Teaching the Sketching of Quadratic Functions Online: A Case of a Rural School in Mopani District, Limpopo Province, South Africa

by

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DISSERTATION

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DECLARATION

I, Kgwedi Itumeleng Prudence, declare the dissertation titled "**Teaching the Sketching Of Quadratic Functions Online: A Case of a Rural School in the Mopani District, Limpopo Province"** hereby submitted to the University of Limpopo, for Master of Education in Mathematics Education has not previously been submitted by me for any degree or examination at this or any other university. This dissertation does not contain other peoples' data, pictures, graphs or other information unless explicitly acknowledged as being sourced from other people. It is my work in design and implementation and all information conveyed herein has been properly accepted.

22/07/2023

Ms Kgwedi Itumeleng Prudence Date

DEDICATION

I dedicate this dissertation to Kgwedi family, my two sisters, Feneshara and Mmagogong, my three brothers, Mashumu, Maruwe and Maruana, my parents, Borolelo and Madumetsa and to my daughters, Lehlogonolo and Bokang.

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ABSTRACT

This study presents an exploration of the integration of technology, pedagogy, content knowledge and learners' mathematical competencies when sketching quadratic functions online. The outbreak of COVID-19 became stressful to the education system, and this motivated me to conduct this study. The situation was dire in rural schools because there were no technological means implemented by the government to assist in curriculum coverage. The study was approached qualitatively guided by the following research question: 1) What are the learners' competencies in sketching quadratic functions online? 2) How to teach the sketching of quadratic functions online using the GeoGebra software?

Participants in the study were eight Grade 11 learners doing Mathematics. The school had ten learners doing Mathematics, one did not show interest and the other one decided to stop attending online lessons. Data were generated using five video lesson recordings that included learners' responses to lesson activities and individual semi-structured interviews that consist of nine questions, and I analysed data using thematic analysis. Themes that emerged from the theoretical framework guided the analysis. The main findings of the study revealed that the educator's technological knowledge is the basic requirement in integrating technology, pedagogical and content knowledge in conducting online lessons. In this study, I used GeoGebra to sketch quadratic functions because it is user friendly and has a free version available. The study revealed that sketching quadratic functions using the GeoGebra software saved time and assisted learners to visualise quadratic functions quickly, accurately, efficiently, and thus enabling comprehension. Learners' understanding of sketching quadratic functions was improved using the GeoGebra software. Thinking mathematically, representing mathematical entities, handling mathematical symbols and formulas, communicating in, with and about Mathematics and making use of aids and tools were the mathematical competencies derived mostly from different questions of the activities. However, it was also revealed that online lessons can have negative impact on the effective teaching and learning when conducted in a poor network connectivity site.

In this study, teaching sketching of quadratic functions online resulted in many challenges. Firstly, due to poor technology infrastructure, there were limited technological devices available for smooth running of online lessons. Secondly, lack of technological knowledge to integrate with other knowledge by the participants affected teaching and learning online poorly. Lastly, poor network connectivity and power cut by Eskom were consistently experienced and affected the online lessons negatively.

Keywords: Online teaching, learning with technology, GeoGebra software, Quadratic functions, Technological Pedagogical Content Knowledge (TPACK), Mathematical competencies.

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CHAPTER 1: OVERVIEW OF THE STUDY

This chapter presents the overview of my study. I start by presenting the introduction and background of the study within the context of COVID-19 pandemic that took the world by surprise and resulted in educational institutions adopting online teaching and learning. This is followed by presentation of the problem statement, context of the research site, the purpose of the study, research questions, research methodology, and significance of the study. I conclude the chapter by providing brief overview of the dissertation and thereafter after-shadowing my presentation of Chapter 1.

1.1. Introduction and background

The COVID-19 pandemic caused havoc in the world. According to Wajdi et al. (2020), CoronaVirus Disease of 2019 (COVID-19) is a respiratory tract infectious disease caused by coronavirus which spread primarily through droplets of saliva or discharge from the nose. The COVID-19 pandemic triggered a huge change in the education systems of many countries including, South Africa. In the education sector, the pandemic mostly affected teachers, learners, and parents, and this resulted in the closure of schools (Tadesse & Muluye, 2020).

While the spread of the COVID-19 pandemic continued to disrupt teaching and learning, Mulenga and Marban (2020) highlighted that online learning is a way of preventing the spread of viruses like Coronavirus. The normal face-to-face teaching and learning was suspended, and the alternative method of teaching and learning was through technology, which required technological knowledge. According to Zhang (2020), normal face-to-face is perceived as a method of classroom teaching that educators use different pedagogies to keep learners engaged in the lesson. Online teaching is a technological approach that strives to re-create the classroom environment in which learners learn and are assessed through computer technology (Ewing & Cooper, 2021).

The Zambian government directed for broadcasting of educational channels and radio programmes for learners to access education (Mulenga & Marban, 2020). The strategy was also adopted by the South African government (Department of Basic Education (DBE), 2020), and educational programmes were broadcasted on televisions and radios for teaching and learning. The study conducted by Mulenga

and Marban (2020) revealed that digitisation in education is a good response to curbing the spread of any global pandemic that needs social distancing.

Dube (2020) discussed the threat faced by South African learners in rural schools. DBE (2020) promoted online learning during the pandemic, however, the mode of learning left out many rural learners and teachers due to lack of resources and technological knowledge. I was fascinated by Dube's (2020) suggestions to enhancing online teaching and learning in rural schools. Though online teaching and learning was possible, it became more stressful for rural schools in 2020 due to various reasons including lack of resources, network connectivity and access to the internet. However, Mutambara and Tsakeni (2022) indicate that online learning can be beneficial to learners if all stakeholders play their roles.

As defined by Mwapwele et al. (2019), a rural school is a school with less allocated budget; that is in a remote environment without proper and adequate educational facilities and less technological resources. In some instances, these rural schools were left behind due to the above-mentioned challenges. Education in rural schools is affected by physical factors such as, an infrastructure in networking that might lead to poor technological facilities. McLoughlin and Luca (2002) argue that it is important that online teaching and learning which comprises of authentic problem-solving skills and tasks is incorporated and instilled in the schools' curriculum. This should accommodate all quintiles so that there is transfer of competencies to the application of knowledge.

The school curriculum needs to be revised to meet the Fourth Industrial Revolution (4IR), wherein networking and robotic tools are essential. According to Enaifoghe et al. (2021), South Africa's education system lacks a technology focus, therefore, it is far from reaching the 4IR transformation. Kayembe and Nel (2019) define 4IR as a major development revolution that involves new ideas, inventions, and the fusion of network integration and the creation of robotic tools.

The 4IR grants the education sector opportunities to create a conducive learning environment and innovation. Shahroom and Hussin (2018) highlighted that the new generation is attached to the use of application software and smartphones. Aligned to Shahroom and Hussin (2018), the current study engaged Grade 11 Mathematics

learners in online teaching and learning that enacted a method which was new to all participants.

The use of Information and Communication Technology (ICT) and blended learning has been used in the developing nations to develop an education system that incorporates a variety of methods of learning and access to knowledge (Mathipa & Mukhari, 2014). Through the use of ICT in teaching and learning, there is potential to bridge the gap of the urban-rural divide (Mihai & Nieuwenhuis, 2015). Therefore, they used urban-rural divide to describe a case where there is a division between urban and rural areas on education system. De Freitas and Spangenberg (2019) saw a gap in ICT integration with rural schools' educators. They further suggested that in-service South African Mathematics educators need training to keep along with ICT for teaching Mathematics.

It is important for educators to understand competencies and abilities of their learners to enable them to design lessons that will enable the learners to engage in conceptual learning. Competency in the mathematical context is defined as the ability to comprehend and put the knowledge of mathematical contexts to practice and judge strategically (Niss, 2003). Mathematical competencies such as mathematical thinking, problem solving, modelling, reasoning, representation, symbols and formalisms, communication, aids and tools are mutually connected and cannot be separated (Jankvist & Kjeldsen, 2011; Niss, 2003). Anyone who is acquainted with these competencies should be able to solve mathematical problems that they come across. Niss (2003) further argues that in mathematics, for one to demonstrate progress in imparting knowledge, the emphasis should be more on the conceptual learning other than the traditional approach or methods. Sketching of quadratic functions plays a great significance in improving learners' competencies and developing a righteous basis for understanding cubic graphs to be learnt in higher grades.

Teaching with technology needs different knowledge for implementation. According to Mishra and Koehler (2009), we have content knowledge, technological knowledge and pedagogical knowledge. The educator who holds technology knowledge is able to implement online classrooms. Technology Pedagogical Content Knowledge

(TPACK) is the basis of effective teaching from integrating content, pedagogy and technology knowledge (Mishra & Koehler, 2009).

Kunwar (2019) asserts that the graph of a quadratic function is a set of points formed by x and y coordinates in a Cartesian plane. The x-coordinates are mapped with the y-coordinates to form points which are plotted and joined on a Cartesian plane to form a sketch. The study by Kunwar (2019) of functions and graphs has demonstrated the importance of quadratic functions which could minimise the cost and maximise the profit or area. Furthermore, learners might develop an understanding when dealing with application of calculus in cubic functions. A quadratic graph is among the schematic ways of showing the interconnection and effect of parameters. According to Hoon et al. (2018), learners develop deeper understanding of functions when they are able to engage themselves in properties and applications of the quadratic functions.

In South Africa, Mathematics educators are expected to use the Curriculum and Assessment Policy Statement (CAPS) to guide their lesson preparation. Among other skills that learners have to acquire, is to master the sketching of graphs. Faced with the challenge of the COVID-19 pandemic that prohibited face-to-face teaching, I was prompted to explore the integration of technology, pedagogy, content knowledge and learners' mathematical competencies when sketching quadratic functions online.

1.2. Research problem

Online teaching is an educational process that uses technology to deliver curriculum content (Kim, 2020). The integration of technology, pedagogy and content knowledge in teaching and learning has been encouraged in the education system. There are still issues regarding the infrastructure, the Internet and digitalisation in rural schools that remain unresolved for online teaching in developing countries (Dube, 2020). However, South Africa is one of the developing countries and has developed a policy referred to as 'South African Connect Policy' that aims at making schools the points of Information Communication Technology (ICT) access (Mwapwele et al., 2019).

The mathematics' curriculum needs to combine the traditional face-to-face method with online method of teaching, learning and assessment. According to Mahaye (2020), there is a need to avail technological knowledge and learning programmes to learners. Such transformational directions include the teaching of Mathematics concepts and processes through technology. However, there are still challenges faced by rural and remote schools and learners in the new blended teaching and learning that require connectivity to implement technology tools (Dube, 2020), while their counterparts in urban schools are already learning online. In mathematical sciences, there have been several studies on the sketching of quadratic functions in a normal face-to-face classroom (Benning & Agyei, 2016; Sumartini et al., 2019; Akhsani & Nurhayati, 2020), but a few studies on teaching the sketching of quadratic functions online. This still requires resources and facilities to be in place.

The COVID-19 pandemic has affected our education system negatively. The pandemic has brought a change in our lives that requires us to shift from the traditional method of teaching to a technological or blended method. In the study by Cardullo et al. (2021), it has been shown that online teaching and learning has been the only choice by several educators during the pandemic. As a result, there is a need for blended teaching and learning to create a conducive environment for learners to explore their competencies in Mathematics, especially when sketching quadratic functions. Technological knowledge in the 4IR is the major knowledge and advances the creation of robotic educators that incorporate teaching online (Mpungose, 2020). Hence, teaching online is an important aspect in the 4IR era. Therefore, the study used an online classroom to teach the sketching of quadratic functions.

1.3. Context of the research site

The Department of Basic Education in South Africa classified schools into five quintile rankings (DBE, 2004). This was done to all Provinces and Districts. The classification of a school in a particular quintile ranking was determined by the level of the community's income, unemployment and literacy. Quintile 4 and 5 are the fee paying schools and quintile 1 to 3 are the no fee paying schools. Quintile 1 schools are catering for the poorest 20% of learners (DBE, 2004). The school where the study was conducted is categorised as quintile 1. The gap that is still existing is that most of the

resources from DBE report on learner performance in Mathematics, Science and Technology Education (MSTE) focus on Grade 12 and nothing is been said on Grade 11 performance (DBE, 2022). The school is in a rural area of Mopani District, roughly 40 kilometres from Tzaneen town in Limpopo Province. The area is surrounded by valleys and dusty roads that are slippery when it rains.

The area where the school is situated experiences load shedding and reduction that affected network connectivity. Load shedding is when Eskom places the area under different stages due to a lack of the units capacity (Mbomvu et al., 2021), while load reduction is when a localised area has many illegal connections and experience an overload of power (Mabunda, 2021). During load shedding and reductions, network connectivity is dysfunctional in the rural area and the school premises.

The school offered commercial and sciences stream to a community that is populated by 90% Sepedi and 10% Tsonga speaking people. The learners' enrolment in the school was 245. The research site had two blocks that comprised four rooms each. Out of the eight rooms, one is the staff room, one is the principal's office, and others are classrooms. There are also two mobile classrooms. The school does not have computer room, laboratory or library. Amongst the classrooms, there are Grades 11 A and 11 B. Grade 11 A has only ten learners enrolled for Mathematics. The school has only five laptops and the school Wi-Fi is overloaded by school's administration laptops, educators' and Grade 12 learners' cell phones who are given access to connectivity.

After the South African government announced lockdown regulations from the first quarter of the year 2020 because of the COVID-19 pandemic, all schools were closed to avoid the spread of the virus. Thus, the research site was also affected and later when the lockdown conditions continued to be adjusted, schools were allowed to save the academic year. This particular school, as my research site, had to operate through rotational learning to adhere to social distancing. Rotational learning meant learners going to school on different days of the week. There was limited Wi-Fi connectivity, no ICT infrastructure and a lack of Technological Pedagogical Content Knowledge (TPACK) for most educators to continue teaching and learning remotely.

In my teaching experience, I had never used technology for teaching and learning in the classroom. The school had one projector that was not connected to any classroom. The school timetable was designed for one hour period for each subject. Using a

projector needed one to use the one-hour period to prepare connectivity to his/her class and disconnect it within an hour to allow the next period. Educators moved from one classroom to the other for one hour period to teach the subject allocated to them.

Learners from the research site were never given an opportunity to use technology for learning. They also never used digital devices in the classroom to interact with their educators before COVID-19 pandemic. However, they own smart phones which they had never installed any learning software for learning Mathematics. The research site was not offering any programme or ICT subject. Therefore, digital literacy level in teaching and learning was poor. Most participants had no idea on how to use a laptop and exploring the use of GeoGebra for the first time. The orientation for the online lessons had to be done on how to integrate the technology devices for sketching quadratic functions. Most learners were unable to afford data for internet connectivity since it is expensive because they were from rural area with poor background.

1.4. Purpose of the study

The purpose of the study was to explore the integration of technology, pedagogy, content knowledge and learners' mathematical competencies when sketching quadratic functions online using the GeoGebra software.

1.5. Research questions

The research questions that guided this study were:

1. What are the learners' competencies in sketching quadratic functions online?
2. How to teach the sketching of quadratic functions online using the GeoGebra software?

1.6. Research methodology

The study utilised a qualitative approach. Creswell and Poth (2016) indicate that a qualitative approach gives a detailed understanding of the issue, which in my study was teaching the sketching of quadratic functions online using the GeoGebra software. This study was a case study. According to Merriam (1998), a case study is an intensive, holistic description and analysis of a single instance, phenomenon or social

unit. However, the study took place as a form of online teaching when conducting lessons on sketching of quadratic functions.

The study was conducted in a rural school that was in Mopani District, Limpopo Province, South Africa. The enrolment of Grade 11 learners was 47, with ten (10) of them registered for Mathematics. I taught Mathematics Grades 10 to 12 at the same school for eight years. The participants in the study had never used any application of software for teaching and learning. According to Merriam (2002), researchers in case study utilise three data collection methods: conducting interviews, observations and analysis of documents. In this study, I used participant observations and individual semi-structured interviews as data collection methods. The study conducted thematic analysis guided by the theoretical framework. The themes that emerged were knowledge of the content to be taught, knowledge of learners learning, integration of technology and content, knowledge of strategy to teach and the integration of technology and pedagogy.

1.7. Significance of the study

At a personal level, my interest in the 4IR in education motivated me to engage in the online classroom. The study was undertaken because teaching online is important to our education system in this current state. The results would provide strategical teaching methods for the mathematics concepts. This will shift away from the traditional face-to-face teaching and learning method and accommodating the 4IR needs.

In addition, the outcome of the study will have advantageous applications as it needed to make sense of the Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) with regard to teaching the sketching of quadratic functions online. Arguably, there was limited literature dealing directly with teaching the sketching of quadratic functions online. The study will assist in closing the technological knowledge gap in teaching Mathematics online.

1.8. Brief overview of the dissertation

Chapter 1 provided an overview of introduction and background, research problem, purpose of the study and research questions. The research methodology and significance of the study are also captured in this chapter.

Chapter 2 presented a literature review that has been divided into subtopics which are related to teaching sketching of quadratic functions online. I started by giving a brief introduction that outlines the context that guided the research area. This is followed by the readings that describe online teaching and the benefits of online teaching and learning. I thereafter focus on readings that address challenges that arise in an online classroom, learning with technology, integration of technology in teaching and learning, the role of an educator, quadratic functions and application of the GeoGebra software. Lastly, I discuss TPACK (Mishra & Koehler, 2009) and Niss' (2003) mathematical competencies as theoretical framework that guided this study.

Chapter 3 outlines the research methodology starting with the research approach and research design. These are followed by data collection methods and how data were analysed, quality criteria and ethical considerations.

Chapter 4 presented the findings and results of the study. This included the resources available when conducting the study and later followed by how online lessons were conducted. I concluded the chapter by presenting a summary of different data collected and analysed guided by two theoretical frameworks.

Chapter 5 presented a discussion of the findings to answer two research questions. The limitations of the study and recommendations were also presented.

1.9. Chapter conclusion

This chapter discussed the background and motivation of the study by reflecting on the literature. The problem statement, context of the research site, purpose of the study, research questions, methodology and significance of the study which emphasised the need to explore online teaching in rural schools were outlined. I concluded the chapter by outlining the overview of the dissertation.

CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. Introduction

The disruption of COVID-19 pandemic in the education sector became a global phenomenon (Basilaia & Kvavadze, 2020; Mahaye, 2020 & Schliecher, 2020). From basic to higher education phases, curriculum and assessment were not completed because of the pandemic due to lockdowns implemented to curb the spread of COVID-19 (Rwigema, 2021; Shama & Ikbal, 2020). However, online or remote learning was not in place and arranged (Basilaia & Kvavadze, 2020).

COVID-19 pandemic has pushed policy makers to reconsider blended teaching and learning as a universal approach in which the use of technology has become a necessity. According to Daniel (2020), almost all governments stopped provision of face-to-face teaching and learning instead instructed institutions to adopt online teaching and learning methods. Online teaching and learning became a solution for many schools to complete the curriculum during the pandemic (Sundeen & Kalos, 2022). However, their results revealed that there are still equity issues in rural schools.

On the other hand, the South African education system was affected after 5 March 2020, when the COVID-19 case was first detected. The national lockdown was immediately enforced on most organizations and that included schools. The Department of Basic Education (DBE) (2020) stopped face-to-face interaction of teachers and learners in schools while working on a plan to re-open schools. The use of ICT in schools and programmes to build digital skills should be implemented in South African schools (Maree, 2021). The studies give opportunities to restructure curriculum for teaching and learning.

Since there were no policies, guidelines, and circulars in the DBE on how to teach in the event of pandemic emergence and surge, COVID-19 disturbed curriculum coverage in rural schools during shut down. The pandemic exposed the frailness of the South African school system and revealed the inequality in schools. My study was also prompted by Maree's (2021) view that the pandemic allowed us to reconstruct the curriculum system by integrating technology in the education sectors.

In this chapter, I covered concepts of online teaching, the benefit of online teaching and learning, the challenges that arise in an online classroom, learning with

technology, integration of technology in teaching and learning, the role of an educator, quadratic functions, and application of the GeoGebra software. I present what the main concepts were focusing on. Online teaching and learning as integration of the subject knowledge with digital devices for effective learning. However, the benefit and challenges of online learning differs from different settings. Learning with technology is an ongoing process in the education system. It allows variation of pedagogy to learning.

Integration of technology in teaching and learning is the process of putting in action the digital devices in classroom to unpack the subject content. Role of educator refers to the educator's responsibility to implement teaching that lead to effective learning. Quadratic function is a mathematical concept that refers to a polynomial with two as the highest exponent. The last concept is the application of the GeoGebra software that was used in the sketching of quadratic functions. The theoretical frameworks TPACK and Niss's (2003) competencies as applied in the study are also discussed.

2.2. Online teaching and learning

Liu (2020) defines the concept of online teaching as a network teaching mode of technology in that educators and learners interact in a virtual classroom. I found this definition relevant to my study as teaching and learning took place in a virtual classroom. In addition, Greenhow et al. (2022) define online teaching as the involvement of digital tools and the Internet to present educational material through interactions between educators and learners. Monareng et al. (2020) saw a need for the Department of Basic Education to provide technological resources, data and network accessibility to all schools for the use of online teaching. Therefore, my study sought to explore the integration of technology, pedagogy, content knowledge and learners' mathematical competencies when sketching quadratic functions online using the GeoGebra software.

However, online learning is an interactive teaching method that spans time and geography between teachers and students on a virtual platform (Fu & Zhou, 2019). This is comparable to online teaching, which is a crucial component of education. In other words, online instruction combines a technology method with pedagogy and subject-matter expertise for the objective of learning. This is consistent with the study

conducted by Albrahim (2020) who states that online learning allows non-contact interaction with learners by providing learning materials online.

According to Sikhakhane et al. (2020), there was a need to emphasise the significance of implementing technology in teaching and learning to educators and learners. Additionally, the educational system needs to be rebuilt using digital pedagogy for both teaching and learning. Mahaye's (2020) study focuses on reviewing a formal request of blended learning during the COVID-19 outbreak to be considered. It was found that online teaching gives students access to learning resources and allows them to communicate with the teacher and other students online (Mahaye, 2020).

The educational system is increasingly using technology to teach and learn mathematics. Mhlanga and Moloi (2020) discovered that switching to online learning in South Africa's education system resulted in a massive adoption of various 4IR tools such as digital tools, networking and robotic tools from all levels of education. However, for most rural schools, it might need a great effort to provide data, devices and technological knowledge. Mahaye (2020) advocated for ICT facilities to be implemented in rural schools to ensure effective teaching and learning.

The study by Yao et al. (2020) investigated how teaching is organised in online classrooms. The study reported that live broadcasting teaching methods enhance learners' performance better than recorded videos. According to Attard and Holmes (2020), integrating digital technology requires pedagogy and content knowledge to avoid the ineffectiveness of the lessons. Integrating digital technology for teaching and learning makes learning more accessible however, it might be distracting if not used properly (Attard & Holmes, 2020). I therefore, believe that technological knowledge is key to integration with other knowledge.

In this way, the current study relates to the live broadcasting teaching mode found in Yao et al.'s (2020) work. The study engaged learners in live online teaching and learning for real interaction. However, learner-to-learner interaction did not unfold in the lesson due to less technological resources.

The readiness of educators and learners in implementing online teaching and learning has been researched (Adu et al., 2022; Gumede & Badriparsad, 2022; Juanda et al.,

2021; Scherer et al., 2021; Yates, 2021). To illustrate the educator's readiness at higher institutions, Scherer et al. (2021) explored three dimensions of readiness which are TPACK self-efficacy, online teaching presence and institutional support. Although the importance of readiness in online teaching and learning has been magnified, the study aimed at measuring TPACK for effective online teaching and learning. The findings revealed that profiling educators address the personal and contextual readiness for online teaching and learning.

Ismail et al. (2021) exploring the readiness and reported that educators are ready to integrate technology into their teaching through this challenging world. For beneficial online lessons, the electricity supply should be improved and free internet access as well for the readiness of technology integration in classrooms (Mutambara & Tsakeni, 2022).

Adul et al. (2022) illustrated that the lockdown gave educators no option but to do online teaching which was new to some. Digital teaching and learning was inadequate as educators were not capacitated with the necessary skills prior to the implementation. According to Gumede and Badriparsad (2022), learners need interventions for feasible online learning. The unstable connectivity was still a challenge that learners experienced during online teaching and learning (Mukuna & Aloka, 2020). Furthermore, the cost of data resulted in failure to attend online lessons, and this has been also reported by Dube (2020) that rural schools have been neglected in the process of implementing online learning.

Yates et al. (2021) used Kearney et al.'s (2012) framework to examine learners' experience of digital learning. The framework highlights three characteristics that are: personalisation, authenticity, and collaboration (Kearney et al., 2012 cited in Yates et al., 2021). My study could not relate to the whole framework as it could shift the focus of my study. However, my study was pinned under social constructivism, and I, therefore, found collaboration useful as learners learn. The findings of Yates et al. (2021) revealed that collaboration activities advance the working together of learners.

According to DBE (2020), educators are expected to engage in online teaching and learning to curb the spread of COVID-19. Furthermore, they must provide a highly engaged online classroom and be proficient in online teaching and learning (Bhaumik

& Priyadarshini, 2020). The study that attempted to find out the e-readiness of senior secondary school learners' online learning revealed that there were positive aspects of learners shifting from the normal face-to-face to an online approach (Bhaumik & Priyadarshini, 2020). However, fewer learners felt isolated and mentally exhausted by shifting.

2.2.1. Benefits of online teaching and learning

The concept of online teaching and learning has been generally researched (Scherer, et al., 2021; Bailey & Lee, 2020; Ilmadi, et al., 2020). Bailey and Lee (2020) conducted a survey to explore the benefits, challenges, and strategies in online teaching. The study revealed that educators with experience in the integration of technology perceived fewer challenges in their online classrooms. Educators with experience can use a variety of communication channels when encountering challenges in the planned approach (Bailey & Lee, 2020). In these results, I related my study when challenges arose during my online teaching and learning. My study used bricolage in terms of technological resources for the implementation of our lessons.

Meanwhile, Zakaria and Khalid (2016) explored the benefits and constraints of applying ICT to teaching and learning. The study summarised the literature to unveil the benefit of integrating technology in teaching Mathematics. Therefore, the literature found that teaching Mathematics using technology improves learners' understanding of the concepts and develop interest. According to Ilmadi et al. (2020), online learning is a digital platform that assists educators and learners to continue with educational processes. Therefore, online learning encourages independence and flexibility.

Mobile technology was found to be a useful tool to style technological learning (Ismail et al., 2021). Dube (2020) found bricolage suitable to integrate technology in teaching and learning. Educators who are frequently engaged in mobile devices for delivering curriculum have experience and they explore more in technology (Ismail et al., 2021).

2.2.2. Challenges in an online classroom

The availability and stability of networks have been identified as one of the challenges in rural schools. During Coronavirus pandemic, studies were conducted on the effect of the COVID-19 on teaching and learning to help the Department of Education develop a new plan for covering the curriculum (Dube, 2020; Liu, 2020). Most schools

in rural areas experience problems with networks and unstable connectivity (Cardull et al., 2021; Dube, 2020).

The network signal lost during teaching and learning either from the educators or learners also affects the implementation of the lesson (Liu, 2020). Virtual lessons were recorded and accessed anytime, in case there is a signal lost, or the learner is absent. Hili and Uribe-Florez (2020) identified a lack of knowledge and time as barriers to online teaching for Mathematics. Furthermore, learning of new technology programme and planning virtual lessons consume time.

Moreover, Mihai and Nieuwenhuis (2015) found that educators identified limited time and too much administration when using ICT for teaching. Apart from educators and resources, learners using digital devices for non-educational purposes were identified as a major concern (Mwapwel et al., 2019). With such behaviour pattern, the school might prohibit learners to engage in online learning.

Dube (2020) found that there were many challenges faced by rural schools in switching to online teaching and learning. Furthermore, the study was located within Participatory Action Research and Critical Emancipatory Research (CER) which were adopted as the theoretical lens. CER was chosen because of its objective that ensures rural teachers and learners are included in life-transforming experiences.

The study conducted by Yusuf and Ahmad (2020) for higher institutions indicated that there were many challenges encountered in an online teaching and learning environment. Amongst the challenges were that learners are not focused and unstable internet access thus leading to disruption of lessons. Adu et al. (2022) reported on how innovation and technology were utilised during lockdown for online classrooms. The study adopted a phenomenological design to understand how lectures minimise the challenges in online teaching. The results showed that there is a need for the Department of Higher Education and Training to provide programmes on digital skills and the necessary equipment. The software with flexible features was adopted for problem-solving (Adu et al., 2022).

Similarly, Makuna and Aloka (2020) adopted a phenomenological design and reported on challenges rural educators faced in online learning. Thus, their study revealed poor network access, lack of learning devices and incomplete submission of activities. The study also confirmed that rural study area affects academic development. It could be

deduced from the readings that poor services in rural schools affect the effectiveness of online teaching and learning.

Although Zakaria and Khalid (2016) argued that integrating technology in teaching and learning of Mathematics may be beneficial or challenging, the unavailability of technological resources to most educators and learners has been identified. In addition to these constraints, some educators lack pedagogical knowledge to run technology-integrated classrooms. These results are still burning issues caused by the COVID-19 pandemic (Dube, 2020; Makuna & Aloka, 2020).

According to De Freitas and Spangenberg (2019), learners are not yet engaged in learning that encourages the sharing of ideas through technology due to insufficient teachers' TPACK. Their findings confirm that lack of regular access to technological infrastructure has an impact on teachers' use of ICTs. Educators' inner strength to implement ICT in the classroom is not catered for because their technological basic needs are not well provided (Ismail et al. 2021). It is further confirmed that school infrastructures and facilities fail educators. Educators' perceptions also serve as a barrier to implementing technology in classrooms (Abel et al., 2022), and their perceptions are shaped by cultural spheres and experiences. According to Ignacio (2021), online classes might result in stress on the health of educators and learners. Therefore, mental health programmes in schools are encouraged. The delivery of online teaching and learning is new to most people in the education sector, particularly at the school level.

The study by Mutambara and Tsakeni (2022) investigated the teaching and learning of secondary Mathematics during COVID-19 in Zimbabwe. It stated that poor network coverage disturbed online lessons. On the other hand, Ignacio (2021) stated that there is insufficient knowledge of digital technology for teaching and learning. However, ICT may introduce distractions in the classroom (De Freitas & Spangenberg, 2019). Educators' TPACK might enhance learners' understanding and limit distraction.

Kalonde (2017) found that infrastructure remains a challenge in implementing the use of technology in rural schools. He further elaborated that educators need more time to feel comfortable with technological tool. According to Widayanti and Suarnajaya (2021), different situations yield different challenges when conducting online lessons.

In summary, the challenges encountered are those that mostly affect all learners at the national level (Gumede & Badriparsad, 2022) and in rural schools (Dube, 2020; Mihai & Nieuwenhuis, 2015) during online learning. The educators' challenges revolve around attempts to integrate technology using the TPACK framework (Umugiraneza et al., 2018; Chirinda et al., 2021). The instability of general hugely affect effective online teaching and learning (Adu et al., 2022).

2.3. Learning with technology

The concept of learning with technology has been widely researched in the education sector (Clark-Wilson et al., 2020; Ghavifekr & Rosdy, 2015; Hadman, 2019). According to Ghavifekr and Rosdy (2015), the implementation of technology in teaching and learning is an ongoing process that aimed at improving the accessibility of learning materials. It is further stated that learning with technology is actively engaging learners in their learning and assist in effective lesson preparations.

Integration of technology with different knowledge gives educators the opportunity to implement teaching online. The use of technology has been improved in schools; however, the educator needs to understand what technology tool is beneficial in a mathematics classroom (Hardman, 2019). Online teaching and learning and assessment require the environment with technology infrastructure and quality Internet connection.

Clark-Wilson et al. (2020) appreciated the importance of teaching with technology in schools, particularly in Mathematics concepts. The study surveyed researchers to gain and share insights into learning and teaching Mathematics with technology. The integration of ICT in classrooms allows different approaches to learning such as collaborations, learner-to-learner and teacher-to-learner relationships and a leaner-centred environment (Hernawati, 2019).

According to Dube et al. (2021), many countries opted for online teaching as an alternative way to deal with the trajectories of the COVID-19 pandemic. However, schools in rural communities faced serious poverty. In short, many families cannot afford to buy technological devices. Another challenge is the experience of educators in the use of ICT in their classrooms.

2.4. Integration of technology in teaching and learning

The integration of technology is the process of modifying teaching and learning to improve academic performance (Onyema, 2020). Furthermore, Stein et al. (2020) assert that using different digital tools for teaching and learning resembles technology integration. Bhasin (2012) defines the integration of technology as a process of implementing technology in the classroom to enhance teaching and learning.

