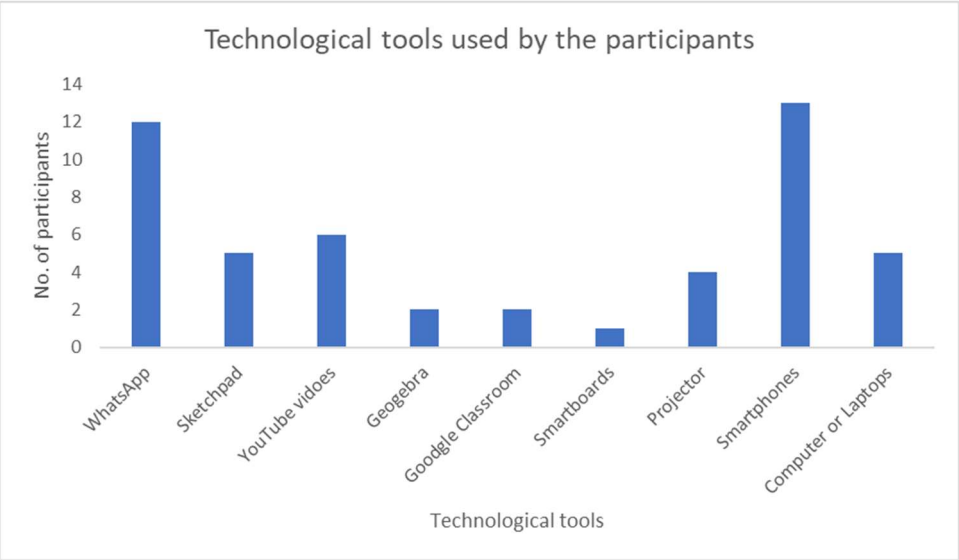


Figure 5.4: Different types of technological tools used during COVID-19 pandemic lockdowns

Based on the depicted results (Figure 5.4), the majority of participants relied on smartphones during the COVID-19 pandemic lockdowns. Another prevalent technological tool was WhatsApp, suggesting that most participants used their smartphones for communication with learners on this platform. Six participants utilised YouTube videos, while sketchpad and computers or laptops were used by an equal number of participants (5 individuals). GeoGebra and Google Classroom were each employed by two participants. Notably, only one person reported using a smartboard.

In a similar study conducted by Fikria et al. (2021), educators utilised applications such as WhatsApp, Google Classroom, Zoom, and Google Forms for teaching mathematics during the COVID-19 pandemic lockdowns. The findings in the current study align with the results obtained in that study. However, it's noteworthy that participants in this study did not employ platforms like Zoom, Google Forms, or Microsoft Teams. This discrepancy suggests that FET mathematics teachers in the Harry Gwala District may face limitations in accessing certain technological tools or may have varying levels of proficiency in digital pedagogical skills. Understanding these disparities is crucial for developing targeted interventions to enhance technological resources and skills among educators in specific regions.

Subtheme 1: Communication tools

During the COVID-19 pandemic lockdowns, participants utilised various technological tools such as WhatsApp, smartphones, computers or laptops, and Google Classroom specifically for communication with their students. The nature of these communication tools varied, with some being interactive and others non-interactive. This observation is supported by insights from participants questioned about their use of technological tools for teaching Euclidean geometry.

For instance, some participants highlighted using WhatsApp to conduct lessons, involving the exchange of voice notes, video sharing, and conference calls with learners.

> *I do conduct my lessons on WhatsApp where I post things, using our WhatsApp chat room with my learners. Teaching using WhatsApp where one will send voice notes, share videos, or have conference calls with learners. I teach, and then they respond in those video calls or conference calls.* (IP1)

QP15 noted: *"I just posted videos though their WhatsApp group"*.

This interactive approach allowed for active participation and response from learners. Additionally, in responses from the questionnaire, QP16 mentioned having *"interactive lessons on smartphones"*, indicating an engaging teaching method QP2 said that they primarily *"utilised the phone to reach out to learners"*, and QP3 described using *"the lesson space of Google Classroom for teaching"*.

These participants' articulations collectively reveal a spectrum of communication tools, some fostering interaction between teachers and learners, while others primarily involve one-way communication. This distinction emphasises the diversity in approaches taken by participants, reflecting the adaptation to available resources and technological preferences during the challenging circumstances of the pandemic. These results align with the recommendation from Dhawan (2020) on addressing challenges in virtual classrooms, suggesting that improved communication with students can be achieved through the utilisation of social media and various messaging apps. In a similar vein, Rambe and

Chipunza (2013) identified WhatsApp as an effective tool for addressing "information asymmetries often observed among students from economically disadvantaged backgrounds" (p. 335).

Subtheme 2: Technological pedagogical tools and aids

GeoGebra emerged as a significant pedagogical tool, as indicated by insights from interview participants. For instance, IP1 emphasised its use, stating, *"I use our GeoGebra software, just to show learners how different angles can be constructed and the relationship between different angles"*. Similarly, IP2 confirmed, *"I use GeoGebra for constructing diagrams"*.

Another tool employed in teaching was Sketchpad, as attested by QP18 who stated, *"I used Sketchpad to prepare the material that I would use during the lesson with my learners"*. This usage highlights the versatility of technological tools like GeoGebra and Sketchpad in aiding educators in preparing and delivering instructional content, particularly in the context of teaching geometry.

In summary, the findings of this study reveal that participants were actively embracing e-learning, utilising various technological tools to sustain their instructional efforts during challenging circumstances. The participants' increasing proficiency in online teaching strategies became apparent through self-reflection. This is corroborated by an excerpt from QP 35, who mentioned, "*I downloaded video lessons from various websites to enhance my knowledge. Additionally, I acquired more effective strategies for teaching the topic through instructional YouTube videos*". Drawing on Mpungose's (2023) perspective, engaging in self-introspection or non-formal reflection enables individuals to uncover crucial aspects of their identities, including love, passion, courage, and creativity. According to Mpungose (2023), this self-introspective process empowers teachers to recognise their strengths and limitations, forming a basis for enhancing their competencies and actively participating in e-learning. Essentially, the success of teachers in the realm of e-learning is intricately tied to their self-efficacy. Through reflective practices, educators can effectively navigate and adapt to the challenges associated with e-learning, contributing to their continued professional development.

5.3.2 In what ways are the FET mathematics teachers from Harry Gwala District enhanced their skills of teaching Euclidean geometry proofs during the COVID-19 pandemic?