Research had been conducted on the integration of technology in teaching and learning (Arkorful et al., 2021; Onyema, 2020; Mailizar et al., 2020; Bhasin, 2012). Mailizar et al. (2020) identified major limitations as they investigate e-learning barriers experienced by secondary mathematics teachers. However, giving learners skills through technology integration now, benefits them in their future life. According to Sasota et al. (2021), the integration of technology in teaching and learning becomes necessary for demonstration processes to enhance learning. It also plays an important role in quality education (Onyema, 2020).

Stein et al. (2020) outlined that although there were difficulties in technology integration, learners' understanding was improved to a higher order. Moreover, the integration of technology enhances productivity and teaching performance (Hero, 2019). The results were witnessed during the pandemic. Although the research targeted a different aim, my study targeted enhancing teaching and learning through the integration of technology. The findings by Hero (2019) indicate that there was a great impact on classroom performance due to the integration of technology.

According to Onyema (2020), the integration of technology promotes curriculum objectives and modernisation of the education system. Informed by literature, South Africa should ensure a strategic plan to integrate technology in all education sectors to result in a creative and innovative community. Kayembe and Nel (2019) pointed out that technology integration in South Africa is hindered by social factors such as inequality and service delivery. Du Plessis and Mestry (2019) have categorised South African rural areas as relatively underdeveloped. They believed that the integration of technology in rural schools would be affected by social factors. Moreover, Venketsamy and Zijing (2022) stated that COVID-19 has forced the education sectors to find an alternative norm for the continuation of teaching and learning. As such, technology

integration was one alternative and educators were introduced to the unfamiliar technology that required necessary skills (Venketsamy & Zijing, 2022).

Inequality was also found in South African township schools. During COVID-19, learners in township schools were unable to transit to technology integration in schools for continuity of teaching and learning (Mkhize & Davids, 2021). According to Kayembe and Nel (2019), South Africa experienced a lack of funds to implement technology in all institutions. Many challenges were experienced in rural schools and teaching and learning was left unattended by policymakers and other stakeholders (Du Plessis & Mestry, 2019). Mkhize and Davids (2021) also identified a lack of infrastructure, digital skills and resource agents as factors that affected the smooth running of technology integration in township schools. Therefore, poor infrastructure looked to be a major problem to integrate technology into the new teaching and learning.

In countries like Ghana, it was revealed that the educators' attitude influences the integration of technology in classrooms (Arkorful et al., 2021). However, in Nigeria, the study conducted by Onyema (2020) which aimed at examining various challenges that obstruct the integration of emerging technology revealed that power supply and poor internet connectivity are among the constraints to a successful technology integration. Stein et al. (2020) had identified a lack of technical support from school authorities as a constraint that limits the success of technology integration.

According to Rahayu (2022), an unstable network was experienced mainly by the rural schools. Developing countries implemented technology teaching and learning with less teaching necessary experience that resulted as a barrier to the implementation (Mailizar et al., 2020). As the researcher, I had limited resources and pedagogy for using the GeoGebra software for teaching practices. Stein et al. (2020) stated that professional development is necessary for educators to implement their roles in the integration of technology.

Augustina (2022) indicated that educators were simply trained on basic technology skills rather than on how to develop the pedagogical features of technologies. Limited time was also identified as a barrier to conducting and practising online lessons (Augustina, 2022). The current study found integrating technology to be time

consuming with the one hour allocated daily to prepare a computer and projector to use the GeoGebra software.

Pedagogical training is essential for effective teaching and learning as we integrate technology (Rahagu, 2022). It was concluded that the training in integration of technology enhances the educators' effort and affection (Arkorful et al., 2021). In addition, educators still encounter challenges in technology integration and therefore, foresee a need for adaptive training programmes (Stein et al., 2020). The results of a study conducted by Venketsamy and Zijing (2022) advised that educators should receive continuous training in technology for effective teaching and learning.

2.5. The role of educator

Seymour-Walsh et al. (2020) showed that the role of an educator in a lesson was to build a learner-centred approach. Therefore, they revealed that the educators had the authority to embrace principles that develop individual and social learning through the materials designed for learning. In addition, Posey et al. (2010) highlighted that the role of an educator is to integrate the technology of his/her choice to meet the needs of teaching and learning. Therefore, the researcher insisted that the educator is responsible for preparing the classroom, design learning materials and give instructions. As a result, learners are responsible for their learning under the supervision of the educator.

According to Chua and Bong (2022), traditional educators' role in a technology-orientated classroom ends up not meeting the students' need due to their frustration with integrating technology. Therefore, young generation educators seemed to fulfil learners' needs when implementing virtual lessons. Hence, virtual teaching led by technologically knowledgeable educators embraces learner-centred rather than teacher-centred approaches.

Educators' awareness of their role in an online classroom to facilitate the process of teaching and learning is important (Engelbertink et al., 2021). The study conducted by Ulla and Perales (2021) highlighted that as educators strive to move to online teaching and learning they work on improving their preparations for online lessons. They also found that the behaviour towards online teaching and learning contributed to the relevant roles of educators. Moreover, Engelbertink et al. (2021) stated that the

educators' role was to support learners in completing their activities and ease the process of learning.

In addition, Mahmood's (2021) study was channelled to online teaching and learning in higher education. The results indicated that the educators are responsible for sharing materials before the class to encourage active participation in the online classrooms. Furthermore, receiving feedback from learners was claimed by educators to improve online classroom management. This was also feasible in secondary schools and applicable to my study. I shared a login link for learners to prepare themselves to be attending on time. However, network connectivity disturbed the processes. Therefore, my study explored the process of conducting online lesson in a poor network connectivity area.

2.6. Quadratic functions

According to Ubah and Bansilal (2018), a function is an expression that explains the relationship between the independent and dependent variables. They broaden the concept of functions by providing characteristics of quadratic functions; the highest exponent of the variable base is 2. A quadratic function sketch demonstrates the connection between inputs and outputs variables. CAPS (2011) shows that we have three forms of quadratic functions: f$(x) = (x + p)^2 + q$, $f(x) = a(x - x_1)(x - x_2)$ and $f(x) = ax^2 + bx + c$. In addition, the effects of the parameters such as $a, b, c, p \; and \; q$ in the above, need to be established so that various problems can be set (CAPS, 2011).

The majority of students today have frequent access to technology, which might be helpful for online teaching and assessing in Mathematics classrooms (Ubah & Bansilal, 2018). The study by Samsudin et al. (2021) highlighted the use of the GeoGebra software to sketch quadratic functions and how it enhances learners' understanding of the topic. The tools found on the GeoGebra software interface are described too. This supported my study as it intended to use the GeoGebra software for sketching quadratic function in an online classroom. I found myself deviating from the content they have chosen because my study chose the sketching of quadratic functions with the effects of parameters.

2.7. Application of the GeoGebra Software

The application of technology in teaching Mathematics is growing in schools. Several applications softwares are available to enhance the teaching and learning of Mathematics in schools (Tamam & Dasari, 2021; Killcman et al., 2010). The use of technology and its importance in our classrooms has been acknowledged by the education system. GeoGebra is a tool that can help educators to plan lessons based on various teaching methods (Arbain & Shukor, 2015), while Zoom is an educational communication software which facilitates the delivery of online learning (Bhatt & Shiva, 2020).

The studies of Arbain and Shukor (2015); Benning and Agyei (2016) and Debnath et al. (2021) show that the use of technology software allows easy investigations into the nature of the graphs and enhances effective learning. Chirinda et al. (2021) used WhatsApp as a tool to support the teaching and learning of Mathematics online. However, I opted to differ with the tool used as WhatsApp is not used for graphing. My study used the GeoGebra software for graphing quadratic functions which was operated using a computer. The study of Putra et al. (2021) used the GeoGebra software to teach the area and perimeter of rectangles to encourage the development of mathematical thinking skills in learners. The result proved that the GeoGebra software supports the learners' ability to think mathematically rather than memorizing the formulas.

2.8. Theoretical Framework

The theoretical framework that guided my study centred on Technological Pedagogical Content Knowledge (Mishra & Koehler (2009) and Niss' (2003) Mathematical Competencies.

2.8.1. Technological Pedagogical Content Knowledge

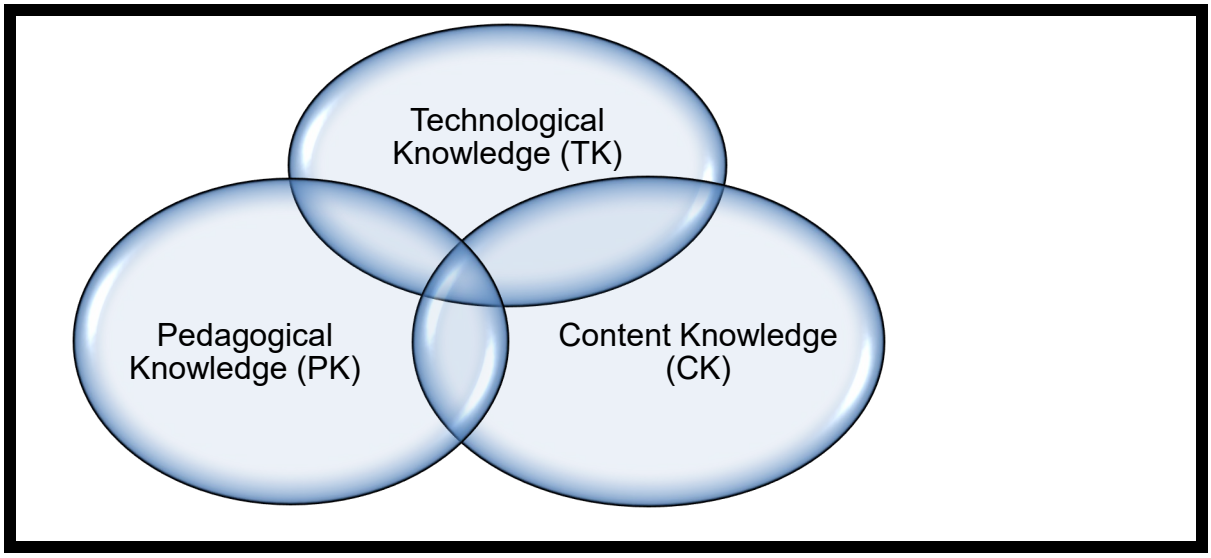


Figure 2.1. Mishra and Koehler (2009) Technological Pedagogical Content Knowledge (TPACK).

According to Mishra and Koehler (2009), TPACK is the basis of effective teaching that arises from the interactions among content, pedagogy and technology knowledge. The framework was used as a lens for understanding technological knowledge integrated into teaching sketching of quadratic functions. It is important to possess knowledge of how technology can be used to build on prior knowledge for development. An educator who brings TPACK into play during the lesson shows a good understanding of teaching with technology (Mishra & Koehler, 2009). The focus was on Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) for effective teaching and learning.

Pedagogical Content Knowledge (PCK) is formed by separate identities which are Content Knowledge (CP) and pedagogical Knowledge (PK) (Mishra & Koehler, 2009). Without ignoring the advantages of educators' PCK, Jacob et al. (2020) stated that PCK enables educators to transform subject content for relational understanding in a learning environment. In addition, PCK is the knowledge that an educator holds that enable him/her to choose relevant content for teaching and also bring along the strategies to implement the same content in the teaching and learning environment (Jacob et al., 2020).

2.8.1.1. Technological Content Knowledge (TCK)

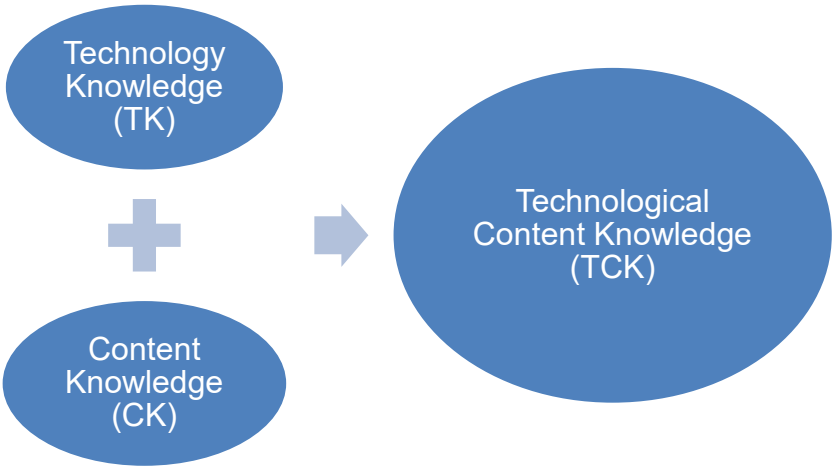


Figure 2.2. Mishra and Koehler (2009) Technological Content Knowledge (TCK)

Technology knowledge is the knowledge that requires an educator to understand information technology to apply and accomplish tasks using technology, while content knowledge is the knowledge about the curriculum content for which an educator has to teach (Mishra & Koehler, 2009). Technological content knowledge refers to when one can develop the necessary technological tool for a chosen content. In this study, the technological tool afforded flexibility in sketching quadratic functions online.

On the other hand, Listiawan et al. (2018) elaborated on how Technology knowledge (TK) integrates with Content knowledge (CK) to solve and complete a task. The study focused on constructing geometric objects using digital software called GeoGebra. As a result, TK and CK as the forming element showed the constructive and obstructive TCK. The constructive TCK supported the process of completing a task while obstructive part of TCK was that the process of constructing geometric objects is not supported properly by the digital procedures made. The study offered an opportunity to research the causes of obstructive TCK. Therefore, one realised that observing TCK educators hold when teaching Mathematics, some difficulties may arise that affect effective teaching.

2.8.1.2 Technological pedagogical knowledge (TPK)

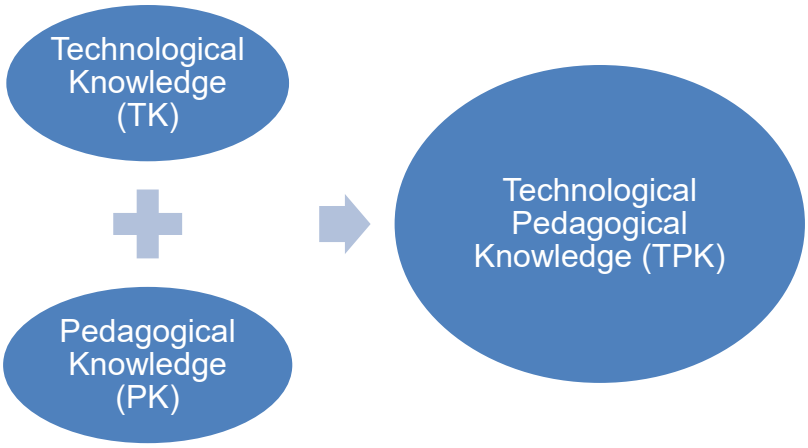


Figure 2.3. Mishra and Koehler (2009) Technological Pedagogical Knowledge (TPK)

Pedagogical knowledge is the knowledge of the teaching and learning methods in a classroom. Moreover, technological pedagogical knowledge is an understanding of how the chosen technological tool can change the teaching and learning methods (Mishra & Koehler, 2009). This includes considering how GeoGebra may be used in an online classroom. Thus, online classroom settings will allow individuals to interact in their learning.

2.8.2. Niss' (2003) Mathematical Competencies

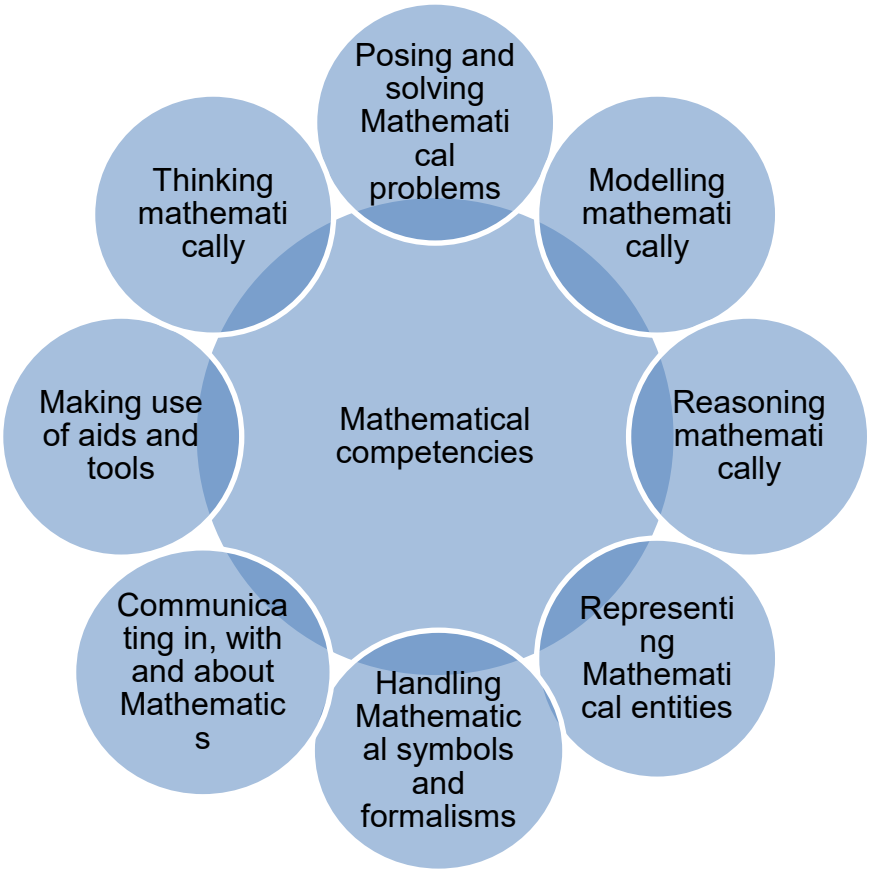


Figure 2.4. Niss' (2003) Mathematical Competencies

The study adopted Niss's (2003) Mathematical competencies to identify the abilities learners display while sketching quadratic functions online. One of the research questions was "What are the learners' competencies in sketching quadratic functions online?" and this was to make sense of the competencies learners display when sketching quadratic functions online in a rural school in Mopani District, Limpopo Province, South Africa. Mathematical competence is the ability to understand and use Mathematical knowledge in a variety of circumstances and mathematical situations (Niss, 2003). Therefore, a learner is in a position to put knowledge skills into practice. Moreover, mathematical competencies are the abilities to apply mathematical procedures, language, axioms and theorems to give solutions to mathematical problems (Caridade & Rasteiro, 2018).

Caridade and Rasteiro (2018) revealed that the given Mathematics problem in the study allowed learners to develop some mathematical competencies than others. Albano and Pierri (2014) addressed conceptual understanding rather than instrumental use for learning. In that case, aids and tools were not addressed at all. Therefore, addressing mathematical competencies depend on the type of Mathematics questions.

During the lessons, I gave learners activities to gain the insights regarding the Mathematical competencies. However, different assessment of Mathematics resulted in different sets of competencies (Niss, 2003). He further identifies the eight competencies as follows: thinking mathematically, posing and solving mathematical problems, modelling mathematically, reasoning mathematically, representing mathematical entities, handling mathematical symbols and formalisms, communicating in, with and about Mathematics and making use of aids and tools.

2.8.2.1 Thinking mathematically

The competency in "thinking mathematically" involves knowing the kinds of answers that Mathematics activities may offer. Learners need to make sense of how quadratic functions are used to interpret and communicate effectively (Booker, 2005). According to Stacey (2007), mathematical thinking is a process that requires the mathematical knowledge and reasoning abilities of a person. In addition, Thomsen and Jankvist

(2022) define thinking mathematically as the process whereby one responds to mathematical materials in and outside the classroom. Putra et al. (2021) define mathematical thinking as the ability that develops from Mathematics learning activities. Therefore, mathematical thinking is a process that comprises of problem solving, modelling and abstracting (Drijvers et al., 2019). In support of Thomsen and Jankvist (2022), I regard mathematical thinking as a process of mathematising a real situation in teaching and learning.

The alignment of curriculum reform fosters learners' mathematical thinking. Drijvers et al. (2019) investigated the alignment of Netherlands curriculum reform and an assessment for a case of mathematical thinking. Most educators are challenged with the rise of provoking questions through the teaching methods adopted in their classrooms. It was also noticed that the assessment reveals fewer tasks appealing to mathematical thinking. Finally, teachers are required to exercise the freedom they have to plan and prepare assessments that assess mathematical thinking skills. In a digital classroom, mathematical thinking is developed in the presence of computing thinking through problem solving (Calder, 2018).

2.8.2.2. Posing and solving mathematical problems

Learners should be able to solve mathematical problems in different ways and find relevant strategies to solve given mathematical problems. The DBE (2011) defines Mathematics as a language and submit that mathematical problem solving enables us to comprehend reality and teaches us to solve problems creatively and critically. According to Polya mathematical problem-solving process is through following stages of understanding a problem, developing a plan by using a model, exercising the plan for better outcome and applying all gathered information for solutions (Chirinda & Barmby, 2018).

In a mathematical problem-solving process, the important part is to enhance understanding of the problem and developing creativity in learners. Chirinda and Barmby (2018) found that the teacher-centred approach does not encourage mathematical problem-solving processes. Therefore, for the stimulation of mathematical problem-solving processes during teaching and learning, educators require the development of pedagogy knowledge. There is a need to support learners

with the language of teaching and learning. However, Palmer and Van Bommel (2020) focused on problem solving and posing with 6-year-olds at the foundation phase. Problem posing is identified as an element of problem solving. The whole process of problem solving is done through the posing of problems to derive a solution (Palmer & Bommel, 2020).

2.8.2.3 Modelling mathematically

The competency in "modelling mathematically" involves monitoring and controlling the entire modelling process, as well as considering or expressing statements mathematically. This competency permits learners to identify the critical points of quadratic functions. According to DBE (2011), the Curriculum and Assessment Policy Statement (CAPS) states that mathematical modelling is important in our curriculum and should be incorporated into all Mathematics sections. In consideration of the skills identified in the CAPS document, my study engaged learners in sketching quadratic functions using the GeoGebra software.

Mathematical modelling is a process of mathematising the real model such as structuring and idealising the real world (Maab, 2006). Similarly, Leong and Tan (2020) define mathematical modelling as a bridge to show how Mathematics is connected to real-life problems while working as a solution. The study confirmed that a few learners experienced difficulties in formulating a model and in reasoning out the solution. Maab (2006) has shown that most learners were able to develop modelling competencies within problems with known and unknown contents, however, there were misconceptions and mistakes concerning the whole modelling process. Furthermore, the results showed that educators need to be selective of the teaching methods to allow and support modelling in the classroom.

Leong and Tan (2020) investigated mathematical competencies and the study was underpinned on Models and Modelling Perspective theory which suggests that learners with modelling competencies should construct models to solve real-world problems. The results revealed that modelling competence is essential when engaging learners with more mathematical modelling tasks.

Developing mathematical models with digital tools reveals new platforms to use Mathematics in solving real-world problems. The study by Carreira et al. (2013)

focused on developing mathematical and computer models with the GeoGebra software. The finding was that translation from graphics influenced the modelling approaches learners choose. A teaching experiment was designed and a sequence of seven tasks was developed over a month.

2.8.2.4 Reasoning mathematically

Learners should be able to uncover the basic ideas in a given line of argument. Learners who can reason mathematically have the ability to understand aspects of mathematics and synthesise information to support their statements (Niss, 2003). Reasoning is a mathematical competency that has complex implications (Herman, 2018). According to Rasteiro and Caridade (2018), reasoning mathematically deals with the ability to provide justification to support mathematical statements. It enables one to produce an argument with supportive evidence.

Moreover, mathematical reasoning is the ability that a learner possesses in order to draw a conclusion based on relevant facts and statements assumed to be valid (Hasanah et al., 2019). Mathematical reasoning is the ability that is attained by learners through mathematical materials in finding the truth (Widiyasari & Nurlaelah, 2019). Therefore, it is concluded that mathematical reasoning enables learners to identify problems in real-life situations and apply mathematical skills to solve their daily problems (Scholar & Akbar, 2020).

Despite the different types of mathematical reasoning, learners still experience difficulties when dealing with reasoning in general. The results showed that learners are not certainly depending on real-life in the learning environment to develop reasoning skills but on the pedagogy educators bring to the classroom (Herman, 2018). Scholar and Akbar (2020) assert that Mathematics teaching and learning triggers mathematical reasoning among learners. According to Hasanah et al. (2019), learners with mathematical reasoning have a high understanding of mathematical materials. Therefore, problem solving in Mathematics requires the ability to reason mathematically.

2.8.2.5 Representing mathematical entities

This competency in “representing mathematical entities” deals with the understanding and utilization of different representations of Mathematical objects and situations

(Niss, 2003). However, Caridaade and Rasteiro (2018) indicated that representing mathematical entities focus on the ability to present Mathematics objects, language and problems. I, therefore, located my study in the latter definition; the focus was on representing the quadratic function using GeoGebra software. Learners must be able to recognise a sketch of a represented function and move parameters (Alpers, 2013). The discussion of mathematical representation by Samsuddin and Retnawati (2018) shows that real-world problems and Mathematics are treated separately. I foresaw that Mathematics can be represented by using real-world objects as the mathematical entities for the understanding of Mathematics in a learning environment.

Samsuddin and Retnawati (2018) indicated that educators' knowledge of Mathematics may also contribute to learning with representation. In addition, Mitchel's Role of Teachers was developed which supports teaching and learning that helps learners link the representation with real-life situation. However, there are challenges in using representations, as they requires the ability and knowledge to choose representation to connect it to real life (Samsuddin & Retnawati, 2018). Therefore, my study engaged learners in the representation of contexts using graphs through the GeoGebra software.

2.8.2.6 Handling mathematical symbols and formalisms

A learner is competent in handling mathematical symbols and formalism when s(he) could translate a mathematical problem from natural language to symbolic language. S(he) must be able to recognise a quadratic function and manipulate symbols as variables and for elements (Niss, 2003). As stated by Caridade and Rasteiro (2018), a learner has the ability to use formal language and transforms symbolic expressions. In addition, it involves having an insight into the meaning of mathematical symbols. In the case of quadratic functions, a learner would be expected to express quadratic functions symbolically and graphically even when learning through digital software. However, developing mathematical symbols and formalism competency requires some mathematical symbols basics and ability to handle a certain set of the number systems (Aguilar & Cataneda, 2021).

2.8.2.7 Communicating in, with and about Mathematics

Competency in “communication in, with and about Mathematics” deals with understanding others’ written, visual or oral work that has mathematical content. In this study, it would include the learners’ ability to understand the forms of quadratic functions and the development of formulas (Alpers, 2013). This is about visualising and interpreting mathematical definitions, statements, rules and theorems (Caridade & Rasteiro, 2018). Learners with mathematical communication skills develop higher level of thinking that easily finds solution to existing real-world problems (Joko Supriyanto & Hairun, 2020). Mathematical communication in learning facilitates the thinking and understanding of concepts. The meaningful mathematical activities prepared for online classroom assist in improving learners’ mathematical communication skills.

According to Luneta (2015), the learners who lack mathematical communication skills might be a result of a teacher-centred classroom. He believed that educators are developed professionally to attain pedagogical knowledge that would ultimately improve their Mathematics. It is important to note that learners need time to analyse the mathematical concepts and initiate solutions for the development of Mathematics communication skills.

2.8.2.8 Making use of aids and tools

Competency in “making use of aids and tools” concerns knowing the existence and properties of tools and aids for mathematical activities. It also includes an understanding of the limitation of the aids and tools (Niss, 2003). Making use of aids and tools involves having insight into the tools and aids used in Mathematics context. It includes the use of technological tools to understand and interpret Mathematics.

According to Astafieva et al. (2020), the use of digital tools enhances learners’ conceptual learning of Mathematics and builds learners’ critical thinking. Therefore, a collection of basic systems of computer mathematics contributes to the formation of learners’ mathematical competencies. Bakri et al. (2021) adopted the use of tool to teach polynomial function in calculus. They developed an innovative tool “Graph Puzzle” for sketching of polynomial function. Although it was conducted on university students, the use of a developed tool that embodied a learning approach improved learners’ performance and skills. Additionally, on a national level Mthethwa et al.

(2020) used a dynamic GeoGebra software as a tool for learning. The results revealed that analytical thinking and understanding of content emerges from a classroom that uses the tool for learning. Given the local and international literature for making use of aids and tools, it affords learners to be at their best level of mathematical competence.

2.9. Studies that used TPACK

Studies that used TPACK are based on the educators' integration of technology in teaching and learning. The study by Mokotjo and Makgalwa (2021) used TPACK and conducted four qualitative case studies to illustrate the views and experiences of educators in the integration of the GeoGebra software. The participants were purposively sampled from different high schools in North West Province. The researchers used semi-structured interviews to gather data. The results revealed that the use of the GeoGebra software creates an exciting learning environment for learners (Mokotjo & Makgalwa, 2021). The Department of Basic Education (2018) encourages a learner-centred Mathematics classroom where learners explore and make sense of Mathematics.

The focus in Umugiraneza et al.'s (2018) qualitative study on Mathematics educators revealed that almost of the participants had never used computers to teach Mathematics. A questionnaire was used as a data collection method. The questions were related to educators' technological, pedagogical and content knowledge (Umugiraneza et al., 2018).

Juanda et al.'s (2021) study reports on Biology educators' readiness to integrate technology with pedagogy and content knowledge to implement online learning. The study aimed to provide an overview of the educators' TPACK skills in an online learning environment. The study was guided by the TPACK framework designed by Mishra and Koehler (2006). Their finding was that Biology educators had sufficient TPACK skills to implement it in their classrooms, although improvement was needed. While Juanda et al.'s (2021) study focused on Biology, my study was on Mathematics, sketching quadratic functions using the GeoGebra software.

Tunjera and Chigona (2020) reported on how educators integrate technology into the curriculum. Unlike Juanda et al. (2021) and Tunjera and Chigona (2020) used more than one collection method to gather data, that is, through one-on-one interviews and

observations. The study adopted a framework with constructivism theory to develop a deeper understanding of technology-enhanced pedagogy. Although the two studies opted for different research designs, both recommended that educators need professional development in technology integration for improvement.

A study by Hernawati (2019) reported that educators can use cellular technology to increase the learners' knowledge. The study aimed to give an overview of the literature on educators' TPACK skills and their positive impact on the learners' achievement. One of the recommendations was that educators need to design lessons that are technology integrated to support the learners' competencies.

Chirinda et al.'s (2021) exploratory study in a context of historical disadvantage highlighted that the DBE focused on Grade 12 learners. The education system forced the adoption of emergency remote teaching for Grade 12 to complete the curriculum since they were to write school leaving examinations. Grade 12 public school educators who participated in their study had adequate qualifications to teach (Chirinda et al., 2021). Their study exposed that implementing technology in teaching and learning needs integration of technology, pedagogy and content knowledge. Therefore, their study illuminated those educators as learners in technology-integrated classrooms learn by trial and error for them to identify the effective technology tool.

Saralar et al. (2018) reported on how a pre-service educator utilises her TPACK in a classroom. In the study, a descriptive case study was adopted to explore changes in her TPACK, and the participant rated herself as an effective user of technology. The observations, semi-structured interviews, documentation of lesson plans and GeoGebra activities were used to gather data. Therefore, Saralar et al. (2018) were guided by TPACK Standards and Development Model Rubrics to generate the four themes that were used to analyse their data. The results revealed that participants' skills to utilise TPACK improved in every succession of the lesson.

In summary, the studies that used TPACK focused on educators' knowledge to integrate technology. Chirinda et al. (2021) and Umugiraneza et al. (2018) conducted their study in a disadvantaged research site, that resulting in less experience on the use of technology. I fail to locate my study in Juanda et al.'s (2021) study because the focus was on different subject content. The above studies adopted TPACK as the only framework that guided their research. Hence, I adopted two frameworks to identify

mathematical competencies learners display when integrating technology, content and pedagogy knowledge.

Based on the studies analysed above, it was evident that TPACK model is an effective system to identify gaps in teaching environment. Most of the studies in the section indicated that the similar findings that the use of technology, pedagogy and content knowledge in teaching creates an exciting learning environment for learners. This is evident from studied conducted by Mokotjo and Makgalwa (2021), Hernawati (2019) and Saralar et al. (2018).

It is also evident that there is a gap and improvement is still needed in some areas as revealed by Juanda et al. (2021), and Tunjera and Chigona (2020) that educators need professional development in technology to keep up with the developments in teaching with technology in classrooms. I saw a gap that the studies had nothing on the use of GeoGebra to sketch quadratic functions to explore the integration of technology, content and pedagogy knowledge. However, the studies proved that there is an improvement when TPACK model is implemented in learning and in line with the 4IR which creates excitement for the learners.

2.10. Studies that used Niss's (2003) Mathematical competencies

In this section, I focused on the application of Niss (2003) mathematical competencies in different areas of Mathematics.