The second research question sought to comprehend how teachers enhanced their professional development during the challenging and unfavourable circumstances of the COVID-19 pandemic lockdowns. In essence, the second question delved into the strategies employed by participants to enhance their proficiency in utilising digital resources for teaching Euclidean geometry proof amidst the constraints imposed by the pandemic lockdowns.

Theme 2: Developing technological pedagogical skills.

This theme illustrates the methods through which participants improved their abilities in teaching Euclidean geometry proofs amid the COVID-19 pandemic lockdowns. Several participants affirmed that the global shutdown did not hinder their learning; instead, it presented new opportunities for acquiring knowledge.

Subtheme 1: Dependency on online workshops

Online workshops emerged as the predominant method through which teachers honed their technological skills, a viewpoint substantiated by responses from various participants. When queried about the ways in which they enhanced their competencies in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns, participants provided the following insights:

> *I attended virtual workshops organised by Stellenbosch University.* QP18
>
> *Through online seminars.* QP19
>
> *I participated on virtual workshops on SHARP webinars.* QP20
>
> *I attended online webinars organised by Answer Series.* QP21
>
> *I attended online workshops organised by private companies.* QP22
>
> *I attended online lessons organised by private tutors for grade 11 and 12 learners.* QP26
>
> *I attended virtual workshops organised by Sharp and Answer series.* QP35

I attended and trained on my own online classroom course which I paid for. IP2

These responses collectively highlight the prevalence of online workshops as a favoured avenue for teachers to actively engage in professional development and enhance their skills in teaching Euclidean geometry proofs during the pandemic lockdowns. The widespread preference for online workshops reflects the adaptability of teachers to remote learning environments and a notable shift in how educators seek professional development opportunities. This shift may indicate a growing reliance on virtual platforms, necessitating ongoing efforts to enhance the accessibility and effectiveness of online learning resources for teachers.

Subtheme 2: Reliance on internet and YouTube videos

Participants expressed that when faced with challenges in understanding the use of technological tools, they turned to online resources, particularly through internet searches and watching YouTube videos. For example: *"After facing challenges with problem-solving, I went through training on using Google to search for information online"* (IP2), and *"I downloaded video lessons on various websites to enrich myself. I also learned more efficient strategies to teach the topic on YouTube videos"* (QP19).

Furthermore, participants indicated the use of YouTube videos to enhance competencies in using online teaching platforms: "*I watched YouTube videos to enhance my knowledge of teaching online"* (QP31), and *"I watched YouTube videos to learn how to teach online"* (QP35). Additionally, QP13 emphasised the role of YouTube videos in learning how to teach Euclidean geometry proofs online, stating, *"Through watching videos on YouTube of how to teach Euclidean geometry proofs online, I was able to teach my learners. I also attended Answer Series webinars"*. These instances underscore the participants' proactive approach to self-directed learning through online resources when faced with technological challenges.

In addition to acquiring TPK from YouTube, participants also gained CK through watching YouTube videos. When questioned about their use of platforms like YouTube to improve their CK of Euclidean geometry, the majority of participants responded affirmatively. Out of the 34 participants who provided responses to the question, approximately 76.5% (26

participants) indicated a positive response, while 23.5% (8 participants) responded negatively (Figure 5.5 below).

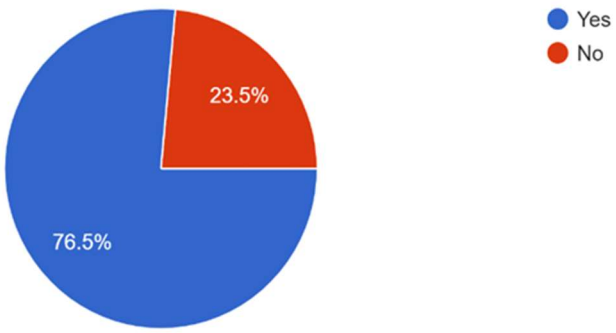


Figure 5.5. Participants' use of YouTube to enhance knowledge of Euclidean geometry

The results in Figure 5.5 highlight the participants' continuous commitment to enhancing their competencies. Even when traditional avenues for skill development, such as face-to-face workshops, were inaccessible due to closures and social distancing measures, participants demonstrated adaptability by embracing self-developmental strategies.

Subtheme 2: Reliance on other colleagues

In addition to online workshops and YouTube videos, participants relied heavily on peer support for assistance. QP6 cited *"networking"* as a means of enhancing competencies in teaching Euclidean geometry, and QP33 emphasised the importance of seeking assistance from colleagues: *"I asked for help from my colleagues who are more experienced"*. QP9 expressed satisfaction with the support from colleagues during challenging times, stating, *"I used a WhatsApp group for teachers when I came across challenging problems"*.

Furthermore, participants highlighted the collaborative relationship among teachers. QP9 stated:

> *Teachers do help each other and are always willing to help with any maths problem. WhatsApp groups for maths teachers are like a non-ending workshop, problems are shared, and anyone with a pen and paper gives ideas on how to approach a rider.* (QP 9)

QP35 asserted: *"I used our WhatsApp group to post and address certain challenges"*.

The participants' statements indicate a reliance on their colleagues for solutions or information when facing challenges with specific digital technologies. This collaborative approach underscores the importance of peer support in navigating issues related to the use of digital tools, showcasing a collective effort to address challenges and share expertise among the teaching community.

Moreover, a few participants conveyed that government stakeholders, such as subject advisers, played a supportive role in assisting teachers on their development journey. For instance, IP1 highlighted that subject adviser provided training on the use of digital tools, stating, *"our subject advisers are assisting us to make use of technological devices in order for us to teach"*.

IP1 further explained how subject advisers aided in enhancing skills for teaching Euclidean geometry using technological tools, stating, "*So, the issue of GeoGebra, I think one was exposed to it by our subject advisers, and that is where I actually got hold of the software and how to use it, and now, I am using that"*. IP2 echoed similar sentiments, mentioning that they acquired skills in using a calculator online primarily through workshops organised by subject advisers, specifically through Casio.

In addition, QP27 expressed satisfaction with the assistance received from subject advisers in improving skills with technological tools. The participant stated, *"I have asked for assistance from subject advisers, which was so beneficial to me"*. This emphasises the significant role played by subject advisers in ensuring that teachers are well-equipped to navigate the challenges of teaching online, a necessity heightened by the impact of the COVID-19 pandemic lockdowns.