Jaworski (2012) used mathematical competencies to identify the understanding of engineering students. The study used an enquiry approach and there was also modification to teaching. The study was a case of a rural school and was guided by TPACK for effective planning, organising and teaching. Geraniou and Jankvist (2019) conducted a study that had a desire of having mathematical competencies and digital competencies work simultaneously. The 4IR forced them to combine the two competencies, as many schools have included digitals in the school curriculum (Naidoo & Singh-Pillay, 2021). This is supported by Laursen (2010) cited in Vorobjovs (2020) who regards mathematical competence as the abilities which are integrated into five abilities. According to Niss (2003), there are eight mathematical competencies while Laursen (2010) categorised the eight into five mathematical competencies (abilities).

Nevertheless, Astafieva (2020) defines mathematical competence as the ability to develop and apply mathematical thinking to solve problems in real-life situations. Therefore, for the effective formation of mathematical competencies, the absolute approach to content and organisation of Mathematics activities should be included. Against this background, my study sought to complement and connect to the work of Niss's (2003) for a successful exploration. Vorobjovs (2020) explored mathematical competence and adolescents' characteristics. The participants were learners at the age of 15. The finding was that adolescents' mathematical competence is a set of skills and attitudes that allow them to understand and think critically towards learning Mathematics.

Based on the studies analysed above, it was understood that Niss's (2003) mathematical competencies allows critical thinking to solve a mathematical problems. The studies revealed that the content and pedagogy knowledge in designing activities are important in the formation and identification of the mathematical competencies (Astafieva, 2020; aworski, 2012). None of the above studies were conducted online but there were technology tools integrated in their researches. Therefore, there is a gap that was existing that the exploration of the mathematical competencies was not done when sketching graphs using GeoGebra software. My study was conducted online to explore the integration of technology, pedagogy, content knowledge and learners' mathematical competencies when sketching quadratic functions online using the GeoGebra software.

2.11. Chapter conclusion

In this chapter, the concept of online teaching was discussed with reference to the work of other researchers. –A literature review was presented. The theoretical frameworks for this study, namely, TPACK with two elements selected Technological Content Knowledge and Technological Pedagogical Knowledge and Niss's (2003) mathematical competencies were also presented. The study was concluded with studies that used TPACK and Niss's (2003) mathematical competencies.

In conclusion, I position my study where GeoGebra software was used to enhance participants understanding and instil positive attitude. GeoGebra is an interactive geometry, algebra, statistics and calculus application, intended for learning and

teaching mathematics and science to improve teaching skills and learning experience in schools and allows learners to visualize mathematics (Mokotjo & Makgalwa, 2021). The rapid developments of technology require the education system to adapt and improve education quality. These demands affect the education field and involves teacher innovation and creativity in implementing learning by developing a technology based, learners' oriented learning system such as TPACK and GeoGebra. The studies that use Niss's (2003) mathematical competencies left a gap in the formation and identifying of mathematical competencies in an online classroom when sketching quadratic functions using GeoGebra software. I therefore located my study in the exploration of Niss's (2003) mathematical competencies when learners sketching quadratic functions online.

CHAPTER 3: RESEARCH METHODOLOGY

The previous chapter defined and outlined the literature related to the subject matter of this study and the theoretical framework that guided the study. In this chapter, I presented in detail the methodology employed in this study. This chapter commences with research approach and design, sampling techniques and participants. Furthermore, it presents data collection procedures and methods, data analysis. It then concludes with discussing the qualitative criteria and ethical considerations of the study.

3.1. Qualitative approach

The study utilised a qualitative approach. Creswell and Poth (2016) indicated that a qualitative approach gives a comprehensive understanding of the issue, which in my study was exploring the integration of technology, pedagogy, content knowledge and learners' mathematical competencies when sketching quadratic functions online using the GeoGebra software. Using a qualitative approach to research helped me gain more insight into technological content knowledge and technological pedagogical knowledge and the competencies learners display when sketching quadratic functions.

Qualitative research is in the social constructivism epistemological perspective where knowledge is constructed (Merriam, 1998). The terms describe, translate, and understand are associated with qualitative research. Therefore, the use of qualitative research is underpinned by the understanding of how people make sense of what they experience and their daily lives. In this methodology, I was concerned about the meaning we attach in integrating technology to our teaching and learning and mathematical competencies displayed by learners when sketching quadratic functions using the GeoGebra software. A qualitative approach is found within the TPACK and Niss's (2003) Mathematical competencies theoretical frameworks to ensure that the theory chosen fits the data collected (Taylour et al., 2015). The rationale of using qualitative approach was to explore the integration of technology, pedagogy, content knowledge and the learners' mathematical competencies when sketching quadratic functions online using GeoGebra software.

In addition, Yusuf and Ahmad (2020) viewed a qualitative approach as perfection in exploring unfamiliar phenomena and understanding values and attitudes. However, their study used synchronous and asynchronous learning approach to accommodate learners with poor internet access. According to Persada et al. (2022), synchronous learning is a scheduled method that allows face-to-face online interactions between educators and learners. While asynchronous learning is a method that allows learners to access learning materials anytime and anywhere. There is less interaction that affects learners' and educators' communications. My study implemented an asynchronous approach for online interactions with learners while teaching and learning took place. A qualitative approach was chosen to match with interpretivism as the research paradigm in their study (Dayal & Tiko, 2020). It has been argued in the literature that a qualitative approach provides a huge possibility to explore and understand a situation that exists at that particular time (Govender, 2018).

3.2. Research design

There are eight designs characterising qualitative research: phenomenology, grounded theory, case study, ethnographic, narrative analysis, critical qualitative, postmodern-poststructural and basic interpretive qualitative (Merriam, 1988). According to Merriam (1988), phenomenology focuses on how meanings are built out of a structure of an experience. Grounded theory allows the researcher to build localised substantive theories that deal with real-world situations. A case study is an intensive, holistic description and analysis of a particular instance, phenomenon or social unit which has boundaries. An ethnographic design is used to study human society and its culture. Narrative research is used in data that reveal someone's experience in a story form. Critical qualitative research informs feminist research. The main focus in this design is the social context and to free ourselves from constraints that are limiting. Postmodern is a non-format design which relies on its rhythm and structure. Basic interpretive qualitative is used to comprehend the meaning of a situation that has inductive strategy and expect descriptive outcomes (Merriam, 1988).

My study was positioned as a case study as it had boundaries (Merriam, 1988). The boundaries for my case were a Grade 11 classroom and teaching sketching of quadratic functions using the GeoGebra software online. In addition, Ashley (2021) defines a case study as a design that observes situations where less is known. This

study was conducted as a form of online teaching within the concept of sketching the quadratic functions. The purpose of the case study is to fully understand the groups under the study (Becker, 1968 as cited in Merriam, 1998). Therefore, in the study I had to make sense of how to integrate technology in teaching the sketching of quadratic functions. The case study allowed me at an experiential level to become aware of teaching and learning online.

Merriam (2015) characterised a case study in three special categories which are particularistic, descriptive and heuristic. A particularistic case study is a study that focuses on a particular phenomenon, situation or event and the importance of what it reveals. A descriptive case study is a study that yields a rich thick description of the phenomenon with many variables for a longer period. A heuristic case study explains the reader's understanding of discovering new meanings of the phenomenon under the study. Therefore, I located my study in a particularistic case study because the study explored the integration of technology, pedagogy, content knowledge and the learners' mathematical competencies when sketching quadratic functions online using the GeoGebra software. The study conducted by Draves (2019) opted for a particularistic case study for the exploration of one's identity as a music educator. According to Brown (2019), a particularistic case study examines specific instances therefore, it fitted to examine the experiences of few educators regarding digitalisation.

The impact of School From Home (SFH) on primary class teachers was explored in depth by Rasmitadila et al. (2020) using a case study. Their case was to explore the perception of primary classroom educators of online learning. The study conducted by Basar et al. (2021) examined the effectiveness and challenges that online learning presents to learners' ability to learn because of its relevance to the study. A case study was used to gather rich information on how learners react and change behaviour towards the implementation of online learning. Therefore, it allowed the study to conclude that online learning was ineffective due to online infrastructures (Basar et al., 2021).

A case study conducted by Almanthari et al. (2020) focused on examining the views of secondary Mathematics educators on e-learning implementation barriers. They revealed that learners' barriers are more than those faced by educators and those that are school, and curriculum related. According to Nasir et al. (2022), a case study was

utilised to investigate readiness in the implementation of online teaching of Mathematics. In their study, Google Meet software was used to conduct the online teaching, the use of it yielded a deeper understanding of teaching delivery methods. This is supported by Yin (2003) cited in Nasir et al. (2022) that a case study is an appropriate tool that provides a deeper understanding of a case. Additionally, the result from the case study revealed that inactive learners disturb educators' emotions which results in ineffective online lessons (Nasir et al., 2022). Therefore, integrating online teaching and learning of Mathematics in rural schools needed experienced educators to perform well.

According to Rasmitadila et al. (2020), a case study unlocks the data collection instrument for relevant findings to the research question. The study by Dayal and Tiko (2020) also adopted a case study to explore how private education centres cope with schooling during the pandemic. The finding from their case study revealed the insight into the role played by the implementation of online lessons during the COVID-19 pandemic, which is that ICT enabled connection between educators and learners to their curriculum.

3.3. Sampling techniques and participants

In this study, a non-experimental design of survey research type was adopted, and non-probability sampling technique of purposive method was used to select the samples for analysis. According to Alvi (2016), sampling is the process whereby participants are extracted from a population. He categorised sampling into two broader types: probability and non-probability sampling. Probability sampling is a sample of the study such that every member can be assigned to each unit of the population objectively while non-probability is a sample that depends on a subjective decision of the researcher (Alvi, 2016). My study was not subjected on random sampling and to generalise the population therefore, non-probability sampling was convenient to the study. There are seven methods of sampling found in non-probability. The methods are volunteer, convenient, purposive, quota, snowball, matched and genealogy-based sampling. I chose purposive sampling for its benefit. It gave access to set the criteria for elements of the study. In a population, it is important to sample participants whom most can be learnt from to have an understanding of their perspectives (Merriam, 2002). The researcher selects participants that would give best responses for the

study (Bhardwaj, 2019). However, the disadvantages of purposive sampling include its ineffectiveness to be carried out to a large population (Thomas, 2022).

In addition, purposeful sampling is the process in which the researcher selects the most productive participants from the population to answer the research questions (Marshall, 1996). I, therefore, employed a purposeful sampling method for the selection of participants and Mathematics content used in the study. This was influenced by convenient permission to approach the Grade 11 learners. Purposive sampling refers to sampling that seeks out the best cases for the study conducted (Mweshi & Sakyi, 2020). It also implied that the sampled participants are related to the topic for rich data. Therefore, my study sampled the participants based on their knowledge of Mathematics and on my judgement that they provided access to the relevant information. According to Thomas (2022), it allows the utilisation of different approaches as needed for benefitting outcomes to the study. In addition, purposive sampling saves time (Thomas, 2022).

Purposive sampling was selected in a study that aimed to explore teaching and learning of Mathematics during COVID-19 using emergency remote teaching (Chirinda et al., 2021). The choice was done because the study focused on the educators who teach Grade 12 in public secondary schools. For their study, Yilmaz and Sonmez, (2022) used purposive sampling to select the participants. The reason for purposive sampling was to ensure that the participants in the study had never taken a face-to-face course during their study.

On the other hand, Merriam (2009) cited in Nasir et al. (2022) used purposive sampling in her study for its benefits and suitability for researchers who want to explore and understand a concern. The judgement of participants was based on being Mathematics rural school educators and other aspects that gave rich data (Nasir et al., 2022). My study was a case study that led to the judgement of participants from rural school for the necessary data collection.

The result of Chirinda et al. (2021) showed that the COVID-19 pandemic offered policy makers the opportunity to reshape policy frameworks concerning technology implementation. According to Yilmaz and Sonmez (2022), their participants were interested in non-educational activities in an online classroom which was a different

case in a traditional classroom. Therefore, firstly, in online learning, learners need to be engaged regularly so that they don't lose focus to the lesson as it is difficult to control what they do rather than normal traditional learning. Secondly, the emotional feeling that should be attracting attention during teaching and learning was absent (Yilmaz & Sonmez, 2022).

The study was conducted at a secondary school in Mopani District in Limpopo Province. The school had a principal, Head of Department and seven College and School educators (CS1). The school was offering the Science and Commercial stream. The enrolment at school was 245 learners, 45 learners were enrolled for Science stream and 97 learners were enrolled for Commercial stream in Further Education and Training (FET) phase. In the General Education and Training (GET) phase, we had 59 Grade 8 learners and 44 Grade 9 learners whom were enrolled for nine subjects which are compulsory by the Department's policy. The school had 15 learners enrolled for Science and 18 learners enrolled for Commercial stream in Grade 12. In Grade 11, we had 10 learners enrolled for Science and 34 learners enrolled for Commercial stream while in Grade 10, we had 19 learners enrolled for Science and 45 learners enrolled for Commercial stream. My major responsibilities at workplace included teaching Mathematics on FET phase, Natural sciences on GET phase and Sepedi in Grade 8.

The study was conducted in my Mathematics classroom at the school where I was working. The school had ten Grade 11 learners registered for Mathematics, however, the overall Grade 11 learner enrolment was 47. The choice of participants was permissible in a case study, where the case study was my Grade 11 Mathematics online classroom (Merriam, 1998). Only one learner from the Grade 11 Mathematics classroom showed no interest to participate in my study, and the other one decided to stop attending. Therefore, I had eight learners who participated in the study until the last day of attending the online lessons. The teaching of sketching of quadratic functions online took place after school.

The school had integrated less of technology for teaching and learning due to the poor infrastructure and lack of resources. In teaching Mathematics, no technology software was used and so the participants had no experience of using technology to teaching and learning in the school. My experience in teaching Mathematics from Grades 10-

12 was eight years and my highest professional qualification was BEd Honours in Mathematics Education. In my teaching experience, I had never used any application of software tools to teach, except for a non-programmable scientific calculator. However, I had a laptop that I used for my studies and for generating teaching materials.

Additionally, learners participating in my study failed to pass Mathematics test in their previous Grade (Grade 10), except for one learner who managed to score a minimum pass mark of 30% at the end of term 4 in 2021. The test in term 4 included quadratic functions that carried ± 20 marks. However, learners qualified to proceed to Grade 11 as they passed other subjects and failed Mathematics. Therefore, almost all learners had a gap in content knowledge of quadratic functions. Finally, none of the participating learners had used a computer for learning Mathematics.

3.4. Data collection procedures and methods

According to Merriam (2002), researchers in a case study utilise three data collection methods: conducting interviews, observations, and analysis of documents. The observations and interviews were utilised in my study as suggested by Merriam (2002). Question 1 and 2 focused on learners' interest of the use of GeoGebra to sketch quadratic functions. Question 3 focused on the technology knowledge in identifying the actual sketching on GeoGebra software. The focus was on challenges learners encountered in an online assessment when designing question 4. Question 5 and 6 focused on learners' experiences with the use of GeoGebra to improve their knowledge. Thus question 7, 8 and 9 focused on the recommendation and possible advice that could be given to GeoGebra software users for improvement in learning. The observations' key focus was on the content taught, knowledge of learners' learning and integrating technology with content. Additionally, it focused on teaching strategies and the technological tools used.

Data were collected from Grade 11 online classroom of 10 learners, where one did not show any interest, and the second one attended only a few lessons and stopped coming. I was involved for transmitting knowledge, in an online activity session. I conducted an orientation to assist learners on the use of computer and software implemented in learning Mathematics online. The orientation lasted for two days and

teaching and learning for an hour every day for a month. TPACK assisted in making briefed lesson observations and asking relevant interview questions

The need for learners to provide a neat sketch drove me to engage in sketching of quadratic functions using the GeoGebra software as they spend time and struggle to provide one using paper and pencil. Mathematics CAPS documents expect the FET learners to learn and investigate quadratic functions and their properties (CAPS, 2011). Therefore, teaching sketching of quadratic functions was part of curriculum. The study by Sumardi et al. (2020) used classroom observations and interviews to collect data in exploring the teaching and learning process in primary school context. I, therefore, relate my study to the methods used by Sumardi et al. (2020).

3.4.1 Availability of technology resources on research site

The bar graph below is a summary of resources available in research site. The school had five laptops and one desktop computer in the office. Of the five laptops, two were strictly reserved for school finances and the South African School Administration and Management System (SASAMS) and the remaining were for teaching and learning. I used three school's laptops and one of mine in addition to this study and sadly, there was unstable Internet connection. A free version of GeoGebra was installed on the laptops for sketching quadratic functions and Zoom for attending.

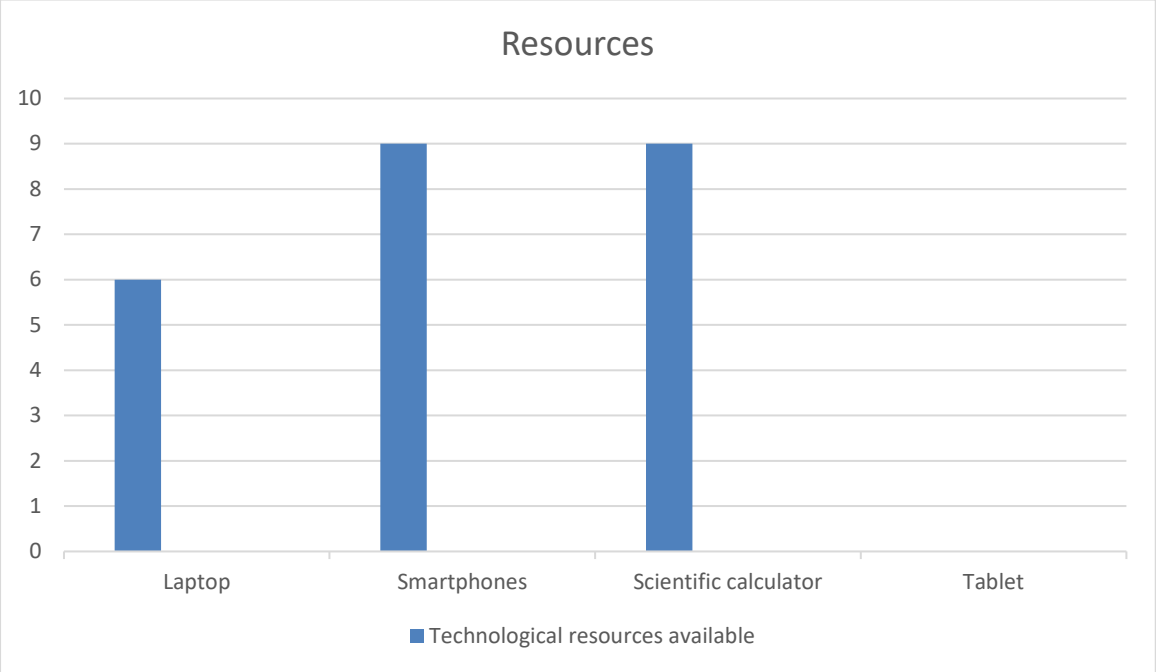


Figure 3.1. Availability of resources on research site.

However, every learner in a Mathematics classroom had a non-programmable scientific calculator, and they all had smartphones but never used any mathematics applications for learning. All the classrooms had no smart-boards connected to school laptops and desktop computer. Likewise, Onyema et al. (2020) revealed that a lack of ICT facilities and knowledge in rural schools holds back the implementation of remote teaching and learning.

According to Dube et al. (2021), it made sense in rural schools where learners are to embrace the bricolage approach for online teaching and learning. Bricolage as defined by Levi-Strauss (1966) cited in Rogers (2012) is a process of using materials and tools at hand to arrive at a solution. Due to the few laptops available in the school, this study allowed the use of smartphones as routing devices for online lessons. Therefore, learners were forced to share the laptops, when one completed the activity, the procedure was to send their work to the cell-phone, delete their work, and borrow the next learner. The disruption caused by COVID-19 in schools, especially in rural communities, should be modified into opportunities by learners (Onyema et al., 2020) and bricolage to improve their digital.

3.4.2 Application of Zoom software used

I installed a free version of Google Meet and Microsoft Teams on the four laptops available and including mine for online teaching and learning to kick start. However, a free version had limited time and access, in some instance unable to record the lessons. In the introductory lesson, we did not have the recording option and the poor response of Google Meet and Microsoft Teams. Google Meet was at first selected as a video conference platform. During data collection, Google Meet was replaced with Zoom for its accessibility and user friendliness. Reflecting on the introductory lesson, Zoom was installed to be used to conduct online lessons. Zoom allowed us to record our lessons and share other applications while on record. It was user friendly for me to conduct online lessons.

The GeoGebra software was used in Zoom lessons to teach sketching of quadratic functions. It was chosen for its ability to sketch quadratic functions and email for submitting learners' responses to the activities (Mokotjo & Makalwa, 2021). The

GeoGebra software was used to sketch the quadratic functions that represent the solutions. It brought a positive impression to learners during comparison of pencil and paper versus the GeoGebra software in a classroom that led to a huge improvement of graphic representation of quadratic functions (Amal-Palacian et al., 2022).

According to Augustina (2022), Zoom is a video chatting platform with useful features used for online lessons. Zoom is a web-based tool that provides great virtual conference and collaborative learning platforms (Serhan, 2020). According to Zulu et al. (2021), Zoom is a modern application that provides video and audio communications through cloud-based peer-to-peer software. In addition, Zoom is a free application that allows learning to take place through videos and audios (Gunawan et al., 2021). Therefore, Zoom was seen as an application that allowed teaching and learning communication by using a webcam and sound (Dharmawati, 2023).

Serhan (2020) investigated the use of Zoom for remote learning to move away from face-to-face. The benefit of using Zoom is that educators can record the lesson to self-assess their TPACK (Zulu et al., 2021). The application allowed educators to upload any material they wanted to share with learners. Augustina (2022) highlighted the useful features of the Zoom application as voice and text interaction, whiteboard, and the ability to record. The Zoom application allowed educators and learners in a long distance to carry out learning activities in an online meeting (Gunawan et al., 2021).

In addition, Zoom enhances collaboration teaching and learning (Zulu et al., 2021). Zoom can be used to record lessons to the advantage of those who missed the lesson due to connectivity (Augustina, 2022). My study also recorded the online lessons that used the GeoGebra software to sketch quadratic functions. During the pandemic era, Zoom application replaced classroom teaching and learning and improved achievement in learning (Dharmawati, 2023).

What I found benefitting and important in Hayuningtias et al. (2022), was the result that showed that the Zoom application supported the ongoing curriculum and kept the interactions amongst the participants in an online class. However, the results of Serhan (2020) revealed that instructors of online learning using Zoom were not ready for the delivery methods of technology integration.

The power cuts from Eskom were identified as a challenge that affects the smooth running of Zoom for teaching and learning (Zulu et al., 2021). This informed me that the load shedding and reduction we were experiencing in South Africa, without backup, the scheduled online learning would be disturbed. Therefore, poor network interfering with technology integration was experienced as a result of Eskom's power cuts (Zulu et al., 2021). According to Sadalla and Larocca (2004) cited in Garcez et al. (2011), video recording is appropriate for teaching practice which requires several activities simultaneously. In this context, the video recording allowed me to explore the use of Zoom and GeoGebra features related to the topic.

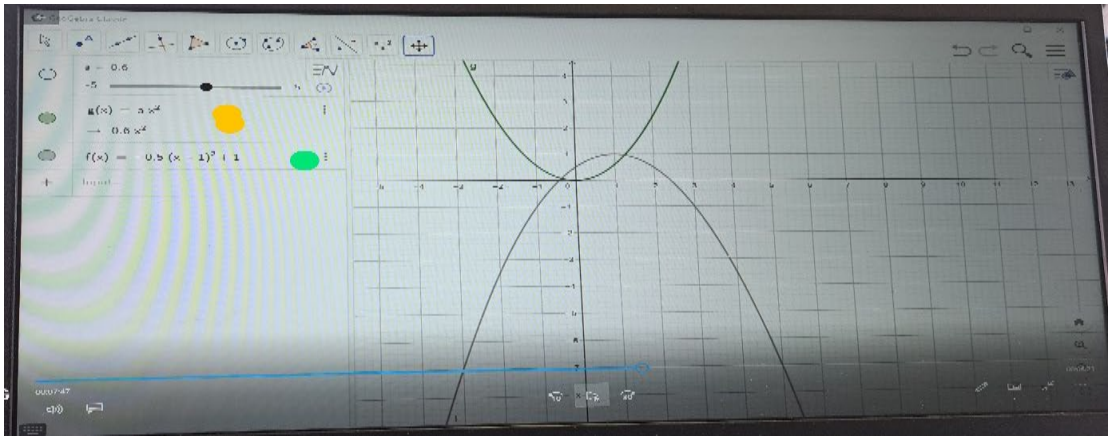
3.4.3 Topic chosen

I taught the Grade 11 functions, with a focus on how to sketch quadratic functions using GeoGebra. Each lesson was arranged for an hour for five days and comprised of one activity, to sketch quadratic functions using the GeoGebra software. However, lessons did not last for five days but overlapped for a month due to poor connectivity. Throughout the lessons, learning to assess sketching of quadratic functions took place, as I interacted with learners while responding to questions. According to CAPS (2011), the teaching of quadratic functions is assigned one week in a classroom but it is not limited to learning outside the classroom.

During teaching and learning online, lessons were prepared for five days with one activity for the lesson. However, lessons did not take five days as many challenges that arose during teaching and learning affected the progress. Activities were displayed during the lesson for discussions and interactions and at the end of the lesson for individual submissions. There was a link provided for all participants to register for attending the online lessons. However, learners used their cell-phones that I installed zoom to attend lessons, their activities were carried out using laptops. Each learner had his/her own email address to submit their work. Activities in each lesson reflected the content taught and were designed for individual work.

Lesson 1 focused on the impact of a which covers the basic introduction of sketching quadratic functions and that included the three forms of quadratic functions. I used the GeoGebra software to sketch the quadratic function and used slide a to show the shapes of the function. I explained to learners how a helped to determine the minimum and maximum values. Thereafter, the learners were expected to give a conclusion on

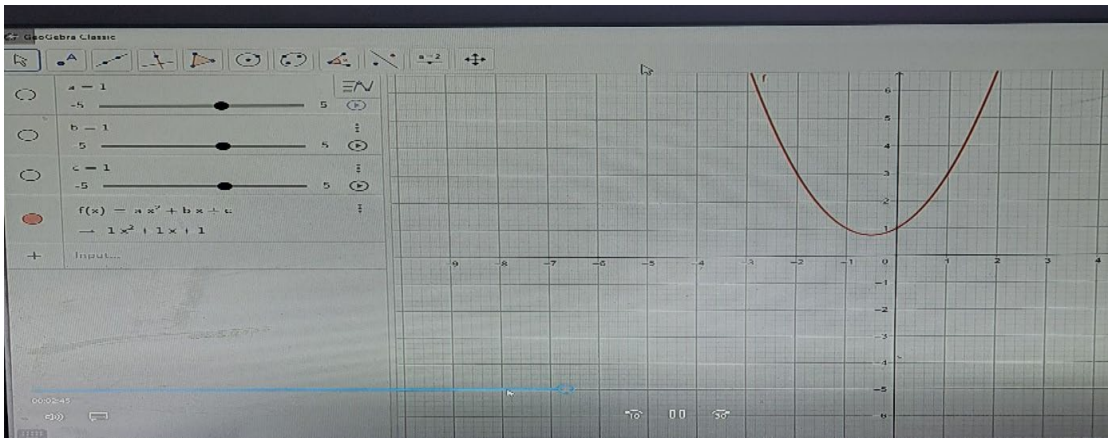
the narrow and wideness of the function as a changes. The function highlighted in yellow below had $a > 0$ and was represented by the green sketch on the Cartesian plane, while the one highlighted in green had $a < 0$ and was represented by the grey sketch.



Lesson 2 focused on the impact of $p\ and\ q$ on quadratic functions. During the lesson, I presented the quadratic function of the form $y = a(x \pm p)^2 + q$ and highlighted the effect of $p\ and\ q$ not forgetting what we had discussed about parameter a. Parameter p had to do with the horizontal shifting of quadratic functions while parameter q had to do with the vertical shift. During the lesson, we looked at the function and discussed all the effects of parameters using slides. However, I did not relate the content with real-life problems for example, finding the maximum cost in businesses and building of bridges in engineering. Therefore, it might have caused learners to learn the concept in isolation. If the engagement of the reality part was available, learners would have interacted more during the lessons.

Lesson 3 focused on the intercepts-roots and described the nature of the roots when sketching quadratic functions. During the lesson, I reminded learners about the nature of the roots in Algebra where the focus by then was not on sketching but rather was determining the nature of the roots algebraically. I presented different sketches of quadratic functions using the GeoGebra software to communicate the nature of the roots. The figure below represented a quadratic function that had non-real roots. I discussed non-real roots with learners looking at all values of parameter a. Learners appeared to understand the nature of the roots during the interaction in the lesson. However, that might not be the reality when looking at their submitted work. The figure

below represents an example of the non-real roots function discussed in the classroom.



Lesson 4 focused on the reflection of quadratic functions along the line. I used GeoGebra and sketched a basic graph that reflected along the line $y = x, x - axis\ and\ y - axis$. I showed learners how to use tools to generate a reflected sketch. All the steps were followed and repeated during the lesson to produce a reflected sketch. In addition, I explained to learners that the reflected sketches represented the inverse of the basic quadratic function. During the lesson, we worked together on the quadratic function activity of $f(x) = a(x - p)^2 + q, where\ a < 0$. The function reflected about the $y - axis$. However, that did not limit me as the educator to show learners the reflection of $f(x)$ about the $x - axis$. Learners were asked questions and responded to them during the lesson.

We experienced network challenges that affected the smooth running of the lesson. The network would just go off in the middle of the lesson and that disturbed the interaction between us. When kicked out by the network in an online lesson I and the learners kept trying to login. Some learners would end up joining later than expected and that would mean they missed out on the lesson. The activity given addressed the sketching of a quadratic function and its reflected sketch about the $x - axis$. Learners were given an opportunity to look at the activity and copy it during the online lessons. I emphasised on how they should have submitted their work.

Lesson 5 focused on symmetric lines and intersection points. I used the definition of an axis of symmetry and point of intersection as an introduction to the lesson. The lesson involved how to find the equation of the axis of symmetry and on a parabola in the two forms of quadratic functions, which were: $y = a(x \pm p)^2 + q\ and\ y = ax^2 +$

$bx + c$. On the first one, it outlined the turning point of the quadratic functions therefore, the axis of symmetry will be $x \pm p = 0 \rightarrow x = \mp p$. On the other hand, the second one is the standard form, therefore, the formula $x = \frac{-b}{2a}$ was applicable.

A link was created and sent to learners' email addresses. All learners accessed the link to login for online lessons that were conducted through Zoom. I created one link to login in all the online lessons. Learners' participation in their learning, what I was saying and how the online lesson was conducted using various applications were important in this study.

In session, the aim was to assess the content learnt during the online lessons. From these sessions, learners were assessed to ensure whether teaching and learning of sketching of quadratic functions online using the GeoGebra software has taken place. Therefore, the sessions reflected on content taught. The session comprises of an individual activity prepared to assess learners, refer to appendix A. The sessions were for individual activities wherein learners login to access the task.

3.4.1. Observations

Observation is a qualitative research method of collecting data (MacDonald, 2012). It is a rich source that captures the context of the social setting, and it gave me a broader view of what was occurring. Observational data represented first-hand experience with the phenomenon of interest rather than second-hand (Merriam, 2002). During the observations, I was the participant observer. In the study, I was required to take risks in order to gain access to understanding knowledge (Ciesielska et al., 2018). My role was to prepare lessons for online classes and teach the sketching of quadratic functions online using the GeoGebra software. I recorded the lessons through Zoom recording while presenting the lessons.

During observations, the focus was on making sense of how I used technology to teach the lesson, integrating the content of sketching quadratic functions with technology, online classroom setting, activities prepared, how learners learn and their responses to given activities. The Zoom recording option was activated to capture and focus on what was mentioned above so that the data could be later transcribed. Hence the observation schedule is attached as appendix E.

3.4.2. Interviews

An interview is a data collection technique that enables participants to describe situations regarding their experience through direct questioning (MacDonald, 2012). There was a visual individual semi-structured interview conducted after the online classroom lessons were done. I used quadratic functions as the research content of the study, with the aim to sketch graphs using GeoGebra. Then I conducted interviews at the end of the online lessons.

The purpose of this interview was to make sense of learners' experiences and acknowledgement of content regarding the learning of sketching quadratic functions online using GeoGebra. According to Dockendorff and Solar (2018), the experience of using GeoGebra increases the acknowledgement of concepts of mathematical representations for learning. Learners' experience of using GeoGebra to sketch quadratic functions enhances their mathematical competencies. Therefore, the interviews assisted in addressing the research question that focused on how to teach the sketching of quadratic functions using GeoGebra software online.

The interview consisted of nine questions. Govender (2018) used semi-structured interviews to collect data. In his study, 10 interview questions were designed but the current study designed nine interview questions that guided the interviews. I relate to their studies for the same method of collecting data however, with different participants. Furthermore, Aliyyah et al. (2020) conducted semi-structured open-ended questions to gain meaningful data.