The subtheme of reliance on others offers a profound understanding of the lived realities of the participants, illustrating how teachers place value on mutual assistance. Participants shared that they could collaborate with their colleagues through WhatsApp groups to seek for assistance when they encountered challenges. Following the tenets of phenomenology,

participants ascribed individual meaning to their experiences of dependency, emphasising their interactions with those possessing greater knowledge than themselves. These results strongly imply that communities of practice play a significant role in the professional development of teachers. According to Ndebele and Mbodila (2022), communities of practice are groups of individuals who willingly come together to share information, insights, and advice. Ndebele and Mdobila (2022) elaborates that these communities serve as platforms where members, sharing common experiences and challenges, engage in joint activities and discussions to build relationships that facilitate mutual learning.

The study's outcomes suggest the need for education stakeholders to establish and promote communities of practice where teachers can share their experiences and support each other in integrating ICT in teaching and learning. By doing so, teachers can enhance their competencies in teaching mathematics through online platforms, thereby contributing to addressing issues such as poor performance by learners in mathematics.

Subtheme 3: Studying further

A subset of participants emphasised that pursuing further studies played a pivotal role in helping them cope with the imperative to teach online using technological tools. This is supported by the statement of QP32, who succinctly noted, *"I studied further"*. Similarly, QP7 asserted that he developed their knowledge *"through reading different textbooks online"*.

IP3 improved competency in teaching Euclidean geometry by enrolling in an online course with Teach Me 2 Tutors:

> *I learned about different platforms to teach online. I also learned some skills to teach Maths in particular. For example, I learned how to draw diagrams on a lesson space, how to share my screen with the learners, how to upload activities for learners, etc.* (IP 3).

IP2 invested their own funds to learn methods of teaching online using digital tools: *"I attended and trained on an online classroom course which I paid for"*. This suggests a strong

determination among participants to acquire additional knowledge and skills for effective online teaching.

5.3.3 What are the Harry Gwala District FET mathematics teachers' experiences of improving their competencies for teaching Euclidean geometry proofs during the COVID-19 pandemic?

The third research question in this phenomenological case study delved into the essence of the phenomena under exploration from the participants' perspectives. Put succinctly, the goal was to uncover the inherent nature of participants' experiences as they sought to enhance their competencies. Theme 3 elucidates teachers' positive and negative experiences in greater detail.

Theme 3: Teachers' experiences of enhancing competencies

This broad theme encapsulates the experiences of selected FET mathematics teachers in the Harry Gwala District as they sought to enhance their competencies in teaching Euclidean geometry. Within this overarching theme, the researcher observed a spectrum of both positive and negative experiences during the participants' professional development journey. Notably, participants not only conveyed their feelings about skill development using digital tools but also elaborated on the factors that influenced these sentiments. Consequently, Theme 3 is further dissected into three subthemes: positive experiences, negative experiences, and underlying factors (refer to Table 5.1). Each of these subthemes is presented and analysed in detail below.

Subtheme 1: Teachers' positive experiences of enhancing their competencies of teaching Euclidean geometry using online platforms

This subtheme encapsulates the positive experiences perceived by teachers as they engaged with digital tools to enhance their skills and instruct learners. As part of their positive experiences, participants affirmed acquiring a diverse range of skills. While some participants enhanced competencies they already possessed, a majority reported developing entirely new skills. This is evident in participants' responses to the question regarding their

experiences in enhancing their competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns.

For instance, QP25 emphasised the significant benefits gained from digital platforms, stating, *"I gained a lot because I learned new methods of teaching Euclidean geometry"*. Similarly, QP26 felt encouraged and increased confidence in using technological tools to teach Euclidean geometry as a result of engaging with online platforms.

In a parallel vein, QP19 highlighted the improvement in teaching competencies, stating, *"My level of competency increased significantly. I could see that learners were accepting my new strategies"*. This collective feedback underscores how engaging with digital tools not only expanded participants' skill sets but also positively influenced their teaching methodologies.

Subtheme 2: Teachers' negative experiences of enhancing their competencies of teaching Euclidean geometry proofs using online platforms

In response to inquiries about their experiences in enhancing competencies using online platforms, participants revealed various difficulties. When asked about their experiences of improving their competencies in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns, QP19 indicated that it was challenging because they were accustomed to face-to-face workshops and found the transition to online workshops unpleasant (QP 19). Another participant unfamiliar with online learning expressed that *"distance learning was not easy because I was not used to online platforms"* (QP24).

It was evident that the above participants struggled with online learning due to their lack of prior experience with online platforms. In a true phenomenological tradition, these participants gave meaning to being unprepared for online teaching due to their limited prior experience before the pandemic lockdowns. Consequently, they faced challenges in devising synchronous lessons that catered to the needs of all learners. These findings align with a study conducted in India by Hassan et al. (2020), which explored teachers' experiences with online teaching and learning during the COVID-19 pandemic. The study revealed that educators were not well-acquainted with online platforms. According to Khoza and Mpungose (2018), the effective utilisation of educational technology in assessment,

curriculum, and instruction requires meticulous planning. They further emphasised that the adoption of technology may falter when imposed on users, particularly teachers who lack sufficient training. These findings indicate a dire need for professional development in digital literacy skills for teachers. Therefore, this study is crucial as it proposes ways in which teachers can enhance their competencies of teaching through online platforms.

IP2 articulated dissatisfaction as follows:

> *In my case, I felt that I did not improve to my satisfaction on the improvement of teaching Euclidean geometry proofs. This was judged on how my learners still have challenges today even though I thought them, due to the COVID-19 pandemic Euclidean geometry took long because learners were not at school. Few competences were attained. (IP2)*

> *The international and regional lockdowns brought a lot of challenges to the education sector as a whole, and this had a negative impact on teaching and learning of Euclidean geometry proofs where learners work collaboratively. I found myself repeating teaching of Euclidean geometry proofs repeatedly since I could not have all my learners online at once. (IP2)*

In a similar vein to IP2, QP18 commented that *"lessons repeated over a long period of time resulting in methods of delivery changing along the way"*.

The presented findings indicate that the absence of learner participation in online classes during the lockdown had a notable impact on the skill development trajectory of teachers in the Harry Gwala District. The reduced engagement of learners in online classes likely hindered teachers' opportunities to refine and adapt their teaching methods. This could lead to a potential gap in educators' skill development, particularly in utilizing digital tools and implementing effective online teaching strategies.

Subtheme 3: Mixed experiences of enhancing their competencies of teaching Euclidean geometry proofs using online platforms

Some participants reported experiencing both positive and negative outcomes in their utilisation of online platforms. For instance, QP35 articulated the following:

> *They were both good and bad. They were beneficial in that I acquired a range of skills in the workshops that I attended. However, they were challenging as I could not enhance my competencies to the fullest due to network issues and a lack of resources.* (QP35).

Similarly, QP21 stated:

> *There was a significant increase in understanding Euclidean geometry since, at the high school level, it was not part of my syllabus. However, at times, it was difficult due to network problems and the necessity to concentrate too much on a small screen, unlike attending face-to-face sessions*. (QP21)

The increased understanding of Euclidean geometry, as reported by these participants suggests that online platforms can contribute to knowledge expansion, although with certain hurdles. Addressing these challenges can help create a more inclusive and effective online learning environment.

Some participants expressed that while using online platforms proved beneficial for them, it did not necessarily yield the same advantages for their learners. This indicates that participants' experiences were greatly influenced by their learners' experiences. QP23 voiced concern for the learners, stating, *"Online learning was useful for me. I found online as the best platform for teaching and learning, even though our kids cannot reach those platforms the way they would like to"*.

Subtheme 4: Underlying factors that influenced teachers' experiences

This subtheme emerged from participants' experiences of improving their competencies using online platforms and instructing learners through digital technologies. As participants shared their sentiments regarding the utilisation of technological tools, they also identified several factors that significantly influenced their experiences in enhancing their competencies for teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns. Some of the underlying factors highlighted by participants encompassed network coverage, data availability, resource constraints, economic status, and learners' negative attitudes.

Subtheme 5: Frustrations at poor network connectivity

Among the underlying factors that influenced teachers' experiences, the most prevalent concern was the availability of network and data bundles. A significant number of participants expressed frustration with the unavailability of a reliable network, a challenge that was particularly pronounced in the deep rural areas from which most participants hailed. The issue of network connectivity aligned with participants' negative experiences in enhancing their competencies. This is evidenced by excerpts from questionnaire participants when questioned about their experiences in improving their competencies for teaching Euclidean geometry during the COVID-19 pandemic lockdowns. The following extracts illustrate participants' struggles with network coverage:

> *It was difficult since network connectivity was very poor in my area.* QP20
> *It was difficult since I had network problems in my area.* QP31
> *Not good due to network issues in our area.* QP34

The additional factor of load shedding in the country further compounds the issue of network availability for participants. QP24 highlighted this challenge, stating, *"Sometimes the network was giving us problems due to load shedding"*.

The frustration expressed by participants regarding network issues directly affects their ability to enhance their competencies in teaching Euclidean geometry. Limited access to

online workshops and resources impedes professional development opportunities, hindering the acquisition of essential skills for effective teaching in the digital age. During the COVID-19 pandemic lockdowns, network connectivity became essential as participants heavily relied on communication with colleagues. QP22 highlighted that network unavailability posed a hindrance to their communication: *"Sometimes we experience a communication barrier due to network problems in our area"*. These findings suggest that network unavailability disrupts effective collaboration among colleagues, limiting the potential for a supportive professional community.

Subtheme 6: Frustrations due to data availability

Regarding the situations that typically influenced participants' experiences, some of the participants mentioned data availability as a factor that perpetuated their negative experiences. QP30 elaborated on how the lack of data for learners resulted in delay of lessons: *"It was challenging because most learners did not have access to data for attending classes, requiring me to repeatedly explain the same concepts"*.

IP1 had a similar problem of data being not available for learners, as well as the problem of network coverage where the learners were located.

> *When it started, my teachings were not effective because for as much as we had our WhatsApp groups already, but now for a long duration, you had some learners complaining of data. Also, because schools were closed, there was no face-to-face teaching and learning. Uh, you know, learners, they will go back to their setups, where some will say, "yes, I have a cell phone device, I have data, but the network coverage is poor." So that is the challenge that one faces. But for those who were in areas where they had access to data and network coverage, we did use our WhatsApp group to continue teaching and to continue teaching Euclidean geometry as well. But to be honest, it was not effective due to the two problems I mentioned in the issue of data, as well as the issue of network coverage, especially in the rural areas.* (IP1)

Similar to the experience of IP1, QP35 faced the challenge of learners not engaging in lessons due to issues with network connectivity and data availability, saying: *"My*

experiences were very bad due to shortage of resources and disadvantaged society, economically very poor. Also, learners' engagement very poor due to network problems and unavailability of data."

The excerpts suggest that learners' lack of participation in online lessons is a factor contributing to negative experiences in enhancing the participants' effectiveness of teaching online. The lack of learner participation may hinder teachers' ability to receive real-time feedback on their teaching methods.

Additionally, participants' expressions reveal that challenges related to network connectivity and data availability have affected teachers' professional development. Teachers experienced delays as they had to wait for learners to be available, train them in the use of technological tools, and assist them in understanding the content being taught. The choice of words in the questionnaire responses, such as *"too much time was taken to teach each topic,"* (QP 10) indicates that the unavailability of network and data somewhat constrained teachers' skills development as they could not access internet. This finding, highlighting the unaffordability of data costs for internet connection among teachers and learners during the COVID-19 pandemic, aligns with similar findings in Ghana (Owusu-Fordjour et al., 2020) and South Africa (Chirinda et al., 2021; Dube, 2020).

The experiences underscore the critical role of network connectivity and data availability facilitating effective online communication between teachers and learners or among teachers. Teaching through online platforms becomes ineffective in the absence of a reliable network connection or data for both educators and learners. This highlights the necessity for implementing measures to address network issues in rural areas. Additionally, these experiences emphasise the need for substantial support, particularly in terms of data, for learners, considering their disadvantaged backgrounds.

Subtheme 7: Lack of technological resources

Some participants identified the lack of technological resources as a detrimental factor affecting their experiences in teaching Euclidean geometry, as explicitly stated by QP29: *"I*

did not have enough technological resources that would make it easier for learners to visualise some of the content matter". IP2 explained as follows:

> *I attempted to use online methods, but the environment in which I teach proved challenging. Most of my learners lacked technological resources such as phones and tablets. Even those with smartphones faced difficulties with data, and proper applications like GeoGebra were not compatible with their devices.* (IP2)

IP1 also expressed frustration over the challenge of having some learners present in the lessons while others were absent due to a lack of gadgets:

> *Unfortunately, some learners did not have the resources to participate in the presentation. Not every learner could benefit because not everyone could attend. Even though the majority could participate, it was not inclusive, and that was not satisfactory for me.* IP1

While teachers reported having access to smartphones, computers, or laptops, they expressed concern about learners who couldn't afford these gadgets. Consequently, teaching and learning were ineffective in some instances. These findings underscore the critical importance of the availability and accessibility of technological resources for the successful application of e-learning.