3.5. Data analysis

Data analysis is a process that involves consolidating, reducing and interpreting what people said and what is observed by the researcher (Merriam, 1998). I used themes drawn from the theoretical frameworks. Ryan (2006) suggests that some of the themes can be drawn from a theoretical framework and organising data into themes is itself a form of analysis. The use of TPACK and Niss' mathematical competencies were to give perspectives that address the successful integration of technology. The study used lesson observations and interviews and the data was transcribed, coded and guided by TPACK. During lesson observations as learners engaged in lesson

activities, I was checking the mathematical competencies they display that are outlined by Niss (2003).

3.5.1. Analysis of data collected from lesson observations

Firstly, I listened repeatedly to the video recordings of each online lesson to get a sense of the data. Secondly, I transcribed the video recordings and read the transcribed data repeatedly to ensure that I accurately represented the raw data. Transcribed data were labelled to what is relevant such as interactions, concept opinions, misconceptions, and activities for codes. I went through all codes created to look out for the themes that emerged from the framework. I checked whether the themes emerged from TPACK indicated anything about the research questions or work in relation to data. In the lessons observed, concepts and activities were discussed which intertwined with the knowledge of the content to be taught under TCK. During the interactions, learners' use of prior knowledge to connect to new concepts was observed. The use of GeoGebra enabled participants to sketch the quadratic functions that connect to the integration of technology and content. Mathematical competencies were also observed. The use of real-life examples enhanced understanding of the concepts and the use of GeoGebra software enabled participants to respond to activities. This means that there was twining of the above with the strategies to teach using technology. The themes provided me with a coherent overall story about the data (Braun & Clarke, 2012). The analysis of data was guided by the themes that emerged from TCK and TPK of TPACK.

Themes that emerged from TCK of TPACK were: 1) Knowledge of the content to be taught (checking the indication of the necessary concepts, highlighting the lesson expectations by the educator and that given activities reflect content taught), 2) knowledge of learners' learning (observing educator's use of prior knowledge in teaching for learners to construct new knowledge and identification of errors and misconceptions learners made) and 3) integration of technology and content (checking technology tool chosen that it was relevant for sketching quadratic functions and learners' access to learning activities).

Themes that emerged from TPK of TPACK were: 1) Knowledge of strategies to teach (checking participants' learning style, educators' teaching style in an online lesson and the use of real-life situation in the lesson) and 2) integration of technology and pedagogy (observing the learning style derived by the chosen tool and that the tool is associated to given activities).

During the lesson observations, I looked for the kind of mathematical competencies learners displayed as they engaged in different activities that involved the sketching of quadratic functions using GeoGebra. The following eight mathematical competencies outlined by Niss (2003) were explored within learners' responses as they engaged with lesson activities: thinking mathematically, posing and solving mathematical problems, modelling mathematically, reasoning mathematically, representing mathematical entities, handling mathematical symbols and formalisms, communicating in, with and about Mathematics; and making use of aids and tools.

3.5.2. Analysis of data collected from interviews

The recorded individual semi-structured interviews were analysed. Firstly, I transcribed the recordings of the interviews and familiarised myself with the transcripts by reading very carefully line by line. The transcribed data were labelled as to what was relevant such as concept opinions, misconceptions and activities for codes. I went through all codes created to look for themes that emerged from the TPACK theoretical framework. I checked whether the themes signalled anything about the research questions or work in relation to data. Learners' responses on question1, 6 and 9 correspond with the integration of technology and content whereas question 2 and 7 intertwined with the content taught. The responses on question 3, 4 and 8 were connected to the integration of technology and pedagogy. Looking at question 5, responses of the data linked to content taught. Therefore, the analysis of data was guided by these themes that emerged from TPACK.

3.6. Quality Criteria

According to Korstjens and Moser (2018), quality criteria is a criterion that is used to justify the superiority of a qualitative study. For the findings to be trusted, I ensured

trustworthiness of the study by maintaining credibility, confirmability, and transferability (Korstjens & Moser, 2018).

3.6.1. Credibility is a way of ensuring that findings are correctly interpreted and represented what is drawn from the participants' data (Korstjens & Moser, 2018). Lincoln and Guba (1995) as cited in Henry (2015) suggest member checks whereby data interpretations and conclusions are tested with participants to establish credibility. For member check, I reflected on the recorded online lessons and recorded interviews with participants to confirm what transpired during the lessons. The participants' responses to activities were received through email to ensure originality. The recorded online lessons were kept for a re-visit.

3.6.2. Confirmability concerns the aspects of neutrality whereby the findings are reality derived from data (Korstjens & Moser, 2018). The consent form was attached to confirm the accuracy of the meeting before they participated. The themes emerged from the identified framework were used for analysing the data. Finally, the recorded lessons reflected the research materials and resources used (e.g. GeoGebra). This was also done for participants' responses to activities, and I discussed how data analysis was done. Therefore, the findings were derived directly from data and guided by the role of the chosen theory.

3.6.3. Transferability concerns the aspect of applicability (Korstjens & Moser, 2018). My study was conducted in a small school found in the rural area of Mopani District in Limpopo Province. The study conducted purposeful sampling due to the number of learners doing Mathematics in Grade 11. The school had 10 leaners doing Mathematics but only eight participated in the study. Online lessons were recorded, and the mathematics topic chosen was functions (sketching quadratic functions). I conducted the study at my workplace (school).

3.6.4. Dependability aims at checking whether the analysis process matches the standard of the design (Korstjens & Moser, 2018). The raw data in the form of videos, audios and scripts were accessible to the supervisor. The transcripts' notes for raw data and paragraphs merged for themes were used in the research. The recorded lessons and interviews were kept /saved on Google Drive with password access.

3.7. Ethical consideration

Qualitative researchers need to eliminate the sense of insecurity in human by planning their studies within the moral bounds (Wa-Mbaleka, 2019). In South Africa, we live in a constitutional democracy with the Protection of Personal Information Act (POPIA). This study was conducted ethically so, that was the reason I considered the following:

3.7.1. Permission to conduct the study

I applied for ethical clearance from the Turfloop Research Ethics Committee and the Limpopo Department of Education Ethics Committee and it was granted (refer to Appendix F). The permission from school management team where the study was conducted was sought (refer to Appendix C) and granted.

3.7.2. Informed consent

I invited parents of Grade 11 learners and explained the reason behind the invitation. The parents and learners were informed of the purpose of the study. I made sure that they understood what the consent form entailed and outlined the data collection process and how learners were going to participate. Thereafter, I issued the informed consent forms to parents agreeing (refer to Appendix D). I asked them to fill and append their signatures. Learners were also requested to fill assent forms (refer to Appendix D)

3.7.3. Voluntary participation

Participants were informed that participation in the study was voluntary, and they were allowed to withdraw their participation whenever they felt to do so. One learner did not participate and the other one decided to stop attending. The two learners' decisions did not affect our relationship in their learning.

3.7.4. Anonymity and confidentiality

I reassured participants that their names and that of their school were not mentioned, as only numbers were assigned to them to ensure anonymity. Participants in the study were 8 learners and myself. Participants were coded as Learner 1 to Learner 8. I applied coding to protect participants' real names in the study. The information used in the study was kept safe in a locked device. I also explained that the confidentiality of the data was maintained and accessible only to the researcher and the supervisor of the study. However, the findings were made accessible by everyone.

3.7.5 Risks and benefits

There were no financial benefits attached to the study. However, participants could benefit from the concepts involved by improving their understanding of the sketching quadratic functions. Only minimal risks were attached to the study and were less than what the participants encountered in their lives. The study had educational goal to achieve, therefore interactions of participants resulted to minimal risks.

3.7.6 Data Protection

Cyber-security software was installed on computers and participants' cell phones for information security. For online lessons, a link was created and sent to participants only. I allowed only participants to access online classroom. Data collected were stored in a Google Drive that was password protected.

3.8 Chapter conclusion

This chapter explained the research approach and design of the study. It described the sampling techniques and participants. It also outlined data collection procedures and methods that covered the resources available for online lessons, application of Zoom software used, and sub-topics chosen for lessons. The chapter also described data analysis, qualitative criteria, and ethical considerations of the study.

CHAPTER 4: FINDINGS AND DISCUSSIONS

4.1. Introduction

This chapter presents the findings and discussions. Deductive thematic data analysis method was used guided by the theoretical frameworks of TPACK and Niss' (2003) mathematical competencies. TPACK as the umbrella framework had the capacity to control the selection of data. The transcripts included educator and learner interactions during the lessons. Lesson activities and learners' responses are presented using figures. I present the concluding thoughts of results from data collected from lesson observations. The chapter concludes with a presentation of data transcription from participants' individual interviews in table form and interpreted the responses information guided by TPACK.

4.2. Analysis of data collected from the lesson observations

The motive of video analysis was to explore the actual practice of teaching the sketching of quadratic functions and identify the integration of technology, content, and pedagogy. The analysis of each sampled lesson recording was structured by the observation instrument. The instrument was structured into two categories of knowledge which reflected the online teaching of mathematics. Analysis was guided by themes that emerged from TCK and TPK of TPACK theoretical framework.

Observation Schedule/Instrument

Type of knowledge	Function
Technological Content Knowledge (TCK)	Able to develop the necessary technological tools for a chosen content. Knowing the necessary concepts from CAPS that link with the use of technology.
Technological Pedagogical Knowledge (TPK)	Understanding how the chosen technological tool can change the teaching and learning methods. Able to use teaching strategies that enable the technological tool to associate with given tasks and real-life situations.

Table 4.1. Observation instrument

Below is a summary of the themes that emerged from TCK and TPK of TPACK that guided the study. Brief detailed has been presented in chapter 3. The themes in 4.2.1. were derived from observation instrument of TCK while those in 4.2.2. were derived from observation instrument of TPK.

4.2.1. Themes that emerged from TCK of TPACK

Figure 4.1 represents themes that emerged from TCK of TPACK. Transcripts and learners' responses to activities were analysed guided by the three themes emerged. Mathematical competencies displayed by learners were identified from data presented.

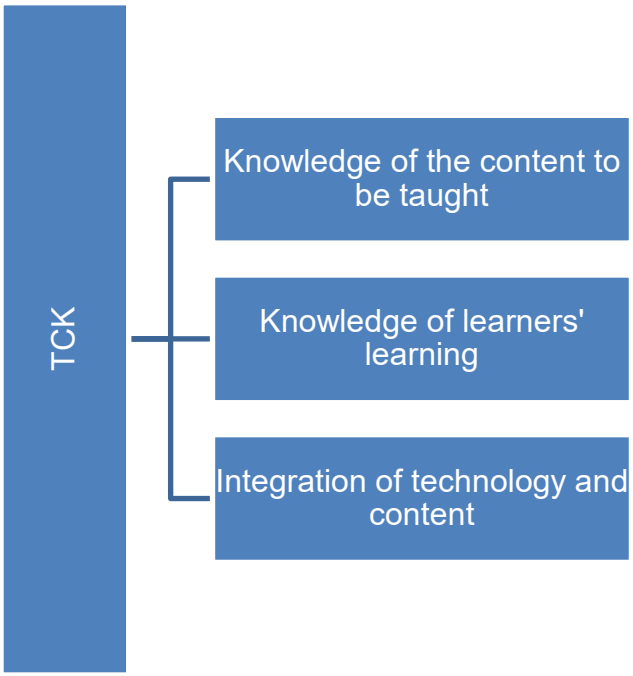


Figure 4.1. Themes that emerged from TCK.

4.2.1.1. Knowledge of the content to be taught

The focus of lesson 2 was on the effect of $p\ and\ q$ when sketching quadratic functions using the GeoGebra software. I introduced the lesson by testing learners on prior knowledge of the concepts to be taught. Learners were taken through a few examples during the lesson. The lesson was clear on how learners move $p\ and\ q$ using the

GeoGebra software to see the horizontal or vertical movement. The influence of $p\ and\ q$ using sketches on GeoGebra and my voice in the lesson was emphasised. The lesson was accurate according to the CAPS (2011:12), “generalise the effect of parameter which results in horizontal shift and stretch”. I thought that it was important to show learners practically how to type quadratic functions and move parameters on the GeoGebra software than simply writing on the lesson plan. I referred to the lesson plan when preparing the lesson on teaching the sketching of quadratic functions using the GeoGebra software. Although, most concepts were not indicated in the lesson plan, the presentation on the GeoGebra software was accurate when associated with the aim and topic that reflected in the lesson plan.

In lesson 2, the focus was on the reflection of the quadratic function about a line. Learners were assessed on the reflection of point and quadratic functions about $y = x, x - axis\ and\ y - axis$. The steps to be followed to find a graph of the reflection was not indicated in the lesson plan, although during the presentation they were demonstrated. Indication of all the concepts and steps of how to use the GeoGebra software to teach the content would have helped me when preparing the lesson to design the relevant teaching strategy. Lines 84 to 86 below showed how I demonstrated the steps for sketching the reflection of a quadratic function using GeoGebra.

Extract 1 from lesson 2

84. Educator: okay. Am going to go to the toolbar on top here. Look at the toolbar. Okay, allow me to do this. On the toolbar I'm going to choose this one here number 3 from the last. Then reflection about a line. Now I’m going to indicate the same point we talked about. Look at the point. Now are you able to see the point?

85. Learners: Yes.

86. Educator: okay. We want the reflection of this point along the line. So this is what we are going to do. We click the point. Then, we click the point of reflection. Oh, let me do this… So, I’m going to look out for the reflection of this point along the x-axis. Then, I’m going to click the line that is… Then, you can see what will happen. You click what you are looking at, and which line you want the object to reflect along. So, I click A as a point then, I want A to reflect along the x-axis. Then, I will click the line which is called the x-axis then this is the new point.

The lesson addressed the objectives of this topic. It was explained how a affected the quadratic function and elaborated on the GeoGebra software, how the sketches look like as a changes. Secondly, p was discussed as the horizontal shift of the quadratic functions. Lastly, q was discussed as the vertical shift parameter. I engaged learners on different quadratic functions which reflected different values of $a, p \; and \; q$ on the GeoGebra software. Below are samples of quadratic functions.

Extract 2 from lesson 2

23. Educator: Because it's not only p that brings changes in our function. We also have we a q, the effect of q on a function. We need to understand that we have a, p, q those are the parameters of a parabola that bring changes to the graph.

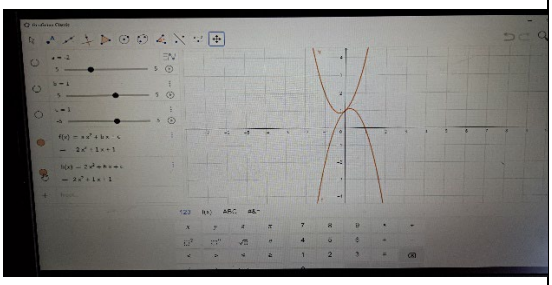
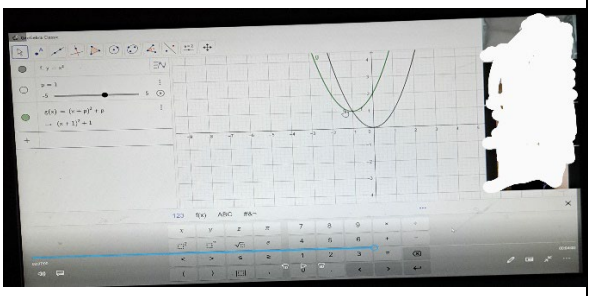
$f(x)\ shows\ a = 2\ and\ g(x)\ shows\ a = -2$	$f(x)\ shows\ p = 0\ and\ g(x) shows\ p = 1$
	

Table 4.2. The effect of parameters.

Specifically in the lesson plan, I indicated and explained how $p \; and \; q$ affected the graph moving from the basic quadratic function. The knowledge of teaching sketching of quadratic functions using the GeoGebra software online was adequate since the observations revealed the use of this software. Therefore, it implied that knowledge of the content was not lacking in the presentation of the lesson. Furthermore, a whiteboard on Zoom was used to summarise the effect of $p \; and \; q$ as their values change. The arrows on the whiteboard interface depicted the direction at which the graph will shift depending on the values of the parameters.

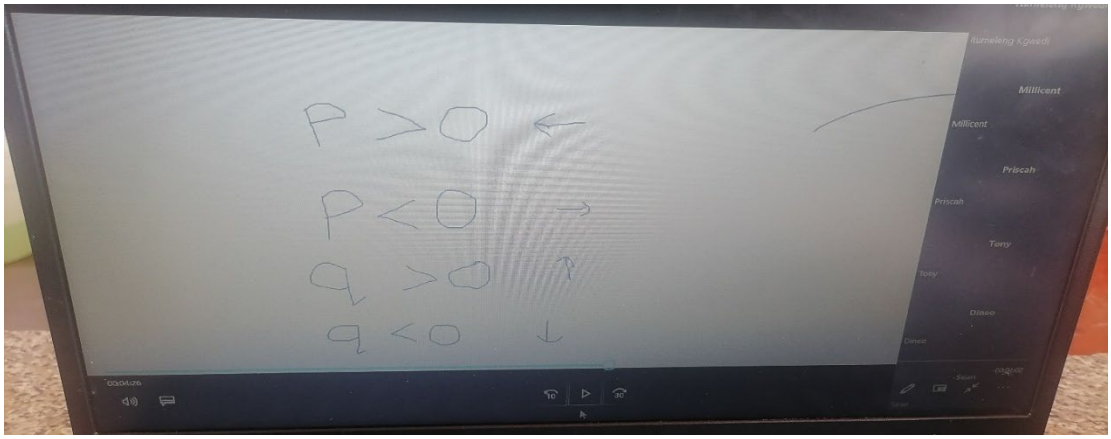


Figure 4.2. The use of a whiteboard in lesson 2.

In lesson 3, the objective was on the intercepts-roots of the quadratic function drawn using GeoGebra in an online classroom. The lesson started by revising with and reminding learners about the previous lesson which was linked to the current lesson. The screen reflected different quadratic functions showing the nature of the roots and identifying the roots. Then, I introduced the y-intercept of the quadratic function. This was followed by the roots/ x-intercepts to identify the coordinates in point form. Learners were asked to look at the graph and identify the roots of the quadratic function. Therefore, the lesson reflected the necessary content of the topic.

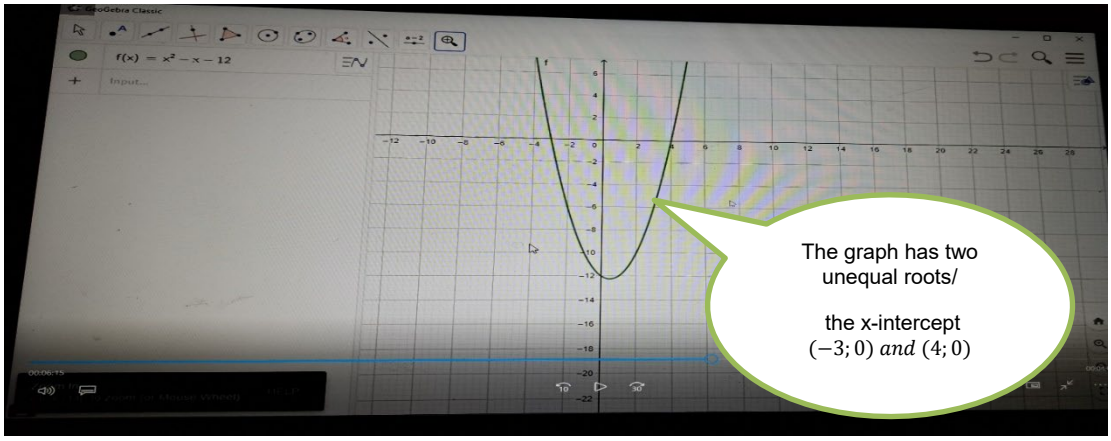


Figure 4.3. Example from lesson plan 3

Figure 4.3 above showed that the lesson plan prepared reflected on the necessary content of quadratic function: x-intercepts/roots of a functions. I introduced the nature of the roots so that the learners could understand the roots of quadratic equations as to whether they were real or non-real. It was clarified what real and non-real meant on a sketches of quadratic functions.

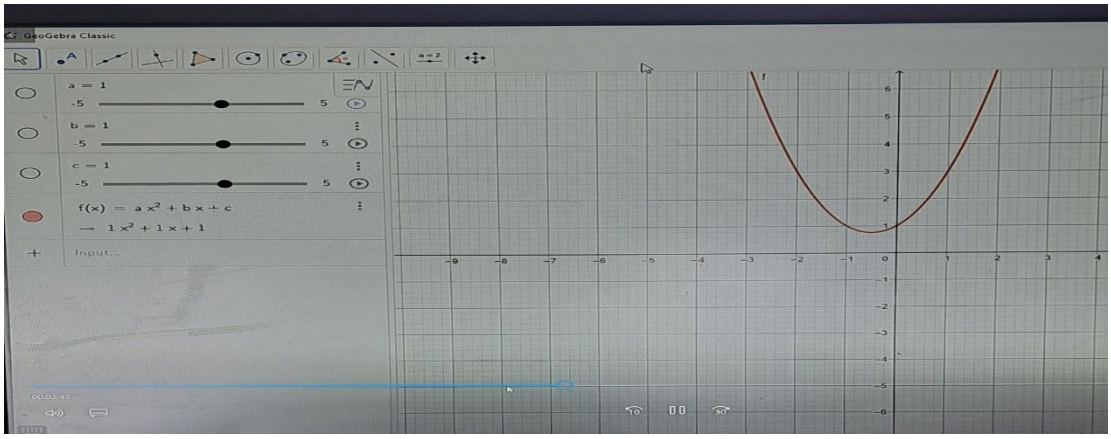


Figure 4.4. Sketch of a quadratic function from lesson 3.

In addition, during the lesson, the GeoGebra software was used to present the lesson which aimed at sketching. Figure 4.5 above from lesson 3 was a presentation of the lesson that reflected the necessary content of the topic. I sketched quadratic function $f(x) = x^2 + x + 1$ which is a parabola and asked learners to identify whether the quadratic function has real or non-real roots. Learner 2 answered the question "the roots are non-real", because learners have seen it on the GeoGebra screen that the graph has not touched the horizontal line (x-axis) as it was explained in the process of teaching.

Extract 3 from lesson 3

35. Educator: oh what I did here was to type quadratic equation with the value of $a = 1, b = 1\ and\ c = 1$. *Then we can move around with the values of* $a, b\ c$. *We can just change and see what we have but now with the one that we have what will be the y-intercept of this function? Do we have Learner 8 in this class? What will be the y-intercept Learner 2?*

36. Learner 8: $y = 1$

37. Educator: thank you. Look at this diagram at this point here, this is where we call the y-intercept. That is where the graph meet the vertical line. So now do we have the x-intercepts of this graph?

38. Learners: no

39. Educator: it means the roots are what?

40. Learner 2: the roots are non-real.

However, there was no link to the lesson with the use of the formula $\sqrt{b^2 - 4ac}$ to identify whether the roots of quadratic functions are real or non-real. The formula is related to the standard form of quadratic functions $f(x) = ax^2 + bx + c$. This was the case as the focus of the study which was on the sketching of quadratic functions using GeoGebra.

In lesson 4, the objective was on the reflection of a quadratic functions along the $x - axis, y - axis \; and \; y = x$. In the extract below, I was trying to be clear about the concepts during the introduction of the lesson. Learners were taken through prior knowledge about reflection. This shows that once learners can understand the reflection of a point, it enables them to move from point and its reflection to quadratic functions. As a result of representing mathematics entities, learners were able to communicate in and about mathematics. In every lesson, I had an introduction to the specific topic for the day. Although it took time to introduce and go through the designed content due to the network, I ensured that what was planned in the lesson plan was covered followed by the activities. Government needs to revise the learning methods due to the pandemic and address the poor network infrastructure (Noor et al., 2020).

Extract 4 of lesson 4

31. Educator: *Thank you. Right. Eh from the previous Grade we talked about ... From the previous lesson ... Sorry we talked about the effect of* $p \; and \; q$ *and we did an activity for that. So, in today's lesson, I want us to talk about the reflection of a point or the reflection of a quadratic function. Actually, we are going to focus more on the reflection of a quadratic function, but I have to take you back to the previous grade and talk about the reflection of a point. This reflection will be a reflection along a certain line. It might be the line called* $y = x$*, which is just the straight line, or it might be the x-axis or the y-axis line. Am I audible enough? Can you hear me, guys? Hello. Are you able to hear me?*

The activity carried out in the classroom addressed the content taught. In the lesson plan, there was a class activity and an individual activity. I wanted to give learners time to discuss the concepts among themselves and a few minutes later share their views. The assessment helped me to gauge how and what learners benefitted regarding the concepts of the effect of parameters $p \; and \; q$. The individual activity had clear

instructions on what to do to sketch the quadratic function and what to observe after the graph had been sketched.

The figure below shows the activity that was given to learners after the completion of lesson 2 and sampled response of a learner. I approached the activities as they appeared in the lesson plan. The first activity in this lesson was for classroom discussion and the last one was for individual submission. Learners collaborated for a few minutes and were allowed to share their findings in the first activity. I ensured that teaching and learning took place as learners managed to answer the first activity under her supervision. Lastly, the individual activity required learners to use GeoGebra to sketch the quadratic functions and observe the effect brought in by $p\ and\ q$.

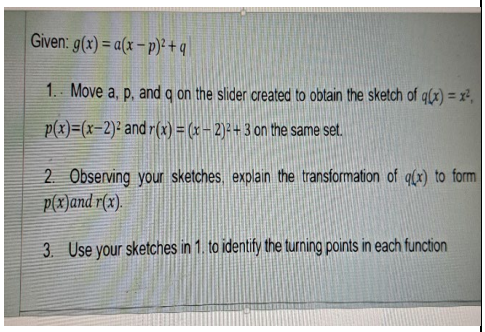
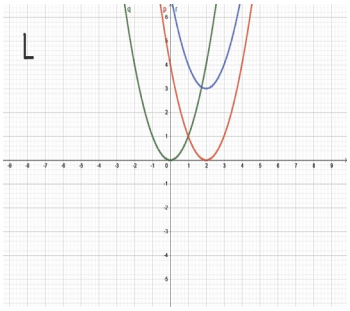
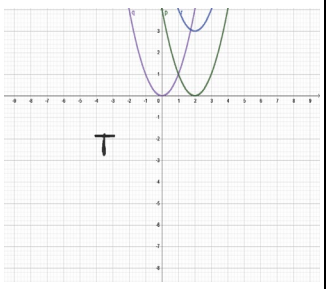
Lesson 2 activity	Learner' response	Learner' response
		

Table 4.3. Lesson 2 activity with sampled learners' response

Immediately after examples and activity were done together with the learners, they were given an individual activity with three questions to solve using the GeoGebra. The questions of the activity were read to learners and were asked if there were any clarity-seeking questions regarding the lesson as a whole.

In lesson 3, the focus was on sketching quadratic functions using GeoGebra to identify the nature of the roots and the coordinates. Therefore, the figure below shows the activity that was given to learners to write and submit.

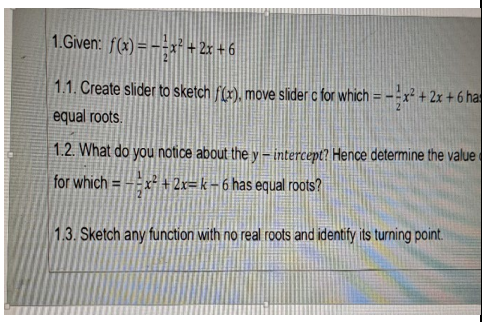
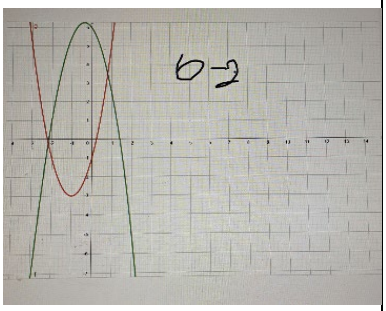
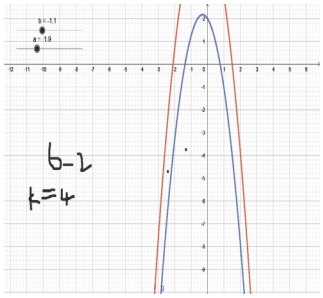
Lesson 3 activity	Learner' response	Learner' response
		

Table 4.4. Lesson 3 activity with sampled learners' response

Lesson 4 activity that was carried out to reflect what had been taught in the online classroom is shown below with sampled learners' responses. The instruction was clear as learners knew that they had to use the GeoGebra software in sketching quadratic functions and Microsoft word software to type in what they noticed. Learners were to plot a point on the Cartesian plane and label it A. On the tool bar of the GeoGebra software, there is a tab named "Reflect about a line" that they were supposed to click on. Therefore, the reflection of the point along the line chosen will appear. Similarly, you typed the quadratic function and enter the button for $f(x)$ to appear on the Cartesian plane. Click the function on the Cartesian plane and go to the tab named "Reflection about a line" then click the line you want the quadratic function to reflect about. The sketch of the reflection graph will also appear on the Cartesian plane.

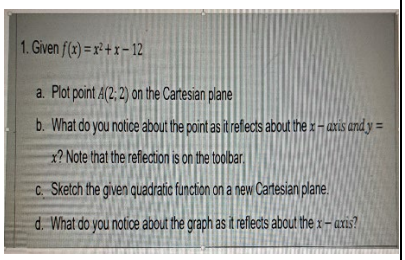
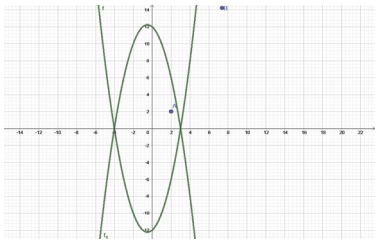
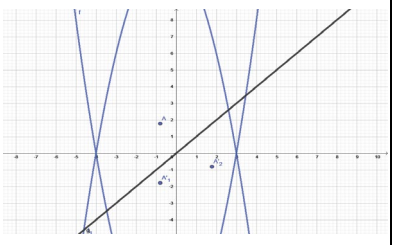
Lesson 4 activity	Learner's response	Learner's response
		

Table 4.5. Lesson 4 activity with sampled learners' response

The solution to this question was fixed as learners were given quadratic equation to work with. The expected solution was the only answer to the question. Hence a learner might have his/ her quadratic function with a correct image that reflected about the $x -$

$axis$. Now we look at what competencies learners applied when responding to the above-mentioned questions in activity 4. As mentioned in the literature, one question cannot address the whole eight mathematical competencies (Niss, 2003). It depends on the set of questions for learners to develop certain mathematical competencies. However, some mathematical competencies come after the other. For example, a learner must be able to think mathematically and generate a statement thereafter, reason mathematically to substantiate the statement. Therefore, below are the learners' responses:

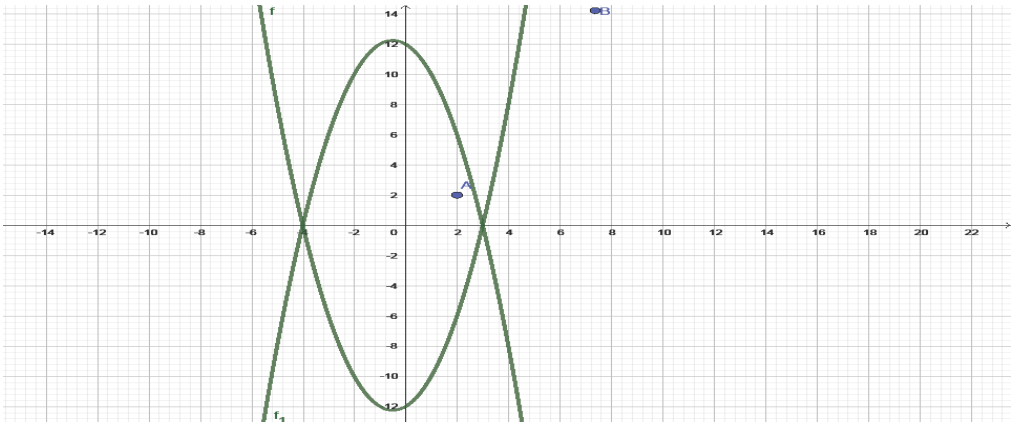


Figure 4.5. Learner 3's response to lesson 4 activity.

Learner 3 in the above response was sketching quadratic function $(x) = x^2 + x - 12$ and sharing what he had noticed as the sketch reflected about the $x - axis$. The sketch of $f(x)$ is correct and it is inverse along the $x - axis$. On the sketch of $f(x)$ we saw that the graph had $y - intercept\ of\ (0; -12), x - intercepts\ of\ (-4; 0) and\ (3; 0)\ and\ lastly, the\ turning\ point\ of\ (-\frac{1}{2}; -\frac{49}{4})$. On the reflection of $f(x)$ about the $x - axis$, we saw that the shape has now changed, and the graph is facing downwards. It related to the first lesson where the effect of a on quadratic function was addressed. The shape symbolises that a is negative and therefore, the equation of the new graph which is the reflection of $f(x)$ about the $x - axis$ is now $f_1(x) = -x^2 - x + 12$. Learner 3 did not write the new equation of quadratic function. Maybe it would have been that the question did not specifically require it. Furthermore, the reflected sketch had $y - intercept\ of\ (0; 12)\ and\ x - intercept\ of\ (-4; 0) and\ (3; 0)$ same as the given quadratic function $f(x)$. Lastly, the turning point of $(-\frac{1}{2}; \frac{49}{4})$.