A significant number of participants highlighted that their learners were unable to attend online classes due to a lack of smartphones, laptops, and even data bundles for internet access. The financial constraints of their parents, stemming from a poor socio-economic background, further exacerbated the situation. This aligns with Mpungose's (2023) study, which revealed that a poor socio-economic status hinders the implementation of e-learning. These results suggest that the success of integrating technology in teaching and learning hinges on the availability of technological tools for teachers and learners. In light of these challenges, there is a pressing need for the Department of Education to establish support systems for teachers and learners. This implies providing necessary technological resources and ensuring continuous access to the internet for effective integration of technology in teaching and learning.

Subtheme 8: Learners' negative attitude towards online learning

Among the factors influencing participants' experiences in enhancing their competencies in teaching Euclidean geometry proofs, learners' negative attitudes towards online learning played a significant role. Teachers found themselves discouraged from continuously improving their competencies, as their learners displayed little interest in online learning. QP26 shared her experience:

> *I found that Euclidean is an enjoyable topic if you can work on the proofs using digital tools such as GeoGebra. Even though most of our learners are not interested in Maths, they perceive it as one of the stressful learning areas in schools.* (QP26)

On a similar note, QP2said:

> *They were good in that I gained a lot of information on the online lessons; I was confident when teaching my learners online because I was well equipped for it. On the other side, they were bad because of absenteeism of learners due to a plethora of reasons. Also, learners' negative attitude towards mathematics and Euclidean geometry was discouraging.* (QP26)

The negative attitude towards mathematics and Euclidean geometry mentioned by both participants indicates a potential need for interventions or strategies to shift students' perceptions and attitudes towards these subjects. This could involve innovative teaching methods or initiatives to make the subjects more appealing.

5.4 CONCLUSION

This chapter presented a descriptive analysis of the study's findings, consisting of two sections. The first section included demographic information about participants, covering age distribution, gender distribution, educational background, and teaching experience in the FET band. The second section focused on the analysis of participants' responses from questionnaires and interviews conducted during data collection.

The analysis revealed three broad themes. The first theme explored the types of technological tools participants used for professional self-development, highlighting communication tools and teaching aids. The second theme discussed how participants enhanced their competencies in teaching Euclidean geometry, with a reliance on online workshops, YouTube videos, social networks, colleagues, subject advisers, and further studying. The third theme delved into participants' experiences in using technological tools, influenced by network coverage and internet data bundles.

The findings were interpreted through the researcher's lens and aligned with existing literature. The discussion encompassed participants' positive and negative experiences in utilising digital tools to enhance their teaching competencies during the COVID-19 pandemic lockdowns. The thematic analysis offered valuable insights into the multifaceted aspects of participants' experiences.

Overall, the conclusion of this chapter consolidates the key findings, providing a foundation for subsequent discussions and implications for the study.

CHAPTER 6: DISCUSSION OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1 INTRODUCTION

The researcher sought to understand the lived-experiences of FET mathematics teachers of developing themselves, especially during COVID-19 pandemic lockdowns. Considering the intrinsic aspirations of the study, the research questions for the study were:

1. How did FET mathematics teachers from Harry Gwala District respond to the need for –e-learning to teach Euclidean geometry proofs during the COVID-19 pandemic?
2. In what ways are the FET mathematics teachers from Harry Gwala District enhancing their skills of teaching Euclidean geometry proofs during the COVID-19 pandemic?
3. What are the Harry Gwala District FET mathematics teachers' experiences of improving their competencies for teaching Euclidean geometry proofs during the COVID-19 pandemic?

To critically explore the phenomenon and address the main research questions, the researcher extensively examined relevant literature in Chapter 2, scrutinising other researchers' findings on teachers' experiences in enhancing competencies using technological tools. The literature review highlighted a notable gap in research, specifically the scarcity of studies focusing on how teachers in the FET phase improve their teaching competencies online, particularly in the context of South Africa's rural schools. Additionally, the literature revealed a lack of exploration into teachers' experiences in enhancing their competencies, particularly in the context of the global shutdown. In response to these gaps, a phenomenological case study was conducted to investigate how teachers continuously enhanced their competencies for teaching online.

To address the critical research questions, a questionnaire and semi-structured interviews were used to generate data that were analysed in the preceding chapter. Chapter 5 presented comprehensive discussions on three overarching themes that emerged from the study, contributing to a deeper understanding of the selected FET mathematics teachers' experiences with the use of digital tools in their professional self-development process. The

study was guided by theoretical frameworks, specifically phenomenology and the TPACK framework.

This concluding chapter commences by summarising the findings in relation to the research questions posited in Chapter 1. It delves into a discussion on the significance of the study, establishing connections between this research and ongoing debates surrounding teachers' experiences of enhancing their competencies, particularly within the context of South Africa. The chapter addresses the limitations inherent in the study and explores its implications. It culminates by providing recommendations for future research endeavours and emphasising key directions for further exploration into teachers' experiences of enhancing their competencies of teaching Euclidean geometry using technological tools.

6.2 SUMMARY OF THE FINDINGS

Participants in this study encountered both positive and negative experiences with the use of technological tools. While some successfully enhanced their competencies, all participants encountered challenges during the process.

The study findings reveal that teachers employed a variety of technological resources—both hardware (physical tools) and software (online platforms)—to elevate their ability to teach Euclidean geometry proofs. The utilisation of these digital tools enabled participants to effectively enhance their teaching competencies during uncertain times. Participants reported successful use of technological tools like WhatsApp, Google Classroom, and collaborative whiteboard platforms to engage with their students and peers. Additionally, tools such as Sketchpad, GeoGebra, and smartboards were utilised by teachers to deliver course content to students, thereby improving their communication skills and TPK, which they initially lacked.

As positive experiences, participants attested to have acquired a range of skills. While some participants enhanced existing competencies, the majority developed entirely new skills. This suggests that the COVID-19 lockdowns provided individuals with opportunities for growth and self-realisation. The skills acquired by participants were CK, TPK, and TCK, indicating that participants developed the essential TPACK skills relevant for modern times.

As a recommendation, professional development training programme supervisors should prioritise the cultivation of TPACK skills.

The study findings reveal that teaching online posed significant challenges for the majority of teachers, particularly those in deep rural areas. Several underlying factors contributed to these challenges, including poor network coverage, insufficient data availability, limited resources, the poor socio-economic status of learners, negative learner attitudes, and time constraints. Teachers faced frustration as they struggled to reach all learners, particularly due to inadequate network connections in rural areas. Furthermore, many learners faced obstacles attending online classes, such as a lack of continuous internet access and the inability to afford technological devices due to their disadvantaged socio-economic backgrounds. It is strongly recommended that the government intervenes by providing support to both teachers and learners.