It can be understood that the learner was able to think mathematically to handle mathematical symbols that resulted in representing quadratic equations graphically, not forgetting that using the GeoGebra to sketch quadratic functions enabled the learner to manage tools that were in the application. Lastly, by responding to the activity correctly, the learner was able to communicate the language of Mathematics in his writing.

However, the last question of the activity was not necessarily looking for the sketch as the results but reasoning to what the learner observed after reflection. The learner wrote “D, the value of x-axis will change and became negative”. As a result of working with reflections, the learner was unable to reason what was observable. Thus, using the GeoGebra in this case directed the learner to the change in shape, turning point and intercepts. The learner would have addressed the question in relation to what was just mentioned. What would have made it difficult for the learner was that the concept of reflection of the quadratic function is introduced in Grade 11.

Mathematical modelling was not addressed by any of the questions in activity 4. It would have been how I presented the lesson that resulted in her not making any relation between the content to the real-world situation. Therefore, this revealed learners’ conceptual understanding of quadratic functions and their reflections.

During the lesson, what is expected of the learners from the lesson was not fairly outlined. Outlining the expectation of the lesson would have resulted in learners knowing and understanding what was expected of them as they were learning. This type of negligence appeared to have caused confusion in learners’ learning. Again, it was not easy to monitor learners’ full involvement during the lesson. Cameras were off to allow the smooth running of the presentations. Looking at that, it might be the learners took advantage that they were not seen by their educator. Knowing what was expected of one as a learner might encourage learners to use the prior knowledge in building a new one. This resulted in less effective online learning of sketching quadratic functions using GeoGebra. However, I would have thought that the aim of the lesson covered what was expected of learners as it stood for the focus of the lesson.

I discussed participants’ experience with the use of technology. The study aimed to exhibit the nature of quadratic functions on GeoGebra through online classrooms in a

rural school. It is expected that participants have no experience with the use of technology in their teaching and learning. Poor infrastructure and network connectivity in rural schools resulted in limited knowledge and experience in technology. Participants were able to send and receive information through email before they could start with the online lesson.

Participants used email addresses to receive a link to the online classrooms and send their solutions to the activities. Before the online lessons could start, I took learners through orientation to the GeoGebra software. In this study, the learners were using the GeoGebra software for the first time to respond to online activities. This might have resulted in the errors the learners made in responding to the activities such as; inserting wrong values of parameters and choosing wrong option for reflection on the tool bar.

Some learners might have forgotten which tool bar to use or how to type in a certain function when responding to the activities. In the figure below, it appeared that the learner 8 was able to plot the given point and sketch the parabola (green colour). These two were well captured as solutions to lesson 4's activity $a. and\ b$ and enabled the learner to proceed in determining the reflection and explain what he noticed. Refer to figure below a learner's initial attempt for point B (reflection of A on learner's response) indicated that he tried to use his knowledge of reflection on the GeoGebra. The learner was able to handle mathematical symbols and formalisms and make use of aids and tools. However, this knowledge was irrelevant to the questions.

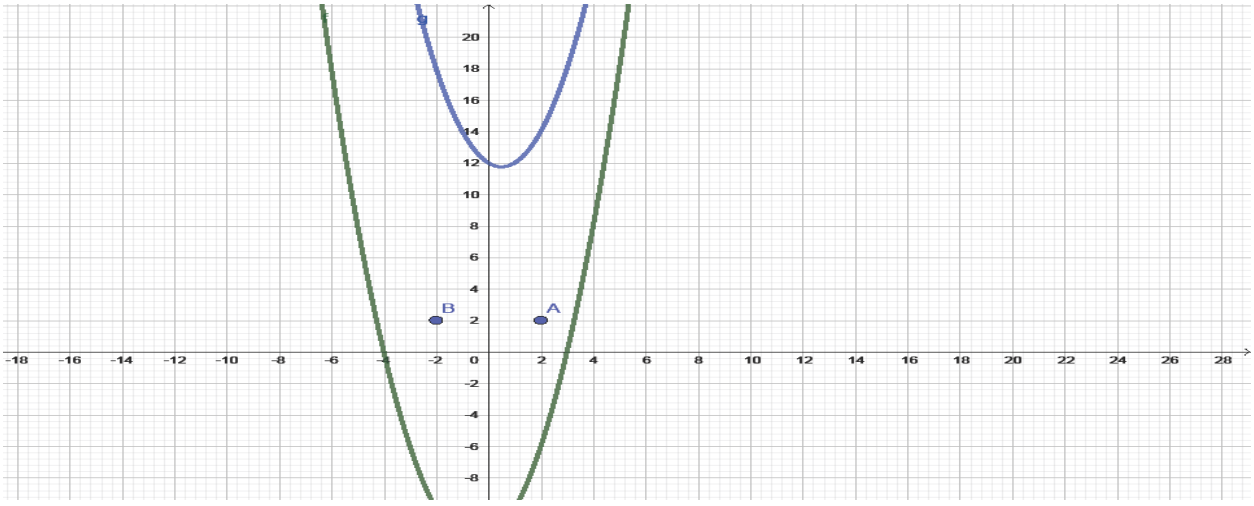


Figure 4.6. Learner's response to activity 1 of lesson 4.

The learner could have clicked the wrong line of reflection after using the correct tool bar for reflection. Through online classroom, learners were able to sketch quadratic functions using GeoGebra. Learner 8's difficulty to sketch the reflection of a parabola along the given line might be the result of limited experience with the technological tool. The figure below showed the results for question 1.2 of the lesson 3 activity. Looking at leaner 8's response to the question, he seemed to have forgotten how to move slider c for the graph to have equal roots, simply implying that the graph had only one x-intercept which would also be the x-coordinate of the turning point. The learner found that $k = 4$ which would result in the y-intercept of $(0; 2)$. Therefore, the learner lacked the experience and knowledge to use technology in answering the question.

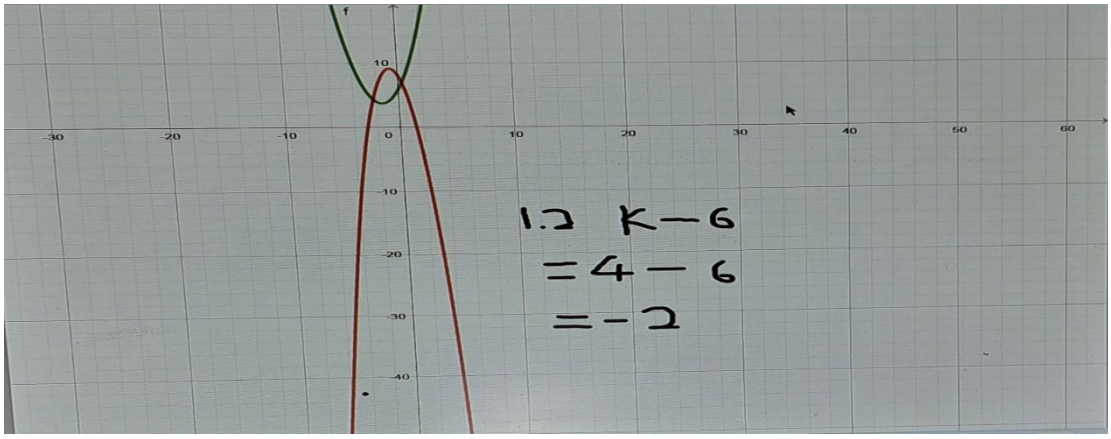


Figure 4.7. Learner 8's response to lesson 3 activity.

The learner was able to make use of aids and tools of GeoGebra to provide a quadratic sketch. However, what was drawn was not answering any question. Looking at $f(x)$, it did not represent equal roots rather sketch with non-real roots. That was supposed to be answering the last question of the activity. Maybe the learner confused the labelling, he was doing all that to answer the last question. The mathematical symbols were handled properly to present quadratic functions however, the learner failed to communicate mathematically to the given statement. Again, it might be that the learner would have thought that labelling was not important in that activity. Hence what was visible matters to the educator to relate to the questions. The function in red colour drawn by the learner did not represent any question. But the sketch of quadratic function showed two unequal roots. The learner might have misinterpreted the content and this error appeared. Sometimes a learner might be too excited for exploring new

things and neglect the main aim of the lesson. On the other hand, I might have not emphasised a lot on the content and gave less exercise during the lesson. Due to many challenges faced during the lessons that could have contributed to limited time of interaction in an online classroom.

During lesson observations, not all the tool bars of the GeoGebra software were used in one lesson as each lesson required specific use of certain tools. It might suit to say all tool bars were supposed to be engaged to alert learners which ones were or were not of benefit to sketch quadratic function. I should have thought that it was important to focus only on tools that would be used to sketch quadratic functions. Such an act could result in learners getting confused when opening incorrect tool bars as they never had seen them before. Using the Zoom platform for online lessons was new to all the participants. The learners learnt the basics during the first lesson, camera and microphones used for effective interactions. As I was preparing the lesson, I learnt that there was a recording option, sharing of documents and few other basic options. During the observations, learners' participation was limited. In addition, there were no breakout rooms created to keep learners engaged. If my experience with the use of Zoom was adequate, I would have observed much of learner engagements in their learning. Furthermore, the teaching methods would have shifted from lecture and demonstration to learner-centred methods.

Results from observation showed that I might have experience with the use of technology. During the online lesson, there was sharing of other applications which did not seem to be a problem to demonstrate them. However, the network was sometimes delaying the process of switching from one application to another while online. Participants found the use of Zoom friendly, such as when to use microphones and cameras. My presentation of the lesson using GeoGebra to sketch quadratic functions seemed effective towards the chosen technology tool that on the other hand limited learners' participation in the lesson

Learners' challenges in articulating the GeoGebra language to sketch quadratic functions might have resulted from poor school technological resources and the individual's inability to use the technology devices available to them for their learning. All software applications used by the learners during their online lessons were new to all of them. This implies that learners were having limitations to move beyond the

sketching of quadratic functions due to insufficient technology knowledge. As lessons unfolded, their experience towards working with the tools of the GeoGebra software improved. The use of the GeoGebra software to sketch quadratic functions improved the participants' computer skills (Misini & Kabashi, 2021). The opportunity to use smartphones for educational purposes improved the learners' study methods and their interactions with the content. According to Onyema (2019), the integration of technology in education is growing fast.

4.2.1.2. Knowledge of learners' learning

Sketching quadratic function addressed different concepts that integrated with sketching such as interpretation and equations. I controlled the attendance of learners in every lesson but, network connectivity was disappointing sometimes. Attendance acknowledgement was done at the beginning of the lesson. As a result of poor connectivity, some learners would joined the lesson a few minutes late. I also experienced poor connectivity wherein I would present the lesson a few minutes later only to find that I am out talking alone. Sometimes we had to wait for a few minutes for the presentation on the screen to be visible. Again, I had to repeat what I said to ensure that the learners did not miss any information for them to construct knowledge and respond to activities. Lines 105-112 from extract 5 highlighted how network connection affected the online teaching and learning processes.

Extract 5 from lesson 2

105. Educator: thank you, that is correct. The middle sign… (lost connection) We are going to have the graph shifting to the left and if it shifts to the left it means… (lost connection) Is it clear?

106. Learners: yes.

107. Educator: do we…

108. (lost connection)

109. Educator: welcome back, yeah network is giving us problems, every day we just have to be patient. So, now, I will go back to the activity, eh allow me to share my screen. Okay, can you all see my screen?

110. Learners: no.

111. Educator: okay let's just wait for a moment; I think it will just popup. Let me know if you see something.

112. Learner 3: yeah now we can see.

Sumardi et al. (2020) viewed teaching as a process to enhance learner-centred classrooms that contribute to learners constructing knowledge on their own. Therefore, as the learning process occurs, learners would demonstrate their mathematical competencies. During the process of teaching and learning in an online classroom, I interacted with the learners by asking those questions. The learners responded to the questions posed as they interacted in the classroom. Moreover, I gave learners an opportunity to discuss solutions among themselves and report back during the lesson. At the end of the lesson, I presented the activity and made sure that each learner knew my expectations.

In session 1, learners were given activities about quadratic functions. Here learners were to explore the effect of b and to reason about the shape after slide change.

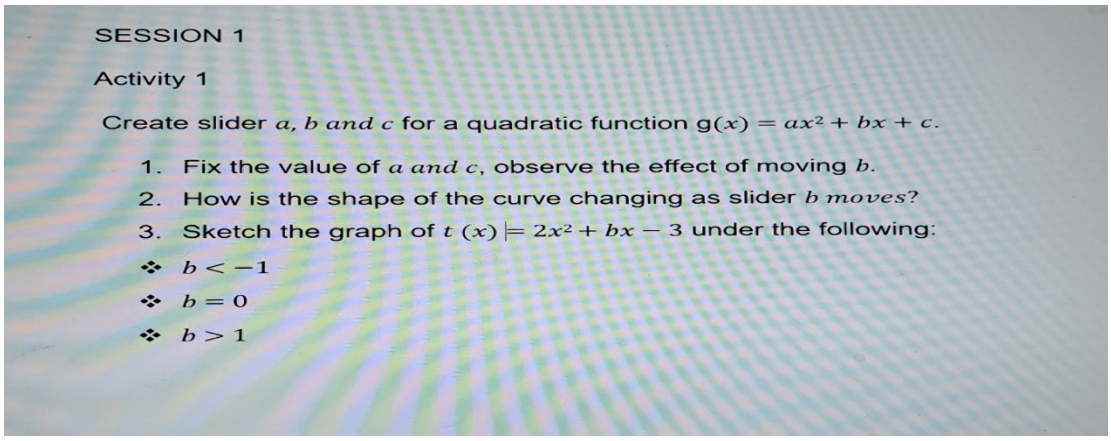


Figure 4.8. Session 1 activity

The learners responded to all questions in activity 1 of session 1. However, I analysed question 3 as the main concept in the study. Learning activity required learners to sketch quadratic functions under the given conditions. Learners' responses from activities were as follows:

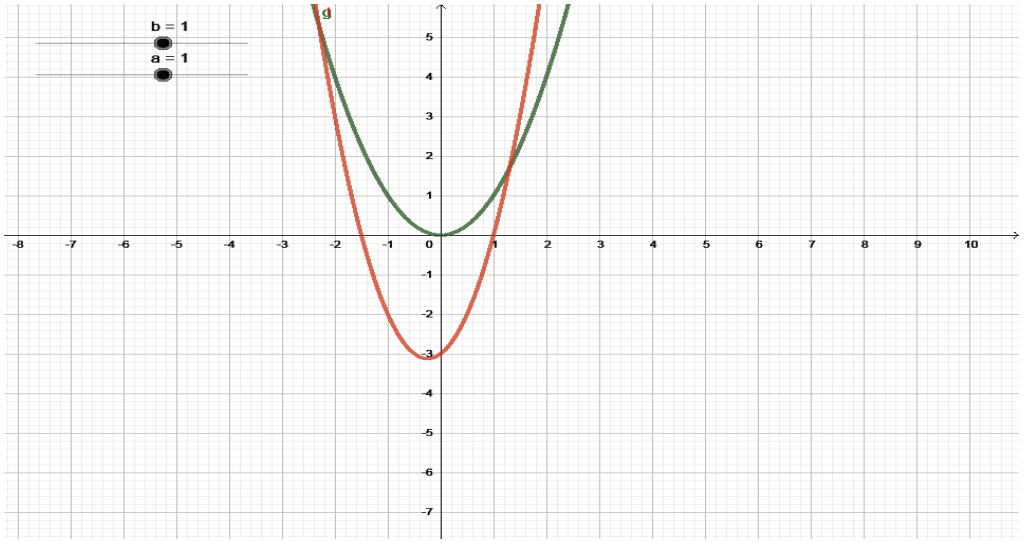


Figure 4.9. Learner 4's plotting response

Learner 4 sketched only two graphs. The green graph did not reflect any of the given conditions, the learner failed to represent mathematical entities during the response to the activity. Therefore, the mathematical competencies displayed by the learner here showed the ability to use mathematical tools and produce a diagram that represents a mathematical idea. The learner communicated the mathematical statement wrongly in responding to the given activity. However, the orange one did not reflect any of the conditions given as she indicated that $b = 1$. Here learner 4 displayed mathematical modelling and represented mathematical entities. She was able to identify critical points of the quadratic function and represent a function correctly. The learners were able to develop sketches that represented quadratic functions and correct shapes. However, these abilities were irrelevant to the given question of the activity. This form of response in Figure 4.13 would be that the learner failed to interpret the given question regarding the value of b. Through this response, the learner would have thought of just sketching any quadratic function.

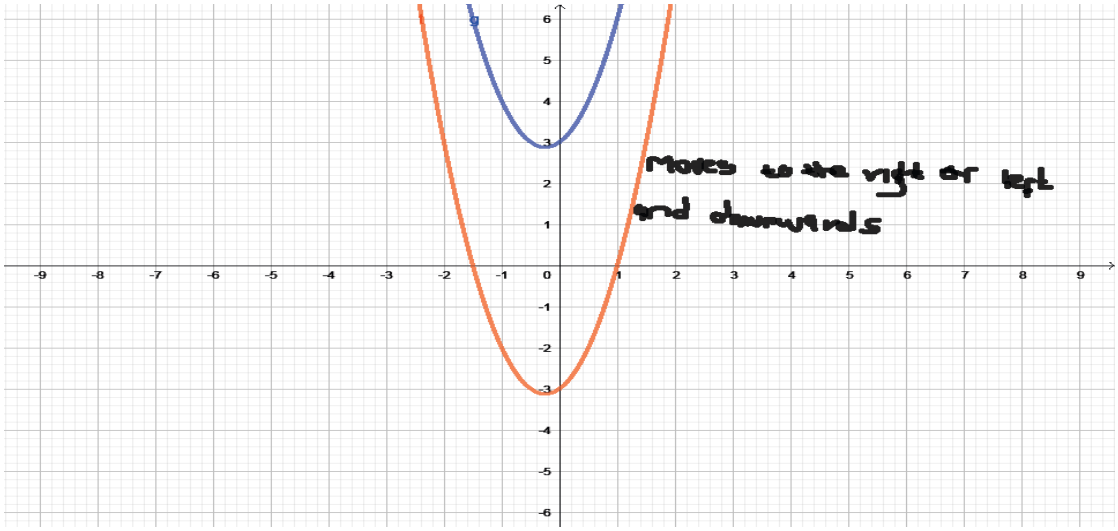


Figure 4.10. Learner 8's response

The learner's intention was to respond to session 1 activity. The orange graph looked the same as the one found in learner 4's response. These learners succeeded in sketching, however, the quadratic functions were irrelevant to the given conditions of the question. The blue graph was his response to one of the conditions on the value of b which was unclear at this stage. Once learners develop an understanding of the type of function given, they can relate a sketch to it. Furthermore, it displayed that when learners are unable to interpret the given information of the activity, they will manipulate the sketch incorrectly.

Learner 8 wrote something to support his sketch of the quadratic function. "Moves to the right or left and downwards" statement did not make sense in responding to the question. For instance, learner 8's sketches are a proof that he was trying to think mathematically. The learner knew the kind of answer, which he thought to be incorrect. In addition, what he wrote on the sketch could have been that he was reasoning mathematically for the sketch he provided. Lastly, the learner understood the shapes of quadratic functions. Therefore, he communicated in, with and about mathematics while responding to the question.

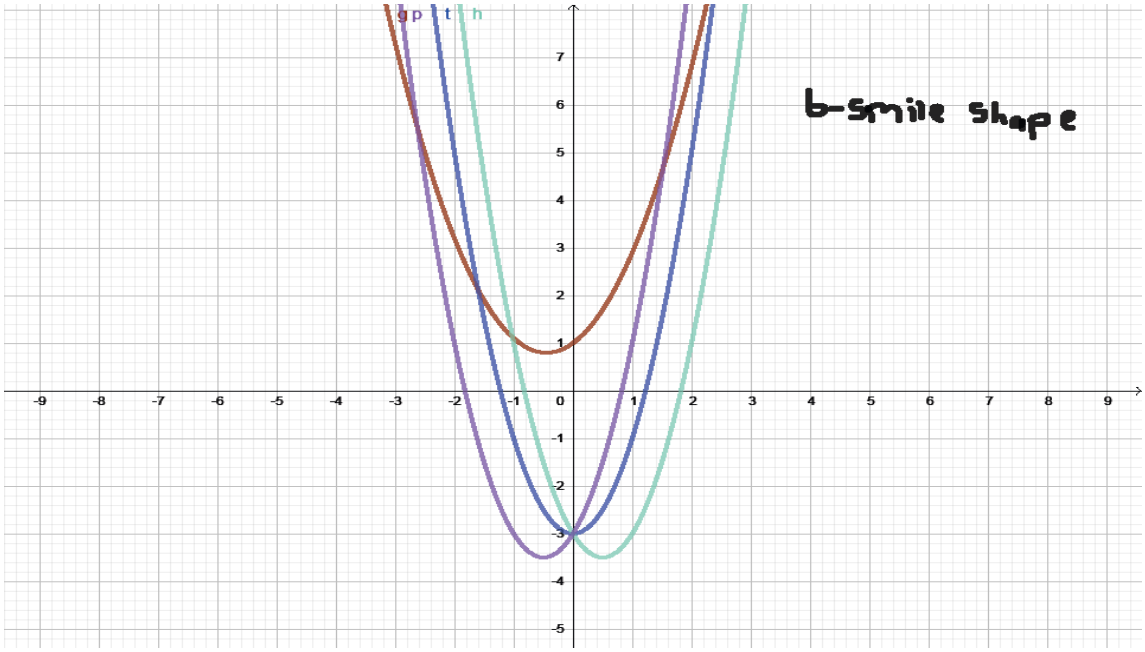


Figure 4.11. Learner 1's response

The learner responded to the three conditions of sketching $t(x) = 2x^2 + bx - 3$. While thinking mathematically, the learner was able to display mathematical entity skills correctly in his solution. Learner 1 was able to interpret the conditions given in the form of symbols and formulas. This was evidence that the learner handled the symbols and formulas on the given question. Handling mathematical symbols and formulas was displayed during the sketching of quadratic functions using GeoGebra. There was communication in, with and about Mathematics as he understood the shapes of quadratic functions. In addition, his understanding and the skills he possessed yielded to correct shapes of quadratic functions.

In his responses, $h(x)$ reflected the condition of $b < -1$. The roots of this graph shifted to the right and the turning point shifted downwards and to the right at the same time. The blue graph reflected the condition of $b = 0$. This evidence reflected the turning point on the $y - axis$. Moreover, the coordinates of the turning point are $(0; -3)$. The purple graph shifted to the left-hand side of the $y - axis$. Through the use of the GeoGebra, the graph represented the condition of $b > 1$. The turning point shifted to the left-hand side of the $y - axis$ and the turning point shifted to the left and downwards at the same time.

Learner 1 was able to engage in strategies that helped him to be selective on the values of b. This seemed to show that the leaner had improved his understanding of

sketching quadratic functions. The learner used relevant tools of GeoGebra when sketching quadratic functions. Therefore, the development of technological knowledge improved, hence the competencies of making use of aids and tools were displayed by the learner.

During the lesson, I engaged learners on prior knowledge for construction of new one. Here I reflected on the previous content so that learners could see the logic of these parameters $a, b, c, p \; and \; q$. It was found in Line 28 from lesson 2 that a learner could recall the knowledge constructed before.

Extract 6 from lesson 2

27. Educator: Okay. Yesterday we talked about how p affected the graphs. Right. So now I want us to go back to yesterday's lesson before we move on so that we connect. And yesterday I indicated that when $p > 0$, what happens to the graph?
28. Learner 3: The graph will shift to the left-hand side.

Looking at Line 35 and 36 from extract 7, it was clear that I led the learners in my questioning to use the prior knowledge to construct the new one. Grade 11 learners were aware that we had the horizontal and vertical lines of the Cartesian plane. Therefore, q would affect the vertical shift as p affected the horizontal shifting.

Extract 7 from lesson 2

35. Educator:…Since p affects the horizontal shift. What do you think about q? What do you think guys?

36. Learner 6: q will affect the vertical shift.

Moreover, I revised with learners their prior knowledge of lesson 3. Although the learners failed to answer some questions correctly, I showed them how to move sliders on the GeoGebra software so that they select the choice of their quadratic functions. At first I presented $f(x) = x^2 + x + 1$ later changed slider b to have $f(x) = x^2 - 2x + 1$ using GeoGebra in the presentation of the lesson.

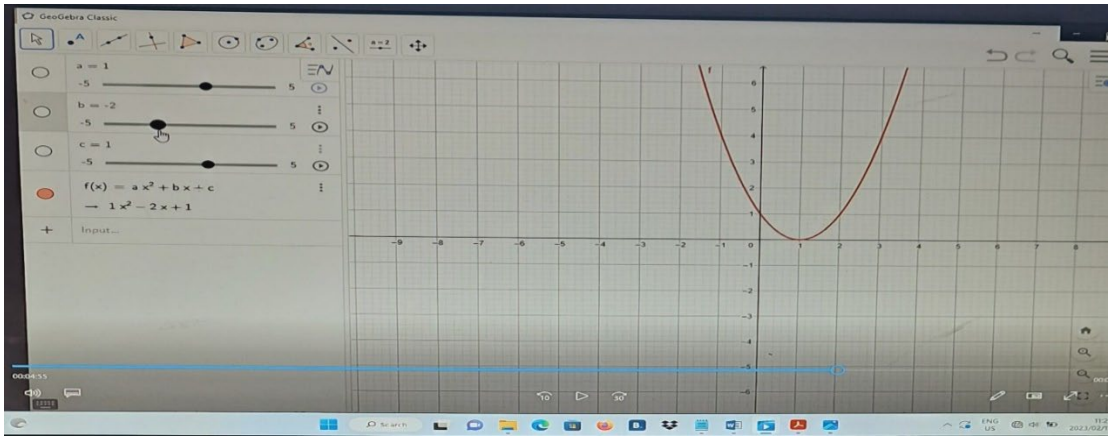


Figure 4.12. Effects of slider b

In lesson 4, I started with Grade 8 work which addressed the reflection of a point along the $x-axis\ and\ y-axis$. The introduction helped learners to build on a more complex concept which in our case was the reflection of a quadratic function along the $x-axis, y-axis\ and\ y=x$ line. The figure below shows an introduction to the main concept.

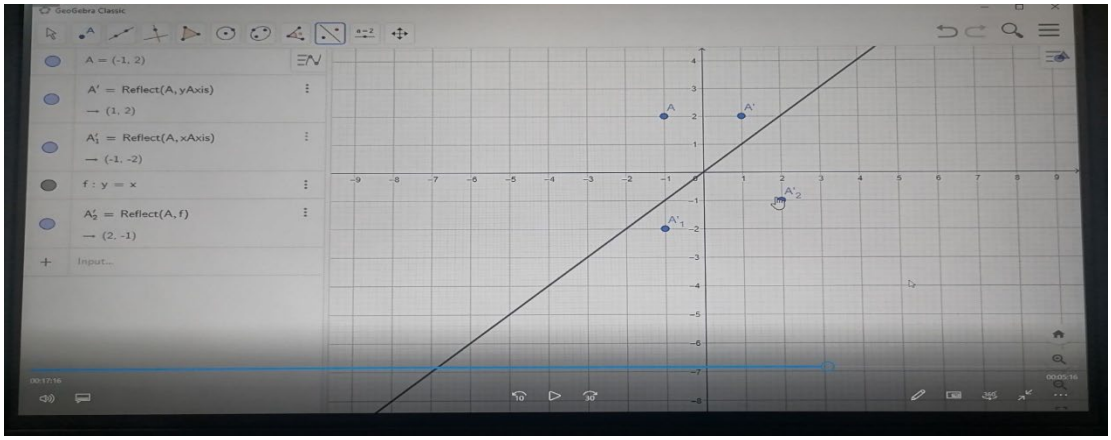


Figure 4.13. Prior knowledge

Errors and misconceptions need to be addressed during the lesson or after assessment. The lesson plan did not identify any possible misconceptions and errors that could arise when teaching the concepts. However, during the lesson presentation, I addressed the misconceptions and errors the learners committed. Lines 92 to 105 from observation data showed the error learners had made by confusing the $x\ and\ y$ values at the turning point from the quadratic equation of the form $y=a(x+p)^2+q$. I kept on building on their responses to address the misconception of not understanding that a point is formed by the x-coordinate and y-coordinate.

Extract 8 from lesson 2

92. *Educator: let me ask the other group, can we have Learner 3? Do you agree with Learner 5's answer?*
93. *Learner 3: yes.*
94. *Educator: are you saying the turning point is* $(-2; 3)$*?*
95. *Learner 3: they are positive. Positive number.*
96. *Educator: let me ask you guys eh which one is the value of* $p\ between\ 2\ and\ 3$*? Remember p affects the horizontal shift and which one is the value of* q*, remember* q *affects the vertical shift. So, what am trying to say is your answer is not correct. Yes learner 7 share with us your answer? Learner 7?*
97. *Learner 7:* $p = 3\ and\ q = -2$
98. *Educator: okay but now what will be the turning point?*
99. *Learner 7:* $(3; -2)$
100. *Educator: it can't be. Okay. Allow me to share the GeoGebra so that we can look at the graph…….okay guys, I think while we are still waiting for GeoGebra to open eh I want to take you back to what we talked about yesterday. Eh lets go back, problem here is p (taking learners to the effect of p and identifying the turning point)……..*
101. *Here we are (back to the question); this is the equation what is the correct turning point to this given equation?*
102. *Learner 8:* $(2; -3)$
103. *Educator: that is not correct. Can we have someone to give us the answer?... are you with us……...give us your input.*
104. *Learner 1:* $(-3; -2)$.
105. *Educator: thank you, that is correct. The middle sign……. We going to have the graph shifting to the left and if it shift to the left it means……. Is it clear?*

I would have not known the errors and misconceptions that could arise when teaching the content. This might have resulted from a lack of experience to the use of the GeoGebra software when teaching the sketching of quadrating functions. Errors were the results of how learners understood and interpreted the content. Educators are expected to look at learners' written work or responses thoroughly to diagnose the causes of errors and misconception (Sarwadi & Shahrill, 2014).

Finally, it would have been because I identified learners' responses to activities and their written responses as solid evidence to analyse the errors and misconceptions. However, emphasizing the errors and misconceptions around the content before learners responded to activities would have improved the learners' interpretation of the content learnt.

Lesson 3 focused on the intercepts-roots and describing the nature of the roots when sketching quadratic functions. Below are sketches that show the change of b to accommodate different roots of the quadratic functions.

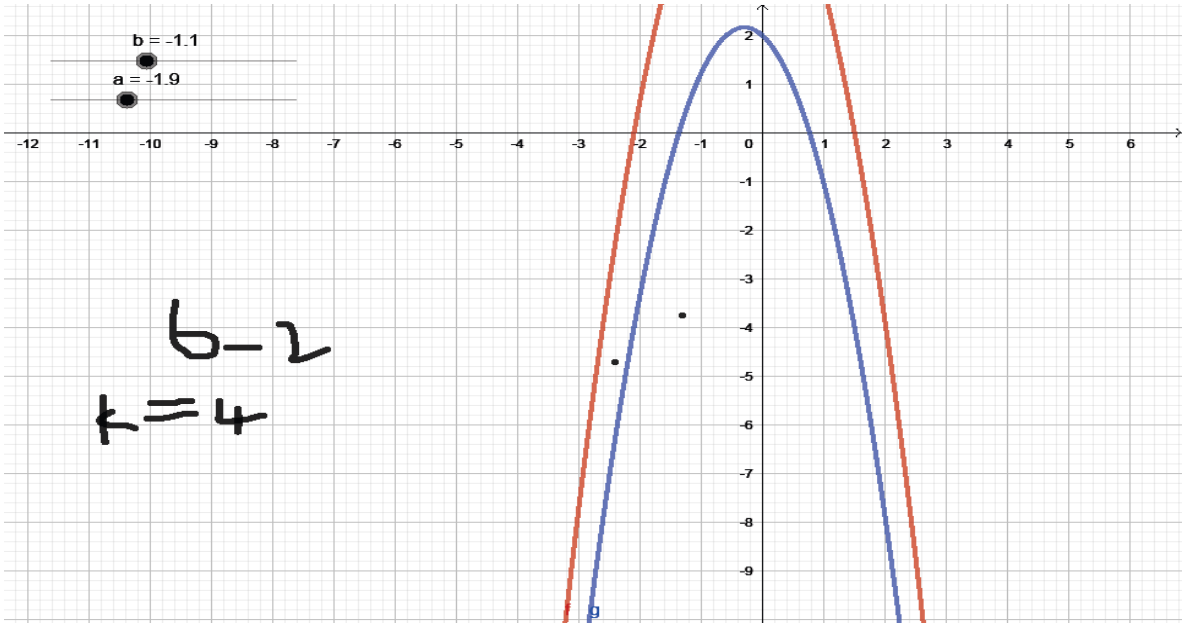


Figure 4.14. Learner 4's response to lesson 3 activity

I looked at how learners responded to the questions and also identify the mathematical competencies displayed. Figure 4.18 showed how learner 4 responded to questions 1.1 and 1.3 of the lesson 3 activity. The learner was able to engage a mathematical tool in GeoGebra software which resulted in quadratic sketches. The representation of the mathematical equation was displayed by the learner, but the mathematical thinking such as to interpret the question of the learner was used incorrectly to answer the questions.

The learner's responses could be the misunderstanding of the nature of the roots relating to the sketch. The response showed two quadratic functions with $a < 0$ and the nature of the roots read as follow: two unequal roots. The reasoning ability was absent to relate the nature of the roots which is the $x - ntercepts$ to the sketch drawn.

Although learner 4 was able to draw a quadratic function, she could have realised that equal roots referred to the sketch touching the $x - intercepts$ once which would also be the turning point of the graph. The communication with and about mathematics to the problems was incorrectly manipulated to solve the problem. The lesson did not enable the learner to realise that non-real roots should result in a sketch that did not touch the horizontal line or restricted from touching the $x - axis$.

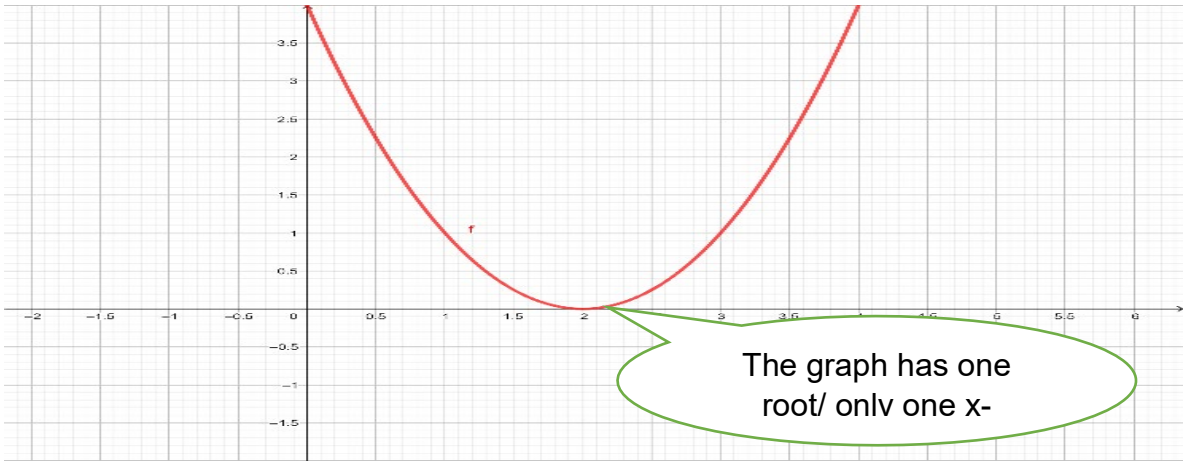


Figure 4.15. Example during the lesson 3.

During the lesson, I demonstrated the type of sketch to expect when we have one root of the function. That would be a way of addressing the errors learners encountered as they engage in activities of prior lesson. In this study, addressing errors and misconceptions supposed to be the priority in the lesson to meet lesson expectations. However, the participants displayed less errors and misconceptions as we move to the next lesson using the GeoGebra. The understanding has also improved in sketching quadratic functions.

4.2.1.3. Integration of technology and content

The online lessons were conducted using the Zoom platform and the use of the GeoGebra software for sketching quadratic functions. The figures below showed how the GeoGebra was conducive during the online lesson. During the lesson observation, the Zoom platform allowed participants in the classroom for each lesson. The participants were able to mute or unmute the camera and microphones. However, it was not observable how many times participants failed before they login.

Below is the evidence from lesson 1 which support that the chosen tool for teaching and learning was conducive. The quadratic equation highlighted with green colour is $f(x)$ (facing down) represented $a < 0$, and the one highlighted in pink is $h(x)$ represented $a > 0$. The learners were able to identify the effect of a on a quadratic function. Visible sliders were visible to enable any changes in the parameters. Learners were unable to move sliders for themselves during online lessons. This was due to a lack of resources, as they used their cellphones to login to the online lessons. If learners were presented with the opportunity to use laptops, this would have given them the chance to move sliders to create their functions focusing on the effect of a in quadratic functions. The learners' understanding of quadratic functions would have been shaped differently if they were offered the opportunity during the lesson.

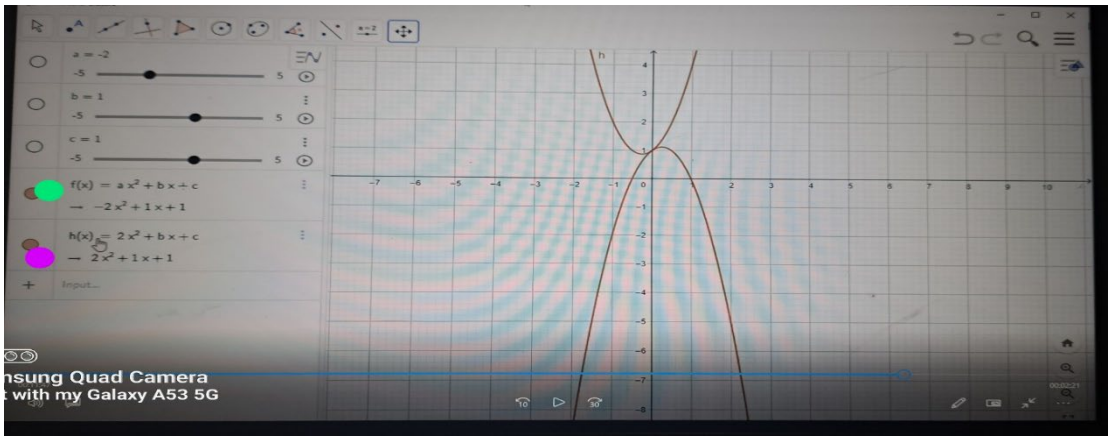


Figure 4.16. Tool used in lesson 1.

Most of the time, the cameras were off for the smooth running of the lesson. It could be the learners were busy with something else not part of the lesson and that could led to misconceptions of concepts. The misconceptions could resulted in the errors the learners displayed when responding to activities. Therefore, in such a situation, it was not easy to control learners' focus unless it was during the interactive phase of the lesson. Figure below is a screenshot from Zoom online classroom that present participants' cameras off during the lesson. Additionally, it might have resulted in poor participation of learners that had been observed in the lesson.

Figure 4.17. Zoom camera off

Line 3 to 11 of lesson 2 show the interaction between I and learners as the value of p changes on the GeoGebra software. Supported by a demonstration from GeoGebra.

Extract 9 from lesson 2

3. Educator: Okay. It's good. Let's continue. As I was saying, we want to see how this p that affects the graph to move horizontally changes. Look at this one. If now our $p = -1$, what I asked before we were lost through the network. I wanted to know whether you heard me when I was explaining. Now our $p = -1$. So, my question is, when $p < 0$ the graph will shift in which direction?

4. Learner 2: To the right.

5. Educator: Yes. The graph will shift to the right. That's correct. Now, look at where it is now. It means the graph has shifted how many units to the right from the original one, which is the grey colour? The graph has shifted how many units?

6. Learner 3: One unit.

7. Educator: One unit. Then what will be the new turning point? What is the new turning point? Learner 5? Give us the turning point, the new turning point of the new graph, which is a green one.

8. Learner 5: 1

9. Educator: the turning point is 1; a point should have the x-coordinate and the y-coordinate. So, rephrase your answer.

10. Learner 5: $(1; 0)$.

11. Educator: Thank you. Right, now I'm going to shift the value of p.

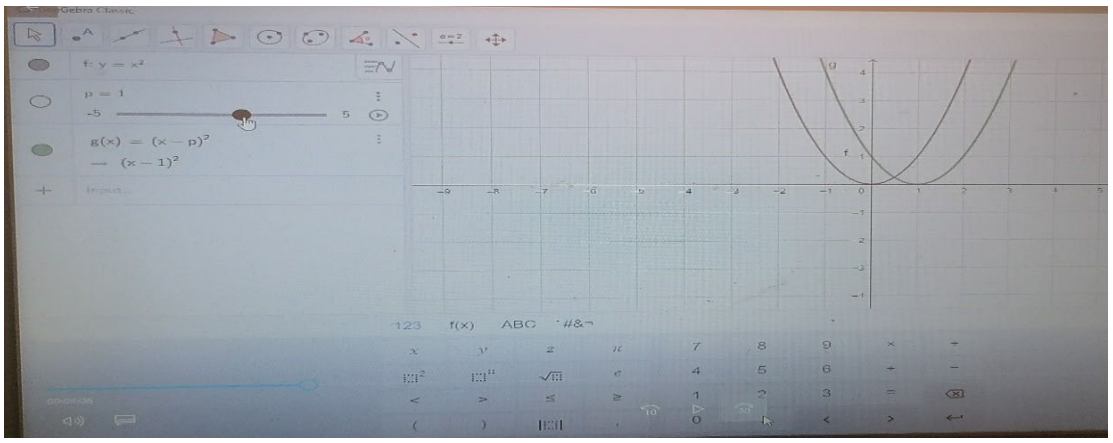


Figure 4.18. Shift to the right-hand side

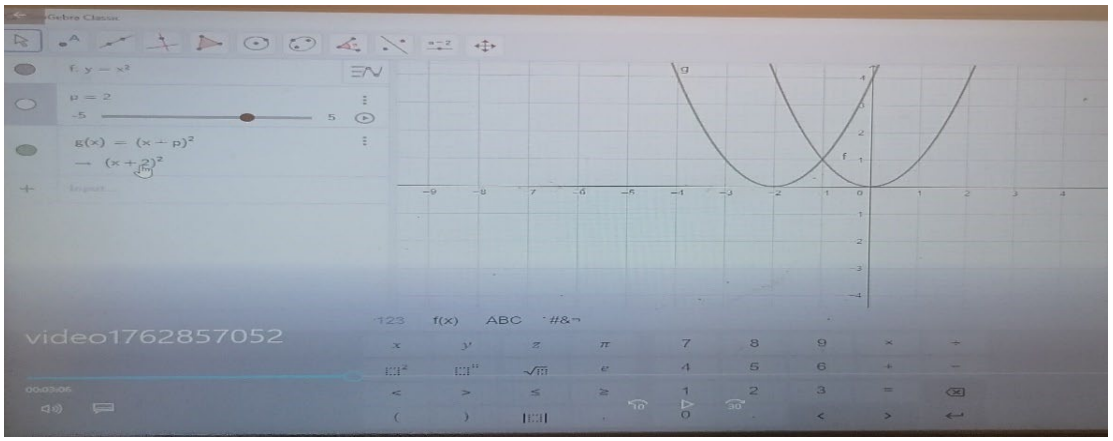


Figure 4.19. Shift to the left-hand side.

I tried to demonstrate the effect of p on GeoGebra as the graph shifted. Demonstration methods of teaching were possible, as the GeoGebra software was capable of presenting many different graphs for as long as one needed them. I kept the lesson going by asking the learners about what they noticed about the turning point as p changes. Learners might have been advantaged by comparing the different sketches presented on the GeoGebra to be able to answer questions. It would have been difficult for learners to conclude if the method of teaching presented one sketch at a time. Therefore, the tool enabled the learners to compare the properties of different quadratic functions as p changes. This was in great support of the study conducted by Bekene Bedada and Machaba (2022) which stated that GeoGebra promotes decent learning and improves the learning of the content.

Lesson 2 focused on the impact of $p\ and\ q$ on quadratic functions.

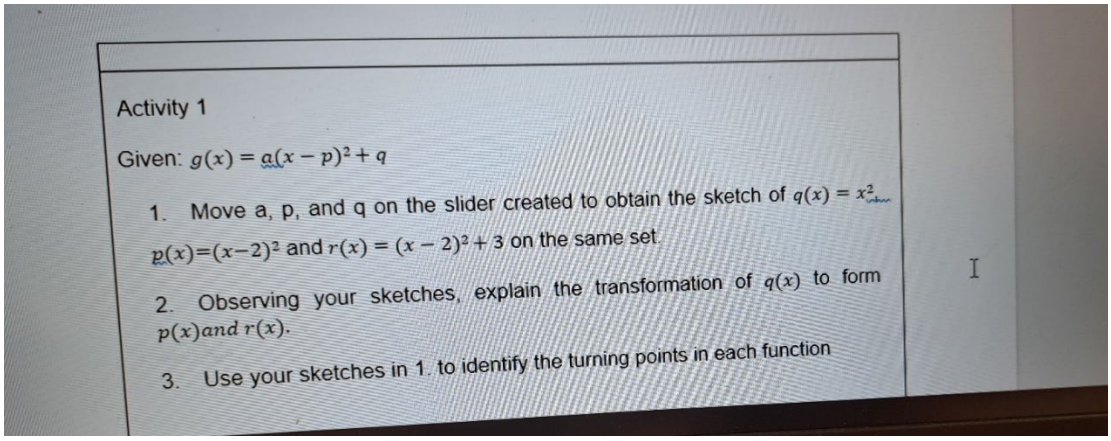


Figure 4.20. Lesson 2 activity.

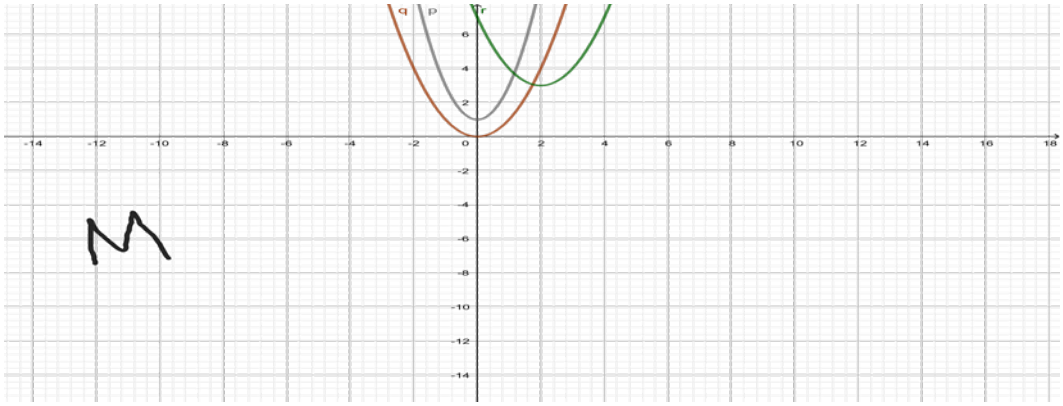


Figure 4.21. Learner 8's response

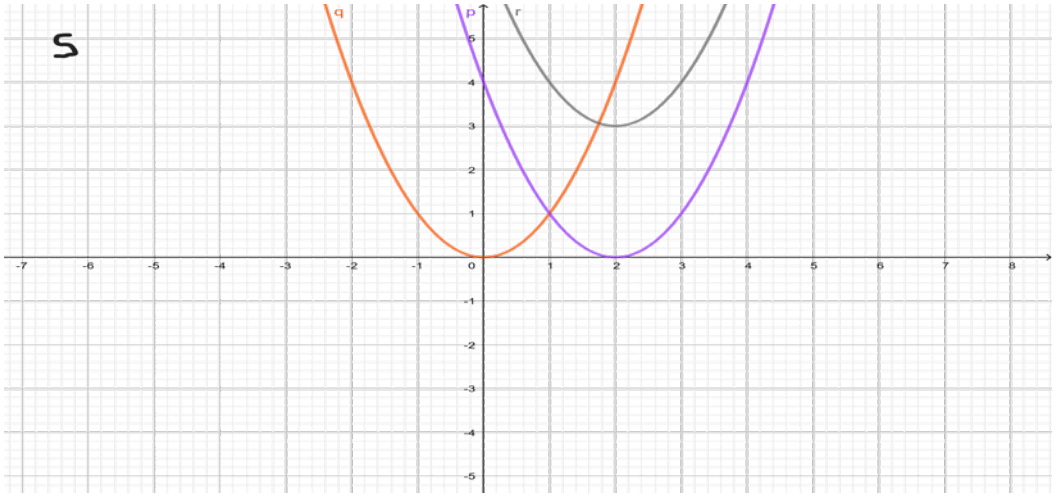


Figure 4.22. Learner 1's response

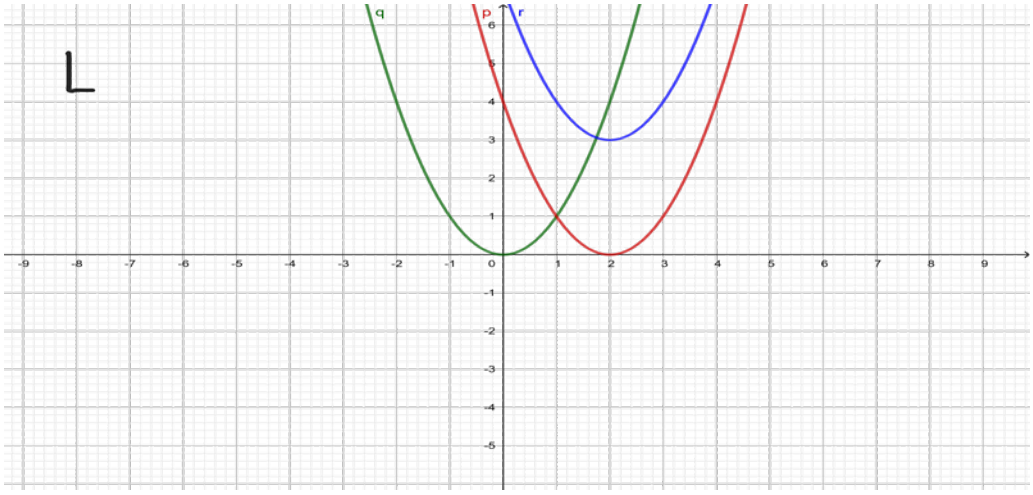


Figure 4.23. Learner 5's response

In their attempt to answer this question, learners seemed to have an idea of using the GeoGebra software input bar as they used aids and tools. Learners understood the given statement as they provided three sketches of quadratic functions. However, learner 8 applied part of the given statement incorrectly for one function. The statement in this activity required the manipulation of variables and mathematical symbols to be represented graphically. Observing the responses of learner 8, the sketch of $p(x)$ shifted vertically with one unit upwards from $q(x)$ which was not related to the given statement and then two units up again for r(x), see figure 4.25. These results illustrated that the mathematical thinking learner 8 applied did not work in his favour. The challenge was to understand that as $p < 0$ the new sketch of the quadratic function will shift horizontally to the left. Parameter p represent the horizontal shift in a Cartesian plane. Despite learner 8's attempt, learners 1 and 5's responses showed that their mathematical thinking enabled them to solve mathematical problems.

Using the GeoGebra software in our lessons was mostly addressing the competence of making use of aids and tools and handling mathematical symbols and formalisms. Nevertheless, mathematical thinking plays a major role as most competencies integrate with it when teaching and learning Mathematics (Thomsen & Jankvist, 2022). Most learners were able to move from one tool of the GeoGebra application to another one. The handling of mathematical symbols was also depicted from the equations inserted to the sketched quadratic functions submitted.

Furthermore, saved and submitted responses to the activity from the GeoGebra limited the opportunity to explore the slider created before the sketching of $q(x), p(x) and\ r(x)$.

Thus, through this lesson, learners were able to use their mathematical thinking to represent mathematical variables graphically. As a result, learners were able to move along the GeoGebra to sketch quadratic functions. However, the learners and I were still at initial stage of teaching and learning online using the GeoGebra software.

The expected solutions for the online activities were also provided that might prove that I had content knowledge when implementing the GeoGebra software in sketching of quadratic functions. Below are figures that showed the expected solutions to question 3 of the activity.

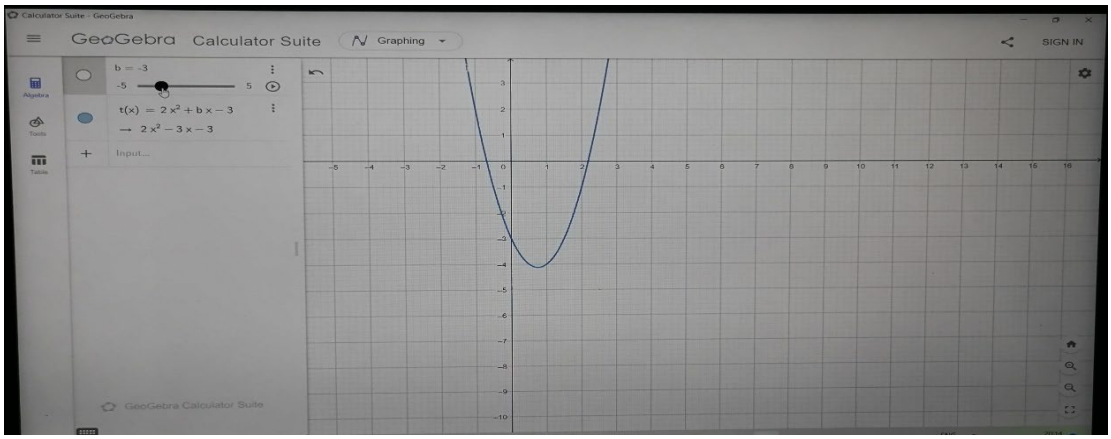


Figure 4.24. Solution to $b < -1$

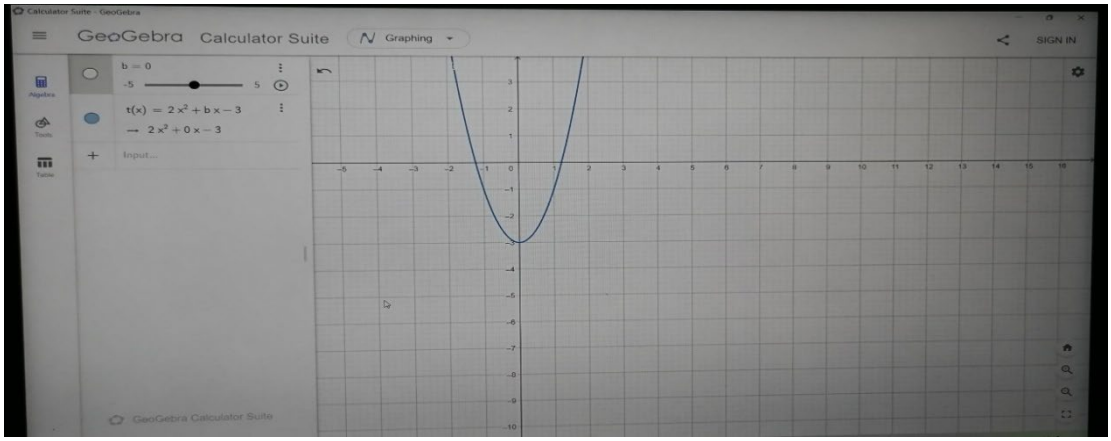


Figure 4.25. Solution to $b = 0$

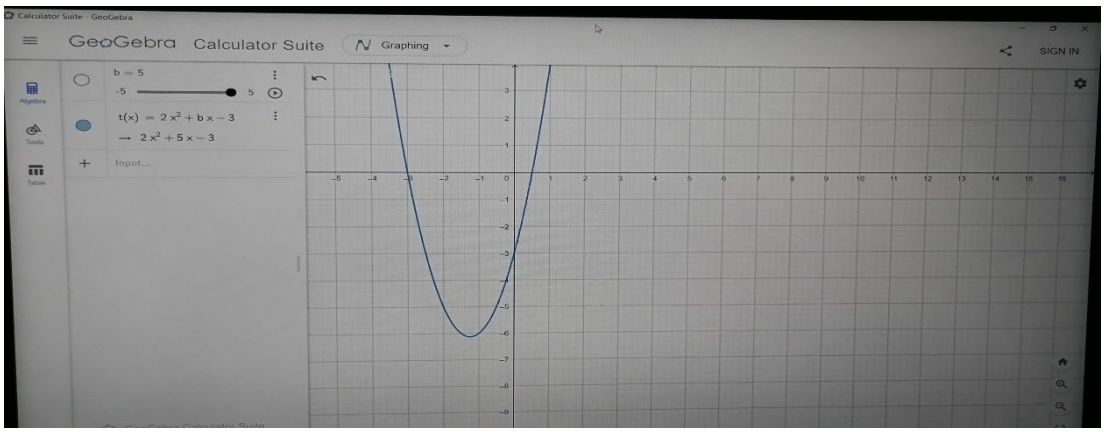


Figure 4.26. Solution to $b > 1$

Accessibility of activities in an online lesson were handle appropriately. Below is how I talked to learners through activities that they needed to write. The content taught during the lessons was assessed, and it reflected the same content of the lesson. For example, line 132 from lesson 2 exemplifies how the learners were guided through in accessing the activities at the end of each lesson.

Extract 10 from lesson 2

132. *Educator: ok then, now let us move to the activity. I will give you time to copy the activity, and then from there you will leave the lesson and go to your laptops and sketch those graphs using GeoGebra. Can you please take down these questions and copy them? While you are busy doing that let me read the activity (reading the questions on the activity). So, it means you going to do number 1 on GeoGebra and you open Word document to do numbers 2 and 3 because you need to write down the transformation and turning points of each graph. I hope this is clear. I will pose here to wait for questions… so it means is clear?*

Lesson plans are designed in a way that activities are displayed at the end. During the online lesson, I plugged the activity after the presentation. Learners were taken through each question in the activity for their writing. The activity was displayed on the screen towards the end of the lesson. This was how the learners accessed the activity and were guided on which tool to use for a response. Furthermore, reading from line 132 of lesson 2, I made it clear to learners about which application to use. The necessary technological tools were for the chosen questions for this activity. It could be presumed that the learners had the technological knowledge to fulfil the needs of the activity to be submitted.

4.2.2. Themes that emerged from TPK of TPACK

Figure 4.27 presents themes that emerged from TPK of TPACK. Transcripts and learners' responses to activities were analysed guided by the three themes emerged. Mathematical competencies displayed by learners were identified from data presented.

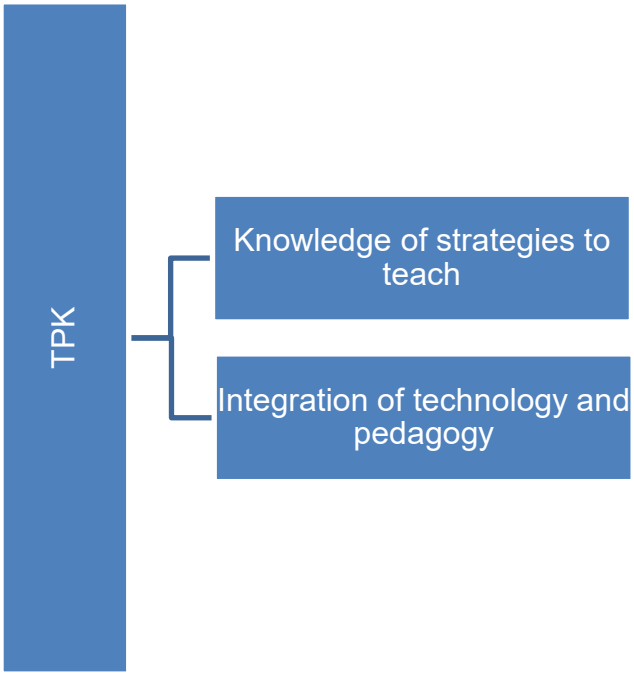


Figure 4.27. Themes that emerged from TPK.

4.2.2.1. Knowledge of strategies to teach

The strategies used in teaching the sketching of quadratic functions observed were the lecture and demonstration methods. The demonstration method used in this study was consistent with the study by Ademiluyi and Olupayimo (2022) which was effective in improving technology skills. The lesson plan did not specify the teaching strategies to be implemented. During the presentation of the lessons, learners were given examples that reflected the concepts taught. I might not have planned to use these methods but was forced by a lack of experience with the technological tool. Lines 102 to 107 from the lesson 4 transcript showed that learners work individually during the lesson to interact.

Extract 11 from lesson 4

102. *Educator: allow me to write this equation, sorry yeah look at this line, which is called $y = x$. The grey line. I want to, I want … along this line. Let us see what will be the new point. Look at the point. Can you give the coordinates of this point of reflection? Hello…Pardon.*
103. *Learner 3:* $(2; -1)$
104. *Educator: correct, let's compare the two points … the original one. What has been affected here or what happened? Just note this coordinates down the original one is* $(-1; 2)$*. Those are the coordinates, the new point I* $(2; -1)$*. Look at the two points and say something. Learner 5? What is that you can say about the two points? Learner 5, are you still there? Yeah. Hello.*
105. *Learners: Yes.*
106. *Educator: please give us the answer now*
107. *Learner 5: the y value is been affected.*

Line 88 from the lesson 2 transcript showed that learners were allowed to discuss the solution to the posed question. Teaching the sketching of quadratic functions online afforded the opportunity for learners to collaborate.

Extract 12 from lesson 2

88. *Educator: Okay, I want us to do this activity together. Eh I will give you the opportunity to respond to this activity. Look at it. Let me read it for you (reading from class activity) I am going to give you a minute to look at these two questions and I will call one by one to present the answer. That one-minute start now, you can talk to someone next to you, you are allowed to talk to someone next to you. (Learners discussing)… open your mic I want to hear your discussion… can we have learner 5 give us the answer to the first question? Can I have the other groups unmute their mics?*

Teaching strategies and use of real-life situations in the lesson was relevant. The content was to be taught using the GeoGebra software therefore, the demonstration teaching strategy helped to do the relevant exposition of the software. I did not engage in many teaching methods and would have observed a different exposition of the software. The teaching methods that were aimed in the lessons were learner-centered methods that allowed learners to formulate questions of their own. Assessments were designed to assess the content taught. During the online lessons, learners were asked

questions, and I built on their responses for the correctness of the solution. All submitted activities were individual works of learners. The study was focused on mathematical competencies learners display when sketching quadratic functions, rather than on the marks obtained.

Lesson 1 did not suggest a real-life example or problem related to the concept to be taught. Examples used in this lesson were indicated in the lesson plan. Observing the presentation of the lesson, a good knowledge of the concept was identified. However, the technological knowledge integrated into the content and pedagogy was limited. In the figure below, the highlighted in green showed one of the examples discussed during lesson 1.

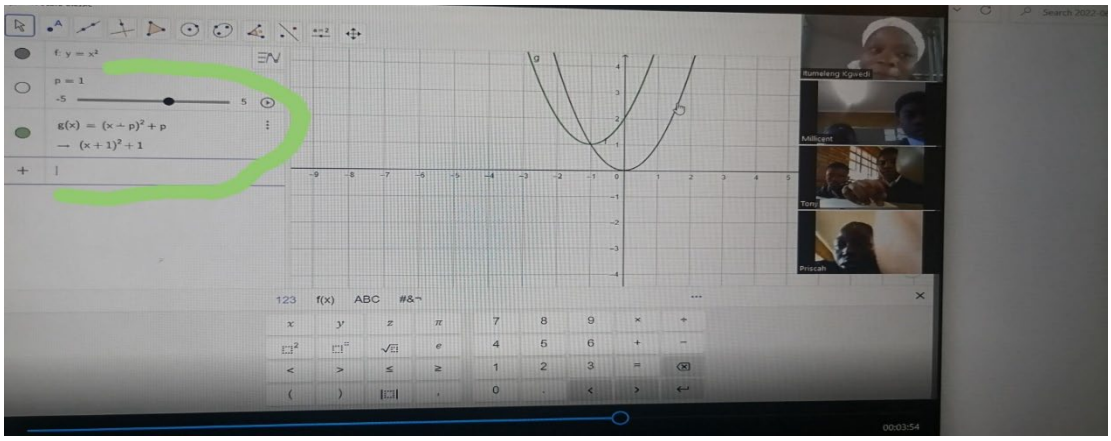


Figure 4.28. Example during the lesson.

The lesson plan for lesson 4 used real-life examples when explaining the reflection of quadratic functions along a certain line. I talked about the mirror as a reflection line to emphasise that along the mirror, one can see his/her image. Lines 8 and 15 below from the lesson 4 transcripts show how I used the real-life example to emphasis on the concept of reflection. The example might have made learners think out of the box and start to relate mathematical problems to what they were facing out there in reality. Without real-life examples, the learners might have treated the real-world as separate from mathematical problems.

Extract 13 from lesson 4

8. Educator: Ok. Right so now when we say this is a reflection along the line, that line acts as a mirror. So, that we can see the image of the original object or the graph. So it's like when you are standing in the mirror, one sees the same image as him/herself

right? So now what we are saying is the reflection of a point or function or relation along a certain line.