Most participants in this study indicated that there were no online mathematics workshops organised by DBE to train teachers on how to use technological tools during COVID-19 pandemic lockdowns. This lack of support resulted in teachers struggling to use technological tools effectively. These findings suggest that thorough training is necessary to enhance teachers' competencies. On a similar note, Mbodila et al. (2019) confirm that successful integration of emergent technology in teaching and learning is determined by the level of support and guidance that is provided to both teachers and students in the use of digital technologies. Similarly, Hu and Garimalla (2014) propose that the way to promote technology integration in teaching and learning is to engage in professional development programmes such as training to support teachers in the use of technology. In summary, this study revealed that without training, technology integration in teaching and learning is difficult.

6.3 IMPLICATIONS AND CONTRIBUTIONS OF THE STUDY

While the use of emerging technological tools for teaching and learning significantly increased during the COVID-19 pandemic lockdowns (Mpungose, 2023), there remains a gap in fully exploring South African teachers' experiences with the integration of these tools. This study aimed to fill this gap by specifically investigating the experiences of selected FET

mathematics teachers in the Harry Gwala District as they enhanced their competencies in teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns.

The findings of this study provide education stakeholders and educators with a set of practical, empirically based guidelines aimed at enhancing teachers' competencies in online teaching. The implementation of these guidelines is likely to positively impact mathematics education performance, as teachers' competencies directly influence learners' academic achievement. The study revealed significant variability in access to technological resources based on learners' socio-economic backgrounds, leading to the marginalisation of disadvantaged learners, and hindering the effective implementation of e-learning. Moreover, the study emphasised the crucial role of teachers' competencies, and self-efficacy in the successful integration of technology into teaching and learning.

6.4 LIMITATIONS OF THE STUDY

Before delving into the limitations of the study, it is necessary to reiterate the study's focus. This research explored FET mathematics teachers' experiences of enhancing their competencies for teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns specifically within the Harry Gwala District. Thus, the researcher did not extend the study to include other districts within the province, nor did she engage with FET mathematics teachers from other provinces in South Africa. As a result, the findings of this study are contextual and cannot be generalised to other settings or studies. Additional research is needed to explore teachers' experiences on a broader scale, encompassing different districts.

Secondly, data was collected through Google Forms from participants in rural areas to comply with the social distancing guidelines during the COVID-19 pandemic lockdowns. This method of data collection may impact the generalizability of the findings. Participants who have limited digital access or are not familiar with online surveys may be underrepresented, potentially affecting the broader applicability of the study's results.

6.5 RECOMMENDATIONS

Based on the findings of this study, the researcher proposes the following practical and theoretical recommendations:

1. The researcher advocates for the intensification of teacher training in the integration of technology in teaching and learning, enabling educators to adeptly incorporate it into their teaching practices.
2. Additionally, the Department of Education is urged to establish support systems for both teachers and learners, ensuring continuous access to devices and internet connections for effective technology integration in teaching and learning. This includes providing necessary technological resources such as computers (laptops), smartphones, routers with sufficient data bundles, and other essential tools.
3. The researcher suggests the creation of e-learning communities of practice in districts. These communities can serve as platforms for teachers to collaborate, share experiences, and disseminate best practices in the utilisation of technology for teaching and learning.

6.6 CONCLUSION

This study explored selected Harry Gwala District FET mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during COVD-19 pandemic lockdowns. This chapter presented a summary of the findings, significance and limitations, and recommendations for further study. The chapter addressed the critical research questions by demonstrating how each research question was answered using the study findings presented in Chapter 5 as well as literature reviewed in Chapter 2 and Chapter 3. This comprehensive exploration sheds light on the unique challenges and opportunities encountered by teachers in adapting to new modes of teaching during pandemic-related disruptions.

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APPENDICES

Appendix A: KwaZulu-Natal Department of Education approval letter

KWAZULU-NATAL PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE HEAD OF DEPARTMENT

Private Bag X9137, PIETERMARITZBURG, 3200
Anton Lembede Building, 247 Burger Street, Pietermaritzburg, 3201
Tel: 033 392 1063
Email: Phindile.duma@kzndoe.gov.za

Enquiries: Phindile Duma **Ref.**:2/4/8/4089

Ms TH Mbanjwa
Impiyamandla High School
HIGHFLATS
3309

Dear Ms Mbanjwa

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"EXPLORING HARRY GWALA DISTRICT FET MATHEMATICS TEACHERS' EXPERIENCES OF ENHANCING THEIR COMPETENCIES OF TEACHING EUCLIDEAN GROMETRY PROOFS DURING THE COVID-19 PANDEMIC",** in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 06 June 2022 to 30 May 2025.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Miss Phindile Duma at the contact numbers above.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

HARRY GWALA DISTRICT

[redacted]

Mr GN Ngcobo
Head of Department: Education
Date: 06 June 2022

GROWING KWAZULU-NATAL TOGETHER

Appendix B: Information sheet for school principals

Impiyamandla High School
St Faiths Road
Highflats
3306
27 July 2022

The principal

Dear Sir/ Madam

REQUEST FOR PERMISSION TO CONDUCT RESEARCH AT YOUR SCHOOL

My proposed title is Exploring Harry Gwala District FET mathematics teachers" experiences of enhancing their competencies of teaching Euclidean geometry proofs during COVID-19 pandemic lockdowns.

I am Thulisile Mbanjwa and I am a student at the University of Kwa-Zulu Natal, currently registered for Masters (Research) in Mathematics Education.

The research I wish to conduct explores Grade 10 – 12 mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during the COVID – 19 pandemic lockdowns. This research could help improve the teaching of Euclidean geometry in the classroom. Moreover, it will enlighten the teachers about the importance of constantly improving their competencies of competencies as we live in a constantly changing time. As a result, it will mitigate the issue of poor performance of learners in Mathematics.

The sample comprises of the FET mathematics teachers in the Harry Gwala District who will respond to questionnaire and will be interviewed. The process of collecting data will be done after school hours and will not interfere with the teaching and learning process in the school.

Please note that the confidentiality and anonymity of the participants are guaranteed. Participants have the right not to participate and to withdraw at any time. All the information gathered during the process will be dealt with as highly confidential and will be destroyed after five years. The interviews will be audio-recorded with the permission of the participant.

I hereby kindly seek your consent to conduct the research in your school.

Yours faithfully

Miss T. H. Mbanjwa (214531164)

For more information regarding this study, feel free to contact my supervisor, Ms BB Goba who is a lecture at the University of Kwa – Zulu Natal, Edgewood Campus. Contact details: 031 260 1127/ 031 260 7607, Email: Gobab@ukzn.ac.za

My contact details: Email: 214531164@stu.UKZN.ac.za , Cell no: 060 413 7996

You may also contact the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Private Bag X 54001

Research Office, Westville Campus

Govan Mbeki Building

Durban
4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604557- Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

Thank you in advance for your contribution in this study.

Appendix C: Information sheet for teachers and consent forms

INFORMATION SHEET AND CONSENT TO PARTICIPATE IN RESEARCH
Date: 15 August 2022

Please accept my warm greetings
My name is Thulisile Mbanjwa, a student (214531164) at the University of KwaZulu Natal, currently registered for master's degree in Mathematics education. My cell phone number is 060 423 7996; my email address is 214531164@stu.ukzn.ac.za / Happiethulie22@gmail.com

You are kindly invited to consider participating in a study that involves FET mathematics teachers. The aim and purpose of this research is to explore FET mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during COVID-19 pandemic lockdowns. This study is expected to enrol 40 teachers from all circuits of Harry Gwala District including Ixopo CMC, Umzimkhulu and Pholela. These teachers will respond to questionnaires in the Google form sent to them via WhatsApp or Email and three teachers will be interviewed after school hours. The duration of your participation if you choose to enrol and remain in the study is expected to be one month, the month of October.

This study does not involve any risks. We hope that the study will create the following benefits: teachers will be informed of the ways in which they can enhance their competencies of teaching Euclidean geometry proofs at the end of the study.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number – I will write it as soon as I get it)

In the event of any problems or concerns/ questions you may contact me at 060 413 7996 or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION
Research Office, Westville Campus

Govan Mbeki Building
Private Bag X 54001
Durban
4000
KwaZulu-Natal, SOUTH AFRICA
Tel: 27 31 2604557- Fax: 27 31 2604609
Email:HSSREC@ukzn.ac.za

Please note that this research is voluntary, and you may withdraw participation at any point. In the event of refusal/ withdrawal of participation you will not incur penalty or loss of the benefits that this study comes with.

Your participation in this study will not cost you much, just the data bundles for responding to the questionnaires. There are no incentives or reimbursements for participation in this study.

Please note that any information gathered during this research study will only be used for research purposes. This study and your participation are independent of your academic record and/or your future at school and will not be used in any way to prejudice any participant at school. Your participation in the study will be completely confidential and anonymous. Pseudonyms will be used in the writing of the research. Any information you give will only be used to the benefit of the programme and will not be traced back to you. The data collected will be stored in the researcher's computer and will be destroyed after 5 years.

Please kindly inform the researcher about any further information regarding this study, feel free to contact my supervisor, Ms BB Goba who is the lecturer at the University of KwaZulu Natal, Edgewood campus, who can be contacted on 031 260 7607.

Thanking you in advance.
Ms T. H. Mbanjwa
.....

Please complete the slip below as proof of your written consent to participation in the study.

CONSENT (Edit as required)

I(Name) have been informed about the study entitled (provide details) by (provide name of researcher/fieldworker).

I understand the purpose and procedures of the study (add these again if appropriate).

I have been given an opportunity to answer questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

I have been informed about any available compensation or medical treatment if injury occurs to me as a result of study-related procedures.

If I have any further questions/concerns or queries related to the study, I understand that I may contact the researcher on 060 413 7996

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban

4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604557 - Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

Additional consent, where applicable

I hereby provide consent to:

Audio-record my interview / focus group discussion YES / NO

_____ _____

Signature of Participant **Date**

_____ _____

Signature of Witness **Date**

Appendix D: Ethical clearance letter

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

03 October 2022

Thulisile Happiness Mbanjwa (214531164)
School Of Education
Edgewood Campus

Dear TH Mbanjwa,

Protocol reference number: HSSREC/00004420/2022
Project title: Exploring Harry Gwala district further education and training mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during the corona virus pandemic lockdowns
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 27 June 2022 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 03 October 2023.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Appendix E: Questionnaire

Research Tittle: Exploring FET mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns.

Please tick the relevant circle where applicable

Teacher profile:

Age:

- o <35
- o 35 – 45
- o 46 – 55
- o >55

Gender:

- o Male
- o Female

Tertiary institution(s) where studied: _____

Qualification(s): _____

Post level:

- o 1
- o 2
- o 3
- o 4

Years of study in mathematics:

- o 1
- o 2
- o 3
- o 4
- o >4

Years of study in mathematics education:

- <3
- 3
- 4
- >4

Number of years teaching in the school sector:

- <3
- 3 – 5
- 6 -10
- 11 -15
- >15

Number of years teaching mathematics in the FET band:

- <3
- 3 – 5
- 6 -10
- 11 -15
- >15

QUESTIONS

1. When COVID -19 pandemic lockdowns were implemented in South Africa, were you able to use the online teaching platforms to teach mathematics in general or Euclidean geometry in particular?
   - Yes
   - No
2. What teaching strategies did you use to teach Euclidean geometry riders, proofs in particular?

   _____

   _____

   _____
3. What technological tools did you use to teach Euclidean geometry?

   _____

   _____

   _____

4. What coping strategies did you use to enhance your skills of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns?

   _____
   _____
   _____

5. In what ways did you enhance your competencies of teaching Euclidean geometry proofs during COVID-19 pandemic lockdowns?

   _____
   _____
   _____

6. What were your experiences of enhancing your competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns?

   _____
   _____
   _____
   _____
   _____

7. Did you attend any virtual workshops such as SHARP webinars, Answer series webinars, AMESA congress etc. during the COVID-19 pandemic lockdowns?
   - Yes
   - No
8. Were there any online mathematics workshops organised by DBE you attended during the COVID-19 pandemic lockdowns?
   - Yes
   - No
9. Did you use platforms such as YouTube to enhance your Euclidean geometry knowledge especially during the COVID-19 pandemic lockdowns?
   - Yes
   - No
10. How was your experience of enhancing your competencies of teaching Euclidean geometry proofs using online platforms?