15. Educator: Ok right eh am saying on today's lesson will be talking about a reflection of a point, oh sorry, a reflection of quadratic function along a line, but I must take you to the lower Grade wherein we talk about the reflection of a point along the line. Here I am referring to, the line acting as a mirror. Let me check if you can hear me guys. Am I still audible on that side?

The technological tool chosen for lessons determine the teaching strategies to implement in that classroom. Knowledge of strategies to teach is essential in presentation of the lessons. The study dwelled much on demonstration and lecture methods rather that allowing learners

4.2.2.2. Integration of technology and pedagogy

There is a lot on how to use the chosen tool. In this study, Zoom was chosen as the tool to conduct the online lesson. The GeoGebra software was chosen as a tool to sketch quadratic functions through online Zoom lessons. Church et al. (2021) outlined ways an educator creates to keep learners engaged in the lesson. During the lesson observation, my role was visible and transparent. Keeping the camera on was one of the aspects discussed. During the online lessons cameras were on for the first few minutes to monitor the attendance. It was discovered that with cameras on, the presentation of the lesson would not run smoothly. Small groups in breakout rooms were also discussed by Church et al. (2021) to keep learners engaged in the lesson. However, I did not initiate the breakout room utilising Zoom in the study. The technological knowledge that I acquired was limited and as a result it affected the engagement of learners during the lessons.

I created the login link to be accessed by all participant and that helped to control who can participate in that lesson. The necessary technological tools were selected in the process of preparing for the lesson. I ensured that every lesson was recorded as data collected. I played a role of designing a lesson plan, lesson activities and sessions that reflected what was taught.

The collaboration learning method among learners was less experienced. Learners responded to the individual activity using GeoGebra software. In addition, the email was used to send learners' responses to activities that never had to do with

collaborative learning. However, the study had no focus on teaching styles but rather on how technology was integrated into teaching and learning. Therefore, I interacted with the learners and learners interacted with learners during the online lessons.

The discussion below associates the technological tool with the given activities. The activities from each lesson reflected the content taught. During the lesson observation, I demonstrated that I had the content knowledge required and was able to decide on using the GeoGebra software as the accurate technological tool. In addition, Microsoft Word was chosen for learners to thoroughly explain what they observed. The GeoGebra software is effective for the teaching and learning process and improves visualisation (Misini & Kabashi, 2021). The figure below shows how the GeoGebra software reflect the different quadratic functions sketched.

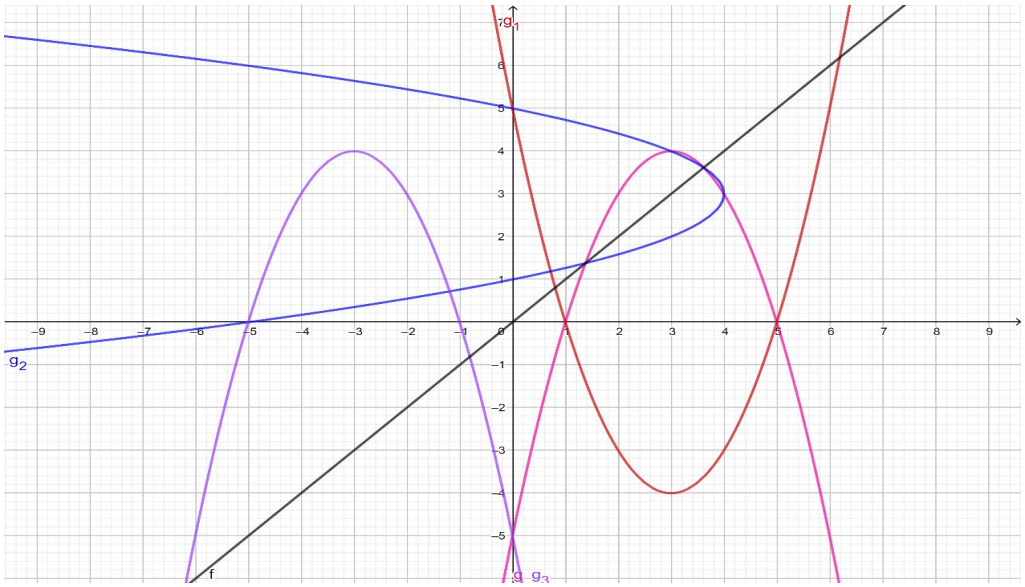


Figure 4.29. Results from chosen technological tool

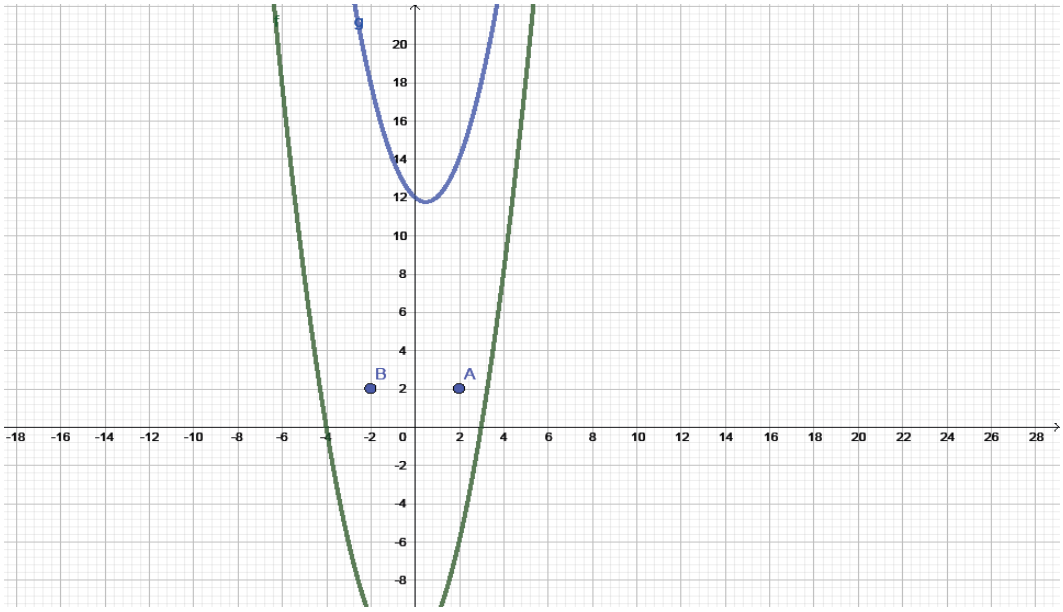


Figure 4.30. Learner 8's response to lesson 4 activity.

Learner 8 in the above response was sketching quadratic function $(x) = x^2 + x - 12$ and sharing what he had noticed as the sketch reflected about the $x - axis$. The sketch of $f(x)$ is correct however, the reflection of the given one along the $x - axis$ is not correct. From the sketch, it seemed that the learner had shifted $f(x)$ 24 units upwards and also reflected the results about the $y - axis$. The learner might have interchanged the concepts of reflection with shifting. It appeared that mathematical thinking was applied wrongly.

The tools and aids of diagrams were manipulated by the learner in the process. Although learners were able to sketch quadratic function $\mathrm{f}(x) = x^2 + x - 12$, the reflection was not supposed to be the same as $f(x)$. Learner 8 would have not realised that $g(x)$ did not represent the reflection about the $x - axis$ but shifting upwards and reflection about $y - axis$. Therefore, one question cannot address all mathematical competencies.

Furthermore, learner 8 failed to provide what he noticed on the sketch. The response to the last question of the lesson 4 activity was "d. sum of veluse from x-axis changes". The response did not make sense at all. This type of response might have been caused by the teaching style as technology was involved. I would have been more precise on instruction for learners as now the use of GeoGebra was not needed to answer the question but use the sketch drawn to interpret. Another factor would have been the use of tools and rules of the GeoGebra software.

The figure below shows learner 1 response to the lesson 4 activity through the use of Microsoft Word as the chosen tool. However, the questions were additional as our focus was on the sketching of quadratic functions.

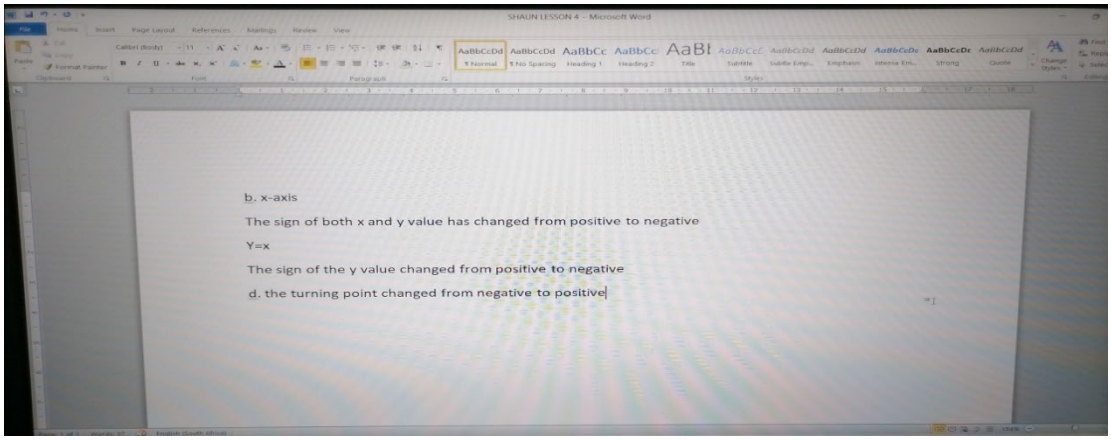


Figure 4.31. Learner's responses to lesson 4 activity.

There were lot of challenges of poor connectivity that affected the integration of technology and pedagogy. Learners were not able to hear clearly at some point as I was presenting, the area experienced network problems (see extract's lines 4-8 below). My response was to acknowledge that I was kicked out of the online lesson by the network.

Extract 14 from lesson 3

4. *Learner 1: mam we can't hear you*

5. Learner 4: mam your network is cutting.

6. Educator: can you hear me now?

Connection lost (17 seconds)

7. Educator: Am back. I wonder what is happening because it seems I have been kicked out by the network again but when I check my network on this side everything seems well and ok. Can you hear me now?

8. All learners: yes

As the problem persisted, I tried another method so that we could be back online. In an online classroom, it is important to keep on checking whether all your learners are still in the classroom so that no one misses the lesson. Line 34 shows how I was

checking on the learners' availability in the classroom and the strategy I used to bring us back to our classroom.

Extract 15 from lesson 1

34. *Educator: hello. Am I audible enough on that side? Yeah, I don't know, it seems the network is our biggest problem today. Eh, allow me to end this lesson. Can we login again? Can we all leave the lesson so that we start afresh? Please leave the lesson all of you.*

4.2.3. Concluding thoughts

The results from analysis of lesson observation revealed that it is necessary for educators to have a strong content and pedagogical knowledge before integrating technology in the lesson. The educator should fully understand the concepts to be learned in order to impart it to learners. In addition, the educator should know how to implement the lesson for effective teaching and learning. It was revealed that I might have been lacking the technological knowledge due to experience. However, that did not stop the integration of technology, we saw the shift from Google Meet to Zoom to continue with the lessons. For integration of technology and pedagogy, we saw learner-to-educator interactions and less of learner-to-learner interaction method of learning. There was limitation to other learning methods in an online classroom.

The use of the GeoGebra software involved learners' mathematical modelling skills and was a quick and easy way to present graphs (Sumartini & Maryati, 2021). Although in the study, I experienced learners' mathematical thinking applied, they made use of aids and tools as they engaged themselves in sketching the quadratic functions. Learners' reasoning when responding to questions during the lessons was acceptable. Most learners were able to present mathematical expressions graphically in their responses to activities. The analysed data revealed that most learners were able to think mathematically when they used the GeoGebra software to learn sketching of quadratic functions.

4.3. Analysis of data collected from interviews

The transcripts of the participants' responses are presented in Table 4.2 to 4.6. to reveal learners' perception on sketching quadratic functions online using the

GoeGebra software. The interpretations of the information were guided by TPACK theoretical framework.

4.3.1. Themes emerged from TCK of TPACK

4.3.1.1. Knowledge of the content to be taught

Interview Question 5 In your experience, was the online assessment fair and effective for your learning? Explain.	
Participants	Responses
Learner 1	Yes, because when you teach online is better than when you are using the chalkboard. The online one is better, no disturbances and is beautiful. In online classes we are able to ask questions because in class we are afraid to ask.
Learner 4	Yes, because I understand everything and what I learned about that is I did not face bad challenges. I understand the most about learning online and I think learning online is better than face-to-face.
Learner 5	Yes, it was fair and effective because it was something different than doing in the class. It was something that was new, and we do with technology.
Learner 6	Yes, it was fair because it helped me to know the functions and also what we had been doing in class. I understand some of the functions we have been doing in class.
Learner 8	Was fair because it will help you to practise.

Table 4.6. Represent responses to Question 5

Learners stressed out how they interacted in an online classroom in table 4.2. Through demonstration in a GeoGebra and use of examples seemed that the lessons were fair

and effective for learning. Learner 1 showed that online assessment was better than the use of the chalkboard. He further indicated that there were less disturbances and tried to stress that sketching using the GeoGebra reflect a beautiful sketch. Therefore, the online teaching of sketching quadratic function using GeoGebra represented the accuracy of what was given according to scale. The use of GeoGebra improved their knowledge of sketching quadratic functions and graph reflection as indicated by Learner 1. The level of understanding was improved.

The knowledge of the content I imparted to learners in the lesson made learners understand better according to the responses of Learner 1 and Learner 6. The experience of using technology was new to the participants and that might have excited them. Learner 5 revealed that the experience of integrating technology in teaching and learning was effective and good for learning. Learners seemed to have enjoyed the use of GeoGebra when sketching graphs.

4.3.1.2. Knowledge of learners' learning

Interview question 2 What is it that you did not like about using the GeoGebra software to sketch quadratic functions?	
Participants	Responses
Learner 1	Sometimes you type wrongly and think that you typed correctly then you get confused.
Learner 4	There is nothing that I did not like.
Learner 5	There was nothing that I did not like because I saw that it was easy than doing in the book.
Learner 6	Is when I write the values then result to wrong graph.
Learner 8	Nothing because it will help you when you are having a real class.

Table 4.7. Represent responses Question 2

The lesson observed, most learners were too 'quiet to participate', which resulted in the assumption that there were no errors such as confusing the p with the vertical

shifts and misconceptions such as labelling q as y-intercept. However, these were spotted in their responses to individual activities. Learner 1 indicated that using GeoGebra application might be confusing. As a result of misconceptions or errors you might type what you understood then resulted to wrong solution. From the observation when the learner responded “There is nothing that I did not like” could be that she understood how it was done by her educator and compared it with a traditional way of teaching the content. Again, it might be the result from anxiety or excitement of using technology for teaching and learning. Learner 6 experienced that you can insert values of parameters that result in wrong graph. This might have been caused by inserting wrong values that did not match with the given quadratic functions. In the GeoGebra software what you insert in the typing bar is very important as it represent a sketch. Being able to sketch quadratic functions goes together with the steps one goes through to represent algebraic equation graphically. Most learners liked everything about using GeoGebra to sketch the quadratic functions. However, educators should facilitate learning process when technology is integrated.

Interview question 7 Would you recommend use of the GeoGebra software to other learners? Why?	
Participants	Responses
Learner 1	Yes, because when you sketch in your book there are many mistakes.
Learner 4	Yes, because GeoGebra is something that is possible while learning online. Is not that tough when you learn online because is more suitable for our mind and to understand everything. I would like to recommend other learners to learn online and understand simple.
Learner 5	Yes, because using GeoGebra is easy than doing in the books, you have to start by doing a table for your graph.

Learner 6	Yes. Because it is helping you how to draw the functions.
Learner 8	Yes. Because it will help them.

Table 4.8. Represent responses to question 7

The concepts were addressed in a manner that alerted learners in their learning that they had to compare the use of the GeoGebra software with the pen and paper method. I became engaged in learners' learning in order to gauge their understanding of what we did in an online classroom. Demonstration of concepts on GeoGebra as we were sketching functions under different conditions motivated learners in their learning. In their experience most learners acknowledged that integrating technology in sketching of quadratic functions improved their understanding. All learners expressed that using GeoGebra should be recommended and implemented in classrooms for learning purposes.

4.3.1.3. Integration of technology and content

Interview question 1 What did you find interesting when using the GeoGebra software to sketch quadratic functions?	
Participants	Responses
Learner 1	It does not take time because I just type only.
Learner 4	I understood everything you were doing, and the graphs were simple. I understand how to sketch the graphs.
Learner 5	Sketching quadratic functions using GeoGebra was easy than doing in the book because in the book you start by drawing a table.

Learner 6	When I was plotting the graphs, it showed that when a is negative it goes down and when a is positive it goes up.
Learner 8	The reflection graphs.

Table 4.9. Represent responses to question 1

Learners indicated that the use of technology made it easier for them to sketch quadratic functions. They emphasised that concepts of the content were understood better when the GeoGebra software was used. Learner 5 compared the use of technology to sketch quadratic functions with the traditional way of doing it. The learner found GeoGebra to be an easy tool to sketch rather than that of using a table with the $x\ and\ y$ coordinates on a paper. Again, it was found that GeoGebra was an easy tool to use when sketching quadratic functions. GeoGebra provided learners with the opportunity to represent and interpret graphs (Sumartini & Maryati, 2021). Most of technology experience excited most learners and Learner 1 found GeoGebra as the application that saves time when one sketches quadratic functions.

According to Learner 8, GeoGebra displayed the reflected graphs in a pleasing manner that was interesting. The software allows as many as possible sketches reflecting on the original sketch. However, the use of pen and paper may be time consuming to have as many reflected sketches as possible. Learner 8 could have found other things interesting but decided to choose the reflection of graphs as they were assessed on this concept. Learner 6 demonstrated the barrier with the language of learning as she responded to the interview questions (refer to table 4.5). However, she identified the concept that was taught in the first lesson and outlined the effect of a as what she understood. Learner 4 indicated that she understood how to draw the graph and found the tool interesting as it made sketching simple. But the response might not mean that she can sketch the graph on her own. The school where the study was conducted still uses chalk boards, papers and pencils for teaching and learning.

Interview question 6
Compared to the past, how do you think using the GeoGebra software improved your knowledge of sketching quadratic functions?

Participants	Responses
Learner 1	It helps on graph reflection because in normal class I was not able to understand. It helped a lot.
Learner 4	Using GeoGebra learning online I did not face anything bad; everything was possible. It made me understand everything so learning this GeoGebra online comparing with my past was simple for me.
Learner 5	Using GeoGebra improved my knowledge because since back then quadratic functions I was not understanding them but doing those classes online when the time goes on, I did understand some of them. And I did differentiate shape.
Learner 6	It improved on plotting functions on GeoGebra and other functions.
Learner 8	By showing that $a > 0$ or $a < 0$. And if $a > 0$ the graph will have a sad shape and if eh…. If $a > 0$ the graph will have a smile shape and if $a < 0$ the graph will have a sad shape

Table 4.10. Represent responses to question 6

The use of GeoGebra improved the learner's understanding of quadratic functions and how to sketch the reflection of it as indicated by Learner 1. The learner could have gained knowledge regarding the reflection of graphs. The GeoGebra is the software suitable for developing the abilities of conceptual and procedural understanding (Sumartini & Maryati, 2021). Learner 4 might have wanted to say as she compared the use of the GeoGebra software with pen and paper method, what was just experienced during the online was the easiest. It could be that GeoGebra made learning easier in sketching quadratic functions during the lessons which might have been the case when she was responding to the individual activities.

Learner 5 expressed that her understanding of the concepts was poor before engaging with the online lessons. As time went on with the online lessons, the knowledge of the learner improved. The contributing factors could have been the choice of the software to sketch the quadratic functions and how I strategized the use of it to teach the concepts. GeoGebra proved to be the easiest application software to implement when teaching graphs. It appeared that I made the right decision of integrating technology to deliver the content. During the introduction sessions, it was explained that GeoGebra was a technological tool that would enable us to sketch different types of functions and also to address other content of Mathematics. However, there are many types of functions, but this study focused on quadratic functions alone. Most learners were able to notice that GeoGebra assisted in sketching functions. That was presumed during the lesson as I demonstrated using all the parameters of quadratic functions. Learner 8 indicated that the demonstrations of effect of a on GeoGebra with different sketches improved their understanding of functions.

Interview question 9 What would you recommend to teachers for improvement when assessing you through the GeoGebra software to sketch quadratic functions?	
Participants	Responses
Learner 1	They must allow us to use GeoGebra when we sketch graphs.
Learner 4	That they should teach us online as I understood the most when I was learning GeoGebra. I understand so much and I have improved.
Learner 5	Recommend them to help us know the laptops and help us to sketch the graphs with GeoGebra in the laptops than drawing in the books.
Learner 6	I will recommend them to continue with our online lessons even if we are done.

Learner 8	To have more learners in her/his class.

Table 4.11. Represent responses to question 9

From learners' responses, I found that learners recommended educators to use technology to improve and enhance their understanding. This meant that creativity is needed in educators as they impart knowledge to their learners. The traditional method of teaching the sketching of quadratic functions might be time consuming and complicated as many sketches were to be added in same Cartesian plane.

Learner 8 supported the use of technology in classroom to encourage learners. However, learners did not specify where, how and what to be improved when using the GeoGebra software. Learners did not sketch graphs on their own during the lesson. Lack of resources costed us the opportunity to conduct assessment for learning on sketching.

The learners recommended that the educators should engage them in the use of technology towards their learning. They preferred using the GeoGebra software to sketch graphs, rather than sketching in a book during the lessons. They emphasised that the use of the GeoGebra software should be implemented as it improved their understanding. Therefore, unpacking the content using GeoGebra should encourage learners to formulate questions and debate among themselves.

4.3.2. Theme emerged from TPK of TPACK

4.3.2.1. Integration of technology and pedagogy

Interview question 3 In sketching quadratic functions using the GeoGebra software which steps did you take?	
Participants	Responses
Learner 1	Unable caps lock for small letters, type and press shift for brackets. Other features were easy as they were on the GeoGebra.
Learner 4	I learnt how to see the coordinates and how to see the reflections in the graph. What I

	liked was how it reflect and how I understood.
Learner 5	Sketching quadratic function using GeoGebra I used the GeoGebra….I used the quadratic functions for sketching the graphs in the GeoGebra.
Learner 6	I use the y… the y…
Learner 8	Steps of showing that the coordinates of the graph are negative or positive.

Table 4.12. Represent responses to question 3

Learner 1 outlined the steps used on GeoGebra to sketch quadratic functions. The learner failed to recognise features on the screen (tool bar) that needs to insert on the typing space. The shortfall might concur with the training learners went through on the use of the GeoGebra software. It was highlighted that all participants used GeoGebra to sketch quadratic functions for the first time. Therefore, it could be learners needed more time to get used to all the necessary steps to sketch.

Looking at the response of learner 4, the learner might had known what to insert on the input space so that a sketch is presented but had no idea that those were the steps to sketch quadratic functions. On the other hand, how I introduced online teaching and learning contributed to the learner's learning in an online classroom. Learner 5 highlighted that she typed the quadratic functions given in GeoGebra to sketch the graphs. However, the steps were not elaborated further. In this instance, the learner was not able to identify the next procedure to follow when typing in the equation.

The two figures below demonstrate that the procedure is also important, as just typing the quadratic function might result in an error. One must create sliders that accommodate the quadratic equation. Figures below were captured from an online lesson when using GeoGebra to sketch quadratic functions. Typing the given equation followed by enter did not reflect the graph. Instead, the message popped out "Unknown command: a" which was highlighted in red. The error message was a direction to insert the value of a. Now the value of a below the red dot had been identified to be -2.

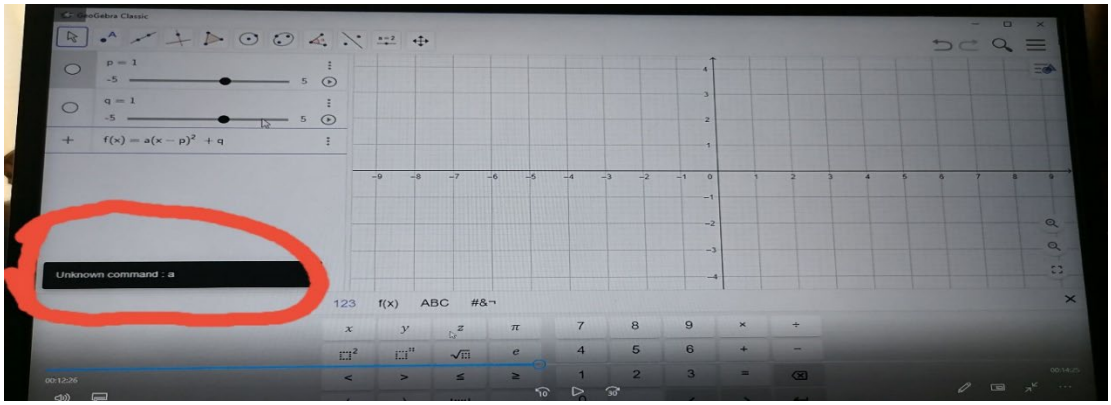


Figure 4.32. Error message

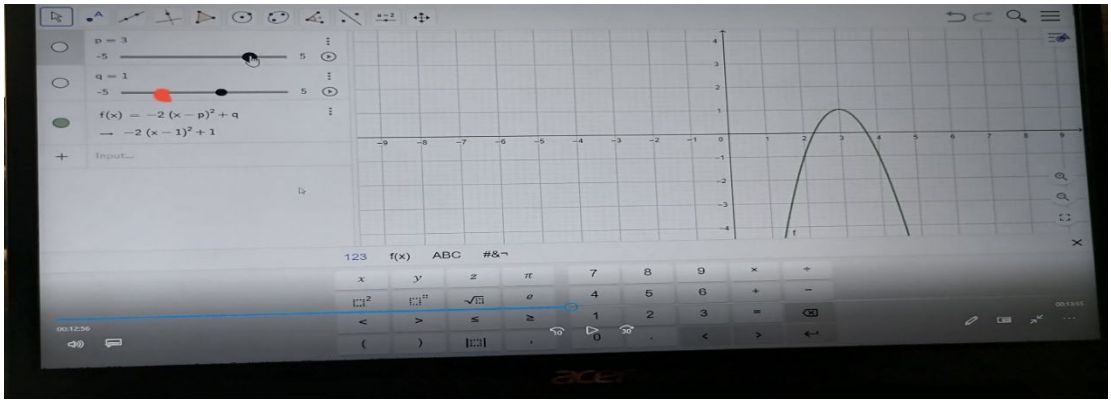


Figure 4.33. Error corrected

The majority of responses reflect that the participants were able to use tools and aids in the GeoGebra to sketch quadratic functions. During the lesson, I demonstrated errors that might results when typing on the tool bar to sketch quadratic functions.

Learner 6 seemed to be confused about the steps to sketch, or it could have been that she did not follow the method applied during the demonstration on how to use the GeoGebra software. The learner failed to answer the question. Summarising from the results, the strategies used in learning the sketch of quadratic functions when using GeoGebra was more of a demonstration than learner centred. Maybe for learners to master the steps, they should have been offered the opportunity to go step by step individually in a classroom under the supervision. Again, they should have collaborated to have a deeper understanding.

Interview question 4 What were your challenges when being assessed online?	
Participants	Responses

Learner 1	Internet connection was poor.
Learner 4	My challenge was to understand what I was learning online and I saw that learning online was better than face-to-face because we were given many examples.
Learner 5	I had no challenges it was easy when doing classes online.
Learner 6	I did not have any challenges.
Learner 8	Data and network connection.

Table 4.9 represent the responses to question 4

Responding to the question, learners outline a number of challenges they faced during their online learning. The progress of learning when technology was used was disturbed by these challenges. Learner 1 had raised the challenge of poor network connection in the area. During load shedding, and power reduction network was extremely poor. The online lessons were disturbed to the point that most of the lessons moved to the next day in order to complete what had been prepared. Learners 5 and 6 did not experience any challenges when learning online. For that response, it would be that the learner was too excited for new exposure to the use of technology in her learning. Learner 8 identified two challenges he experienced during the online lessons. At first, the school offered learners Wi-Fi access to connect. Unfortunately, the Wi-Fi accept limited number then participants failed to connect. Sometimes the connection was poor due to everyone in the school using it. For that reason, participants were provided with data at school premises to connect their mobile devices for attendance.

Interview question 8 What advice would you give to other learners when using the GeoGebra software to sketch quadratic functions?	
Participants	Responses
Learner 1	When you sketch a graph on a GeoGebra learners must relax and focus to avoid making mistakes.
Learner 4	Is to take their time and focus on doing GeoGebra when they are learning. They

	should focus and take notes in online classes.
Learner 5	I will advise them to ask for help if they don't know how to start by sketching quadratic functions using GeoGebra from teachers or other learners who know about it.
Learner 6	I will advise them to use the method that they know so that their graphs are perfect.
Learner 8	To help in knowledge that if $a > 0$ you will see a smile shape and if you don't see a smile shape it means is a wrong graph.

Table 4.14. Represent responses to question 8

Learner 1 and 4 emphasised the importance of maintaining focus when engaged on using the GeoGebra software for learning to avoid mistakes. Therefore, this strategy for learning could enable the integration of technology effectively. Teaching method that was applied could be seen as the cause to the poor understanding of how to assist someone on using GeoGebra. Regular use and experience on GeoGebra should aim at improving learners' performance and enhancing their mathematical competencies. The teaching strategies are important when integrating technology to teaching and learning. There was a need for thorough demonstration of all the steps and access to all features of GeoGebra to participants during orientation.

In summary, learners seemed to have not understood all the steps in sketching quadratic functions using GeoGebra software. I found misconceptions regarding parameters which led to errors committed when moving slides. The knowledge of technology also played an important role. Learners' mathematical thinking were displayed however, interpreting the questions using GeoGebra was difficult (refer to learners' responses). Most learners were excited about using GeoGebra however, that does not mean they understood the concepts.

4.6. Chapter conclusion

This chapter presented data in the form of transcripts, figures and tables. The chapter outlined what transpired during the online lessons with regard to how to sketch quadratic functions in an online lesson using GeoGebra. In addition, the analysis of data collected from lesson observations were guided by the TPACK theoretical framework. In lesson observations, learners were engaged in lesson activities and

discussion targeted the mathematical competencies learners displayed as outlined by Niss (2003). The study presented the concluding thoughts of results from data collected from lesson observations. The study concluded the chapter by presenting analysis of data collected from interviews.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

This chapter offers a summary of the findings, conclusions, and limitations of the study. The recommendations were also outlined. In the literature section, the two theoretical frameworks were unpacked to guide the analysis of the study. Learners from Grade 11 were purposively sampled to participate, and I was the research educator in the study. Lesson observations that included learners engaging in activities and interviews provided data that helped to answer two research questions of the study which are:

1. What are the learners' competencies in sketching quadratic functions online?
2. How to teach the sketching of quadratic functions online using the GeoGebra?

5.1. Learners' mathematical competencies when sketching quadratic functions

According to Niss (2003), single activity is inadequate to assess the whole set of mathematical competencies. In this study, the content of the curriculum chosen was sketching of quadratic functions which might have limited the exploration of all the set of mathematical competencies. In my content knowledge as Mathematics educator, learners should have all mathematical competencies when sketching quadratic functions. However, it depends on the assessment for specific competencies to be displayed. It takes a range of different activities to provide a broadcast of the whole set of mathematics competencies (Niss, 2003).

The findings of the study show that there were four mathematical competencies that were constantly displayed by learners. Those were thinking mathematically, representing mathematical entities, handling mathematical symbols and formulas, communicating in, with and about Mathematics and making use aids and tools. The GeoGebra software was a tool that was manipulated to sketch the quadratic functions. It was found that if learners were having laptops to participate in the online learning rather than use of smart phone they could communicate the mathematical language by making use of technology tools and aids correctly.

The findings of this study showed that thinking mathematically can have misconceptions and results in error when using technology tools. This could result from lack of experience to integrate technology and content by the facilitator of the lesson. The results from learners' responses to activities revealed that there might be

lacked the teaching experience when technology was implemented to drive learners to display the mathematical competencies efficiently. Therefore, learners could have displayed more competencies when learning how to sketch quadratic functions using GeoGebra.

During the lessons when learners responded to questions posed, some failed to connect prior knowledge to build on the new knowledge. It could be that they lacked a good foundation of Mathematics and that resulted in them failing to think mathematically. It was revealed that learners had knowledge of formulas and mathematical symbols but failed to handle them accordingly when sketching quadratic functions using GeoGebra. Numerous studies indicate the importance of engaging learners in activities that develop and enhance learners' mathematical competencies when learning (Vorobjovs, 2020). The lesson plans gave me the opportunity to frame the activity questions that cover the concept of sketching quadratic functions under different conditions.