    _____
    _____
    _____

THANK YOU FOR YOUR PARTICIPATION….
MUCH APPRECIATED

Appendix F: Demographic information of the participants

Demographic information of the participants

Participant	Age	Gender	Qualification	number of years teaching in the FET band
1	46 - 55	Female	HDE	> 15
2	35 - 45	Male	Bed	11 - 15
3	46 - 55	Female	B. Ed. Honors	> 15
4	35 - 45	Male	Bachelor of Education	6 - 10
5	35 - 45	Male	B COM HONOURS IN IR and PGCE	11 - 15
6	46 - 55	Female	BSc & PGCE	> 15
7	< 35	Male	BSc& PGCE	11 - 15
8	35 - 45	Female	B.Ed Honours	11 - 15
9	46 - 55	Male	Secondary teachers' diploma	> 15
10	46 - 55	Female	Secondary Teacher's Diploma	> 15
11	46 - 55	Female	Ace Maths	> 15
12	46 - 55	Male	Ace Maths	> 15
13	< 35	Male	PGCE	11 - 15
14	< 35	Female	BSc Applied Mathematics and PGCE	2 - 5
15	46 - 55	Male	STD (TECH), ACE (MATHS FET)	> 15
16	>55	Male	BSc	> 15
17	< 35	Male	PGCE	2 - 5
18	35 - 45	Male	BSc computer science and mathematics, PGCE	6 - 10
19	< 35	Male	BEd (Mathematics and Physical Sciences), BEd Honours (Mathematics)	6 - 10
20	46 - 55	Female	Diploma and ACE in Math	> 15
21	< 35	Female	Electrical Engineering and PGCE	2 - 5
22	35 - 45	Female	Electrical Engineering and BEd	6 - 10
23	35 - 45	Male	National diploma in Electrical Engineering and PGCE	11 - 15
24	< 35	Male	BSc in Chemistry and PGCE	11 - 15
25	35 - 45	Male	Diploma, BEd in Intermediate and senior phase, and Homours in Management	2 - 5
26	< 35	Male	BEd, Honours in mathematics and science education	2 - 5

27	35 - 45	Male	BEd	11 - 15
28	35 - 45	Female	PGCE	2 - 5
29	35 - 45	Female	Chemical Engineering and PGCE	2 - 5
30	35 - 45	Male	PGCE	11 - 15
31	35 - 45	Male	BSc and PGCE	11 - 15
32	35 - 45	Female	Master's in education, Programme for Mathematics Teaching FET, Honours in Education, BTech, Diploma in Education	11 - 15
33	46 - 55	Male	Diploma studies and PGCE	2 - 5
34	35 - 45	Male	BSc in Mathematics and PGCE	2 - 5
35	< 35	Female	BSc, PGCE, BEd. Honours in Maths and Science education	2 - 5

Appendix G: Interview schedule

Interview questions for teachers

1. How many strategies do you use when you teach learners how to solve Euclidean geometry riders, proofs in particular? Give examples.

2. Which technological tools do you use to teach Euclidean geometry?

3. Do you find these technologic tools effective?

4. How did you acquire the skills of using these technologic tools?

5. When COVID-19 pandemic lockdowns were implemented in South Africa, were you able to use the online teaching platforms to teach mathematics in general or Euclidean geometry in particular?

6. How did you develop your skills of using online teaching platforms during the COVID-19 pandemic lockdown?

7. What were your experiences of enhancing your competencies of teaching Euclidean geometry proofs during COVID-19 pandemic lockdowns.

8. Please reflect in detail on your experience(s) of enhancing your competencies for teaching Euclidean geometry during the COVID-19 pandemic lockdowns? In simple terms, how did you experience improving your competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns?

9. What situations or contexts have typically influenced your experiences of enhancing your competencies of teaching Euclidean geometry proofs during the COVID-19 pandemic lockdowns?

10. Did you attend any workshops organised by DBE or any organisation to assist you to teach mathematics remotely?

11. If there were workshops organised by DBE that you attended to develop you on how to teach remotely, how was your experience of enhancing your competencies of teaching Euclidean geometry during COVID-19 pandemic lockdowns?

12. Did you apply the skills of teaching mathematics remotely to teach your learners proofs in Euclidean geometry? Which online tool(s) did you use in teaching mathematics?

13. How did you experience teaching your learners Euclidean geometry proofs using online teaching tools?

Appendix H: Turnitin digital receipt

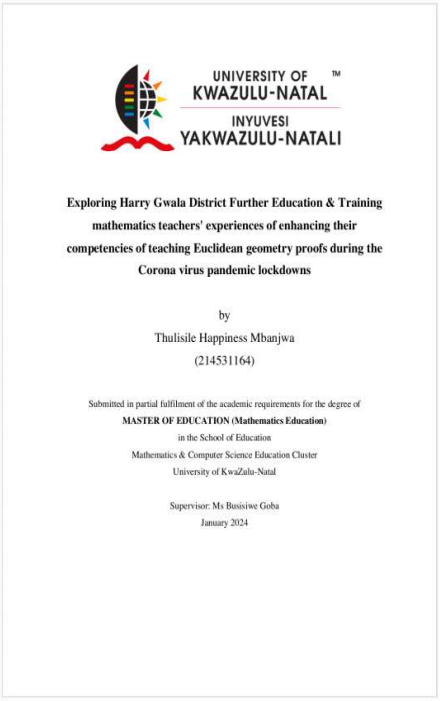
turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	Thulisile Happiness
Assignment title:	Masters dissertaton
Submission title:	Master's Dissertation
File name:	Mbanjwa_thesis_dissertation_final.docx
File size:	2.21M
Page count:	156
Word count:	40,662
Character count:	251,924
Submission date:	07-Feb-2024 04:54AM (UTC+0200)
Submission ID:	2288388151



UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

Exploring Harry Gwala District Further Education & Training mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during the Corona virus pandemic lockdowns

by

Thulisile Happiness Mbanjwa

(214531164)

Submitted in partial fulfilment of the academic requirements for the degree of
MASTER OF EDUCATION (Mathematics Education)
in the School of Education
Mathematics & Computer Science Education Cluster
University of KwaZulu-Natal

Supervisor: Ms Busisiwe Goba
January 2024

Appendix I: Editing certificate

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EDITING CERTIFICATE

Re: **Thulisile Happiness Mbanjwa**
UKZN master's dissertation: **Exploring Harry Gwala District Further Education & Training mathematics teachers' experiences of enhancing their competencies of teaching Euclidean geometry proofs during the Corona virus pandemic lockdowns**

I confirm that I have edited this dissertation and the references for clarity, language and layout. I returned the document to the author with track changes and comments so correct implementation of the changes and clarifications requested in the text and references is the responsibility of the author. The intellectual content of the document is the responsibility of the author. I am a freelance editor specialising in proofreading and editing academic documents. My original tertiary degree which I obtained at the University of Cape Town was a B.A. with English as a major and I went on to complete an H.D.E. (P.G.) Sec. with English as my teaching subject. I was a part-time lecturer in the Department of Homoeopathy at the Durban University of Technology for 13 years and supervised many master's degree dissertations during that period.

Dr Richard Steele
21 January 2024
per email