Sketching quadratic functions using the change of slide on GeoGebra as a process might have affected how learners answered the activity of lesson 3. In each activity given to learners during the online teaching and learning, mathematical competencies were identified and discussed. However, there were difficulties and challenges experienced during teaching and learning. The activities were given to learners to write and send their work through email address platform. The results showed that mathematical modelling was not addressed by the activities learners had to submit but was rarely expressed during the lesson. The mathematical competencies dominated in different responses were:

- Thinking mathematically
- Representing mathematical entities
- Handling mathematical symbols and formulas
- Communicating in, with and about Mathematics
- Making use of aids and tools

5.2. Teaching sketching of quadratic functions online

The sketching of quadratic functions using GeoGebra during online learning improved. I argue that such teaching draws the learners' attention and focus to their learning.

However, online teaching in rural schools had many challenges that may have affected the learners' learning using GeoGebra. Nevertheless, exposure to the integration of technology in teaching and learning led to positive technological knowledge. I found this consistent with the study of Umugiraneza et al. (2018) and Juanda et al. (2021). It was notable that I required the content and pedagogical knowledge to integrate technology when teaching learners. The experience of educators count in the integration of technology. Therefore, the exploration of the integration of technology, pedagogy, content knowledge and learners' mathematical competencies when sketching quadratic functions online was limited.

Lack of experience stresses educators, according to Jeong and So (2020), online classes stress out educators to even resort to trial-and-error approaches. Most educators struggled to familiarise themselves with the new teaching strategies of integrating technology. In this study, I started with Google Meet but failed to record the lessons during the introduction. However, I resorted to Zoom application that enabled the recording of the lessons. During the interviews, learners stated that GeoGebra reduced many mistakes when sketching quadratic functions.

Emphasis was placed that I continue using GeoGebra to teach and assess the sketching of quadratic functions as part of the South African curriculum. This was drawn from the last question of the interviews with participants. Ziatdinov and Valles (2022) asserted that GeoGebra is user friendly to a new user and makes things easier. It is a useful tool that improves the performance and understanding of learners towards their learning in sketching quadratic functions.

Most interviewees sounded excited about the integration of technology in classroom for learning purposes. However, their responses showed that they had misconceptions about the content taught using GeoGebra. GeoGebra was at some point labelled a function, while it is a tool used to sketch a quadratic function. In summary of the interviews, learners might have found the tool interesting and easy to sketch quadratic function but not improved their understanding of the concepts taught. A lack of resources, poor connectivity and my method of teaching would have resulted in ineffective learning.

In the study, it was observed that in some instances where connectivity issues arose there was inactive participation. Due to poor technology infrastructure in the school,

the exposure to use of technology for teaching and learning came unexpectedly due to advent of covid-19 pandemic. In addition, learners would have reflected and responded differently to their learning if they were exposed to technology in their learning before the study was conducted. Therefore, poor infrastructure resulted in less effective teaching and learning.

TPACK guided the study and assisted in exploring the integration of technology with other knowledge I possessed. On the other hand, Niss (2003) helped to understand the learners' development of abilities when sketching quadratic functions. There was a variety of software that could have been used to sketch quadratic functions. Hence, the results shared in this study draw on the use of GeoGebra software. Zoom software was used as an online platform for teaching and learning the sketching of quadratic functions using GeoGebra.

Limited technology resources, data and poor network connection were the most challenges experienced in the study. The poor connectivity sometimes made a lesson overlap with another on the following day for the completion of the lesson. Therefore, the challenge led to online lessons labelled as time consuming. Learner absenteeism was also experienced however, the online lessons continued. Due to a lack of resources, learners were denied the opportunity to engage fully in assessment for learning the content of sketching using GeoGebra in the lesson.

The study revealed that the presence of content and pedagogical knowledge matters for integration of technology in teaching and learning. Thus, the use of GeoGebra not only improves learner performance but enhances the participants' skills development. Next is a summary of what the study found:

- Technological knowledge of participants was limited regarding the software in online teaching and learning.

I had a challenge with the choice of online platform that accommodated the needs of a mathematical classroom. Zoom platform was chosen to conduct the online lesson. During the observations I kept on reflecting on the previous lessons for improvement. However, without experience and training around using technology devices, it became difficult to improve the practices that involved teaching and learning. The features of GeoGebra to sketch graphs are many but our focus was to use the ones for quadratic functions. Therefore, Zoom allowed us in the study to conduct the online lessons

freely. The platform enabled me as the researcher to record the lessons. The process of recording the lessons on Zoom created room for improvement on using GeoGebra to sketch quadratic functions.

- The content knowledge and pedagogical knowledge supported the carrying out of technology in classroom.

The content was relevant to the Grade 11 level and supported by the CAPS document. The effect of parameters was addressed accordingly with demonstration on GeoGebra software. However, the pedagogy that was channeled by lack of resources did not result to effective teaching. It was revealed that resources available limited the processes of making plans of the lessons and strategies applied for teaching and learning sketching of quadratic functions.

- The technology, content and pedagogical knowledge cannot be separated or work alone when conducting online lessons, thus integration is important.

Knowledge of content alone would not guide the facilitator on the use of online platform to conduct the lesson. Having knowledge of the technological tool allowed me to strategize on how to implement the lesson. Technological knowledge alone also could not serve the purpose of fulfilling the Mathematics curriculum. I managed to apply the content knowledge I had in my experience to locate the relevant tool that would advance learners' understanding of the content and enhance their mathematical competencies when sketching quadratic functions. As such I worked on the strategies to engage learners to the online learning. During the lessons, I posed questions to derive learners' interactions among themselves.

- Online lessons took time as a result of poor connectivity. Poor connectivity is caused by poor infrastructure, load shedding and reduction.

Teaching the sketching of quadratic functions online required a stable network. Disturbance resulted sometimes in learners losing interest of what they were learning. However, online lessons could affect the effective teaching and learning when conducted in a poor network connectivity site. Therefore, teaching online required a good connectivity from good infrastructure so that there are no disturbance of the lessons. In the study, we did not experience the smooth running of online lessons

however, sketching of quadratic functions using GeoGebra was done as it did not require any special connectivity.

- The study revealed that as the educator, I shaped online teaching by the choice made on software used.

There were no break out rooms for learners' collaboration. It might have enhanced the effectiveness of online teaching. It might have been caused by a lack of technological knowledge I had when preparing and conducting the online lessons. Lack of experience on the use of technology limited the learning methods. Therefore, different teaching methods were practised but less of learner-centred method prevailed.

- Sketching quadratic functions using GeoGebra saved time, rather than using paper and pen and was easy for learners.
- It was revealed that different mathematical competencies were derived from different questions of the activities.
- Using GeoGebra to sketch quadratic functions improved learners understanding and construction of new knowledge.
- Learners' participation in some instances due to connectivity issues were inactive during the online lessons and thus required that I built on their responses to provoke their thinking.
- Conducting online lessons enhanced my technological knowledge towards the Fourth Industrial Revolution.

Educators who might opt to integrate technology in their teaching of Mathematics content would need to acquire knowledge on how to implement it. All relevant knowledge to teaching and learning must be balanced for effective results. This would help learners and might enhance their mathematical competencies as they respond to given activities. Regular use of GeoGebra and other technological tools might enable educators to explore all features of it and conduct effective lessons. Demonstrations of concepts using relevant technological tools was observed in the study. The strategy on teaching and learning online employed was that the lesson was introduced, we went through activities together, questions were posed, and learners were given individual activities. However, participation of learners was passive at the start. Interactions among them resulted from questions I posed. Therefore, integrating

technology, content and pedagogical knowledge effectively result in active teaching and learning.

5.3. Limitation of the study

Firstly, the study was conducted in a rural school with poor technology infrastructure which might have impacted on the findings. In addition, the school had few learners doing Mathematics in Grade 11, therefore, the results may not be generalised. Besides, the school and learners had few technology devices. Had this study been conducted in a school with many laptops, there would have been active participation and discussions by the learners during the online lessons. Lastly, load shedding and reduction. The study took longer than expected due to poor network connection resulting from load shedding and power reduction.

5.4. Recommendations

It was clear from the findings that the participants' technological knowledge was insufficient to engage in online lessons. Educators should seek training and acquire the technological knowledge to integrate with content and pedagogy and apply it in their classrooms. DBE (2019) aims at defining the professional development for digital learning in the education system. There is a need for curriculum developers and educators to shift away from pen and paper to using GeoGebra in the sketching of functions during the presentation of lessons on graphs. Learners' performance tends to improve when using GeoGebra to sketch.

Educators should design different activities that cover most of the mathematical competencies. Therefore, I suggest that researchers should look at the four cognitive levels of Mathematics versus mathematical competencies. This might result to assessments that address different mathematical competencies. The study revealed that experience counts in conducting online lessons, therefore, educators should practise the use of technological tools in their regular teaching and assessment.

In a study by Augustina (2022) which x-rayed the impact of online learning tools on teachers' effectiveness in public secondary schools, the author suggested that teacher training is needed in online learning for the effectiveness of teaching. This was imposed by the failure to apply instructional technology during teaching and learning

practices. In this study, the research site was a small school that resulted in limited participants. It is, therefore, recommended that further studies involving a wider population sample be conducted on teaching the sketching of quadratic functions using GeoGebra online. Another research could be done on how poor technology infrastructure and network connectivity in rural areas affect teaching and learning in the 4IR.

5.5. Conclusion

In this chapter, a summary of the findings was presented. The chapter captured the findings from data collected from online lessons observations that engaged learners' responses to activities and interviews. The limitations of the study have been captured as well. Moreover, the recommendations from the study are presented.

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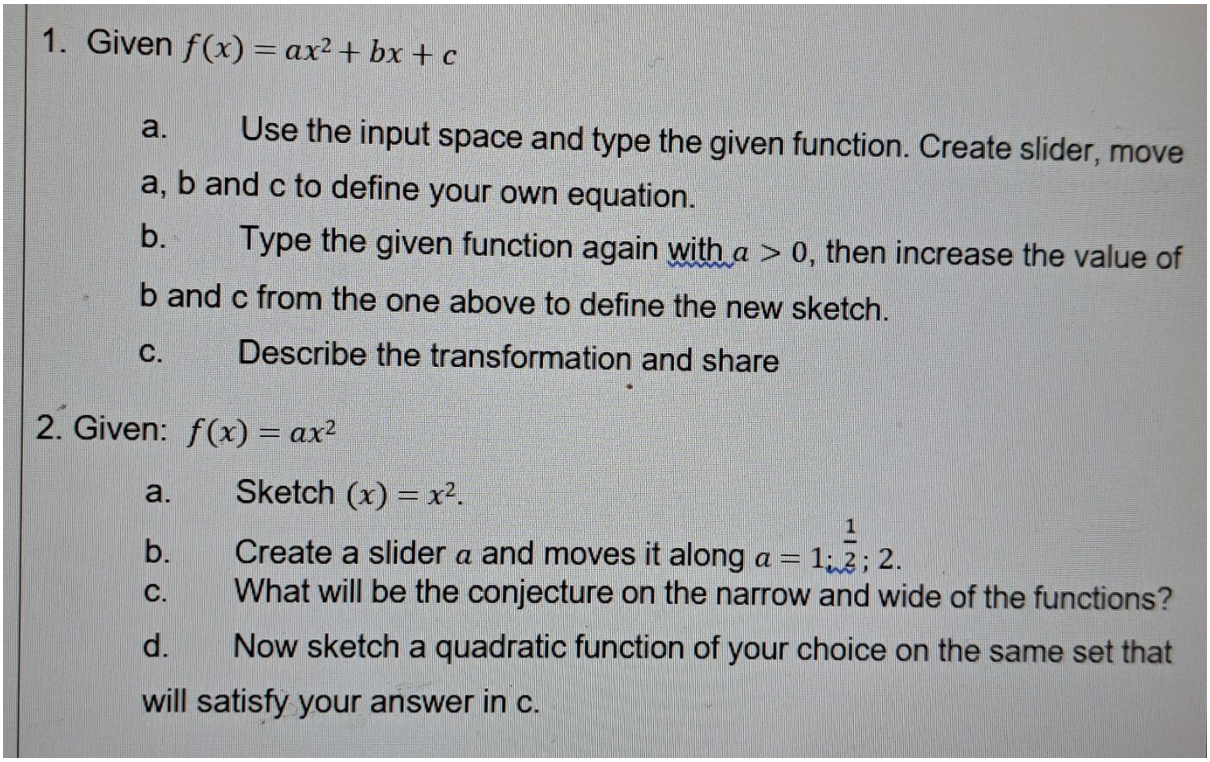
7. APPENDICES

APPENDIX A: LESSON ACTIVITIES

Activity 1



1. Given $f(x) = ax^2 + bx + c$

   a. Use the input space and type the given function. Create slider, move a, b and c to define your own equation.

   b. Type the given function again with $a > 0$, then increase the value of b and c from the one above to define the new sketch.

   c. Describe the transformation and share

2. Given: $f(x) = ax^2$

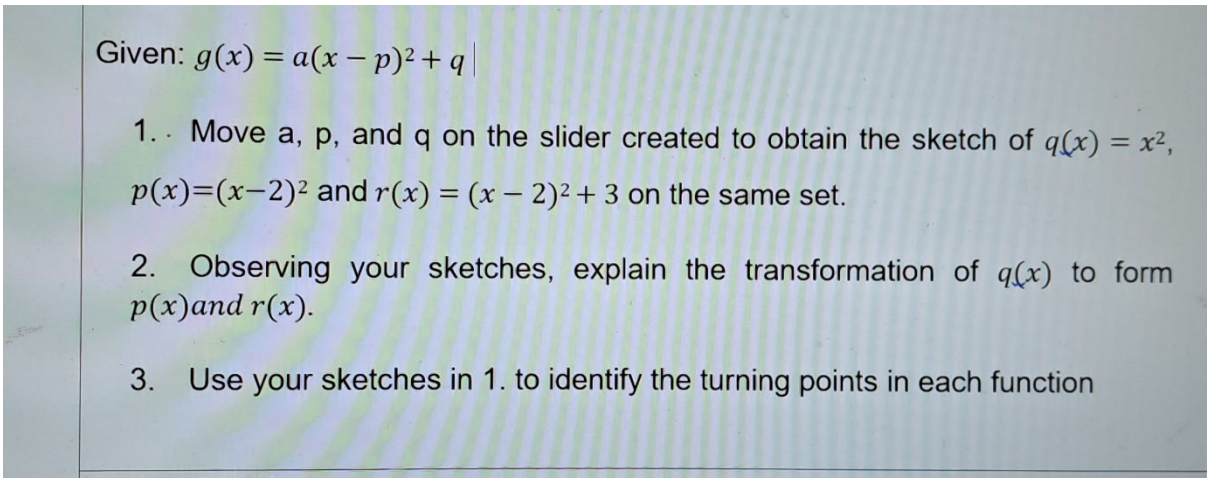
   a. Sketch $(x) = x^2$.

   b. Create a slider a and moves it along $a = 1; \frac{1}{2}; 2$.

   c. What will be the conjecture on the narrow and wide of the functions?

   d. Now sketch a quadratic function of your choice on the same set that will satisfy your answer in c.

Activity 2



Given: $g(x) = a(x - p)^2 + q$

1. Move a, p, and q on the slider created to obtain the sketch of $q(x) = x^2$, $p(x)=(x-2)^2$ and $r(x) = (x - 2)^2 + 3$ on the same set.

2. Observing your sketches, explain the transformation of $q(x)$ to form $p(x) and\ r(x)$.

3. Use your sketches in 1. to identify the turning points in each function

Activity 3

1.Given: $f(x) = -\frac{1}{2}x^2 + 2x + 6$

1.1. Create slider to sketch $f(x)$, move slider c for which $= -\frac{1}{2}x^2 + 2x + 6$ has equal roots.

1.2. What do you notice about the $y - intercept$? Hence determine the value of k for which $= -\frac{1}{2}x^2 + 2x = k - 6$ has equal roots?

1.3. Sketch any function with no real roots and identify its turning point.

Activity 4

1. Given $f(x) = x^2 + x - 12$

a. Plot point $A(2; 2)$ on the Cartesian plane

b. What do you notice about the point as it reflects about the $x - axis\ and\ y = x$? Note that the reflection is on the toolbar.

c. Sketch the given quadratic function on a new Cartesian plane.

d. What do you notice about the graph as it reflects about the $x - axis$?

Activity 5

1. Sketch the following quadratic functions on the same set $k(x) = -x^2 + 16$ and $p(x) = -x^2 + 6x + 7$.

2. Make a point on the symmetric line of $k(x) and\ p(x)$, then find the distance between.

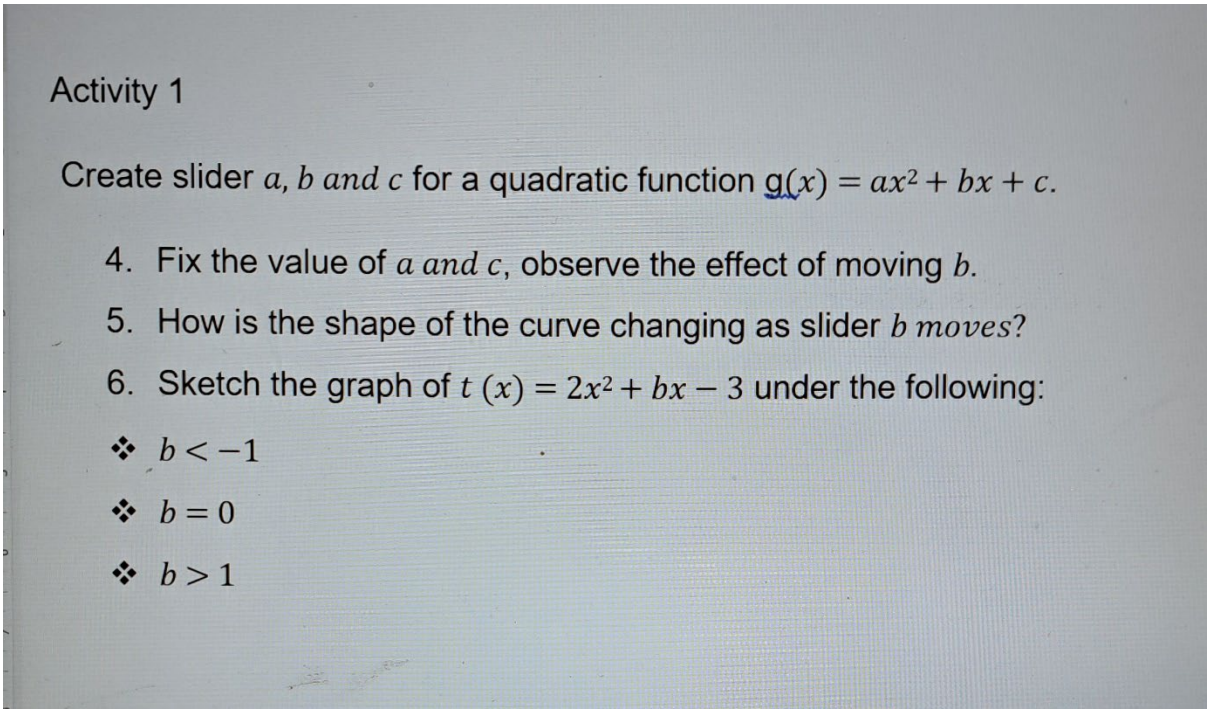
3. Count the difference between the maximum values of $k(x) and\ p(x)$

4. On slider let $a > 0$ and create a new function name it t(x).

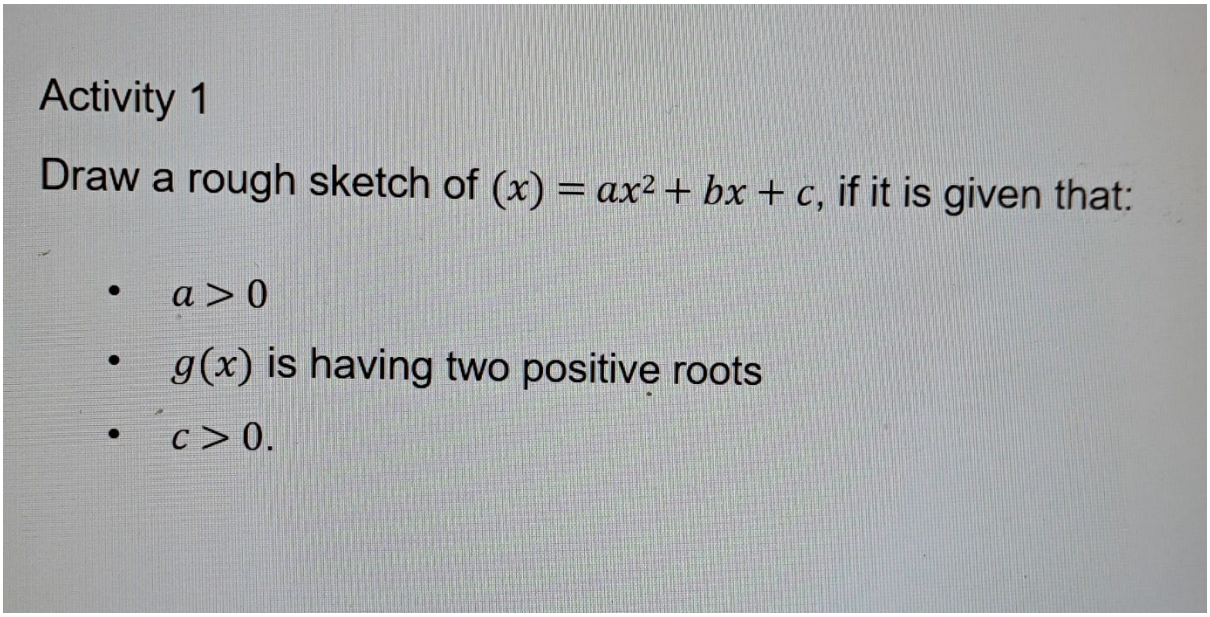
5. Use your own label, to label point of intersection.

WEEKLY SESSION ACTIVITIES

SESSION 1



SESSION 2



SESSION 3

Activity 1

$(x) + 3 = -2x^2$ *and* $y = x - 3$

a. Are the two functions intersecting? Support your answer graphically on your GeoGebra sheet.
b. If yes, mark the points of intersection on the sheet with A and B
c. Which toolbar did you notice as useful to find the length? Determine the length of points of intersection
d. Make a use of free hand shape to mark the range of the quadratic function.

SESSION 4

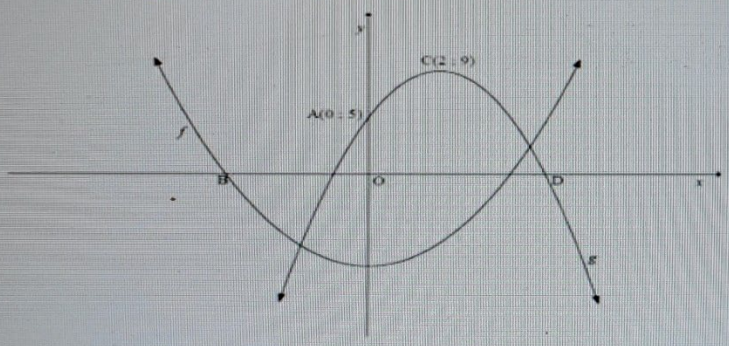
Activity 1

1. The graph of a quadratic function h has the x −intercepts at $x = -5$ and $x = -1$. The y −intercept at $y = 5$. Sketch the graph of h.
2. Hence, label the roots of the quadratic function A and B.

SESSION 5

Activity 1

1. The sketch below represents the quadratic functions of $(x) = \frac{1}{2}x^2 - 8$ and g. The turning point of g is $(2; 9)$ and the $y - intercept$ of g *is* $(0; 5)$. B and D are the $x - intercepts$ of f *and* g respectively.



1.1. Determine the equation of g.
1.2. Calculate the length of BD.
1.3. If it is given that the new axis of symmetry for g is 3 that is the new turning point is $(3; 9)$, draw the new graph and clearly show the intercepts.

APPENDIX B: INTERVIEW QUESTIONS

INTERVIEW QUESTIONS

1. What did you find interesting when using GeoGebra to sketch quadratic functions?
2. What is it that you did not like about using GeoGebra to sketch quadratic functions?
3. In sketching quadratic functions using GeoGebra which steps did you take?
4. What were your challenges when being assessed online?
5. In your experience, was the online assessment fair and effective for your learning? Explain.
6. Compared to the past, how do you think using GeoGebra improved your knowledge of sketching quadratic functions?
7. Would you recommend use of GeoGebra to other learners? Why?
8. What advice would you give to other learners when using GeoGebra to sketch quadratic functions?
9. What would you recommend to teachers for improvement when assessing you through GeoGebra to sketch quadratic functions?

APPENDIX C: LETTER TO THE SCHOOL MANAGEMENT TEAM (SMT)

PO BOX 2206

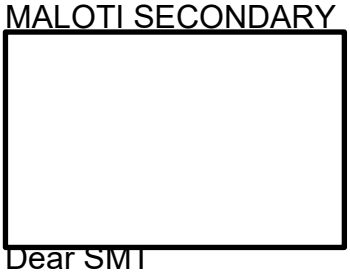
HOEDSPRUIT

1380

01 AUGUST 2021

SCHOOL MANAGEMENT TEAM (SMT)

MALOTI SECONDARY



Dear SMT

A REQUEST FOR PERMISSION TO CONDUCT RESEARCH FOR A MASTER DEGREE

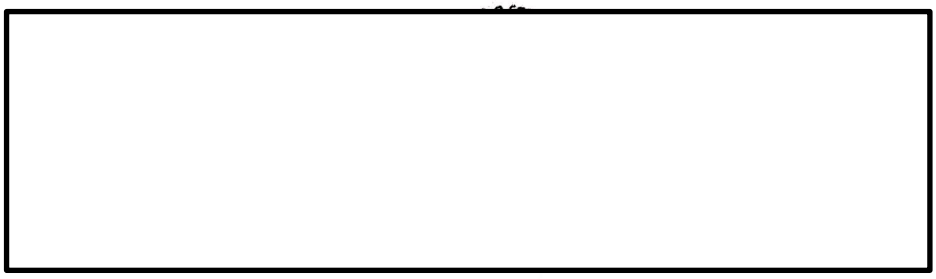
I hereby request for permission to conduct research at your school as part of my study that I am conducting at University of Limpopo. I am conducting research on: **Teaching the sketching of quadratic functions online: A case of a rural school in the Mopani District, Limpopo Province, South Africa.**

The study involves no harm to the school and participants. I will also reassure the anonymity and the confidentiality of the data. The study will employ case study in which participant observations and semi-structured interviews will be used to collect data.

I choose Grade 11 and decided on the content of sketching quadratic functions as learners spend more time and struggle to provide a neat sketch using paper and pencil. Furthermore, it will provide me as their educator the opportunity to identify relevant methods of assessment.

Yours Sincerely

Kgwedi IP



TO WHOM IT MAY CONSERN

The above matter refer:

1. I MALATJIE MM the principal of MALOTI SECONDARY acknowledge the receipt of KGWEDI IP's letter to conduct a RESEARCH in our school.

2. The research was conducted in our school and learners were co-operating and have gained a lot from her.

3. I hope her research will be highly recognized in your institution.

4. Thanking you in advance.

Kind Regards

APPENDIX D: LETTER TO PARTICIPANTS AND PARENTS

APPENDIX D

LENGWALO LA GO YA GO MOTSWADI

Ke kgopela tumelelo ya gago motswadi gore ngwana wa gago a tšeye karolo ka gare ga dinyakišišo tša thuto yaka. Go tšea karolo ga ngwana wa gago go dinyakišišo tše ke boithaopo. Thuto ya dinyakišišo tše e tla thuša barutwana go matlafatša kwešišo ya bona go ntšheng kerafo ya quadratic functions. Direkhote kamoka di tlo bolokwa sephiring. Ke kgopela le bale lengwalo le ka kwešišo, le ge go le bjalo, ngwana wa gago o tla gopotšwa ka se ke modira dinyakišišo.

Hlogo ya thuto ya dinyakišišo ke ye: **Teaching the sketching of quadratic functions online: A case of a rural school in the Mopani District, Limpopo Province**

Nna, motswadi goba mohlokomedi wa ....., ke **dumelelana** goba **ganana** (kgetha e tee) le gore ngwana waka a tšeye karolo go dinyakišišo tše. Ke badile le go kwešiša dinyakwa tša lengwalo le mabapi le go tšea karolo go thuto ya dinyakišišo tše.

Boikano bja motswadi goba mohlokomedi: .....

Lefelo ..... letšatšikgwedi 2022

APPENDIX D

LENGWALO LA GO YA GO MOTSWADI

Ke kgopela tumelelo ya gago motswadi gore ngwana wa gago a tšeye karolo ka gare ga dinyakišišo tša thuto yaka. Go tšea karolo ga ngwana wa gago go dinyakišišo tše ke boithaopo. Thuto ya dinyakišišo tše e tla thuša barutwana go matlafatša kwešišo ya bona go ntšheng kerafo ya quadratic functions. Direkhote kamoka di tlo bolokwa sephiring. Ke kgopela le bale lengwalo le ka kwešišo, le ge go le bjalo, ngwana wa gago o tla gopotšwa ka se ke modira dinyakišišo.

Hlogo ya thuto ya dinyakišišo ke ye: **Teaching the sketching of quadratic functions online: A case of a rural school in the Mopani District, Limpopo Province**

Nna, motswadi goba mohlokomedi wa [redacted],
ke **dumelelana** goba **ganana** (kgetha e tee) le gore ngwana waka a tšeye karolo go dinyakišišo tše. Ke badile le go kwešiša dinyakwa tša lengwalo le mabapi le go tšea karolo go thuto ya dinyakišišo tše.

Boikano bja motswadi goba mohlokomedi: [redacted]

Lefelo Mothlakong letšatšikgwedi 15 June 2022

APPENDIX D

LENGWALO LA GO YA GO MOTSWADI

Ke kgopela tumelelo ya gago motswadi gore ngwana wa gago a tšeye karolo ka gare ga dinyakišišo tša thuto yaka. Go tšea karolo ga ngwana wa gago go dinyakišišo tše ke boithaopo. Thuto ya dinyakišišo tše e tla thuša barutwana go matlafatša kwešišo ya bona go ntšheng kerafo ya quadratic functions. Direkhote kamoka di tlo bolokwa sephiring. Ke kgopela le bale lengwalo le ka kwešišo, le ge go le bjalo, ngwana wa gago o tla gopotšwa ka se ke modira dinyakišišo.

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Boikano bja motswadi goba mohlokomedi: [redacted]

Lefelo Mohlakong village letšatšikgwedi 15 June 2022

APPENDIX D

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Ke kgopela tumelelo ya gago motswadi gore ngwana wa gago a tšeye karolo ka gare ga dinyakišišo tša thuto yaka. Go tšea karolo ga ngwana wa gago go dinyakišišo tše ke boithaopo. Thuto ya dinyakišišo tše e tla thuša barutwana go matlafatša kwešišo ya bona go ntšheng kerafo ya quadratic functions. Direkhote kamoka di tlo bolokwa sephiring. Ke kgopela le bale lengwalo le ka kwešišo, le ge go le bjalo, ngwana wa gago o tla gopotšwa ka se ke modira dinyakišišo.

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Boikano bja motswadi goba mohlokomedi: [redacted]

Lefelo Leretjeng letšatšikgwedi 15 June 2022

APPENDIX D

LENGWALO LA GO YA GO MOTSWADI

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Boikano bja motswadi goba mohlokomedi: [redacted].

Lefelo Leretjeni..... letšatšikgwedi 15 June..... 2022

APPENDIX D

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Boikano bja motswadi goba mohlokomedi: [redacted]

Lefelo Mohlakong letšatšikgwedi 15-06 2022

APPENDIX D

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Ke kgopela tumelelo ya gago motswadi gore ngwana wa gago a tšeye karolo ka gare ga dinyakišišo tša thuto yaka. Go tšea karolo ga ngwana wa gago go dinyakišišo tše ke boithaopo. Thuto ya dinyakišišo tše e tla thuša barutwana go matlafatša kwešišo ya bona go ntšheng kerafo ya quadratic functions. Direkhote kamoka di tlo bolokwa sephiring. Ke kgopela le bale lengwalo le ka kwešišo, le ge go le bjalo, ngwana wa gago o tla gopotšwa ka se ke modira dinyakišišo.

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Boikano bja motswadi goba mohlokomedi: [redacted]

Lefelo ..Mohlakong.. letšatšikgwedi ..15..June..... 2022

APPENDIX D

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Hlogo ya thuto ya dinyakišišo ke ye: **Teaching the sketching of quadratic functions online: A case of a rural school in the Mopani District, Limpopo Province**

Nna, motswadi goba mohlokomedi wa Mashita Mamanyoha,
ke **dumelelana** goba ~~**ganana**~~ (kgetha e tee) le gore ngwana waka a tšeye karolo go dinyakišišo tše. Ke badile le go kwešiša dinyakwa tša lengwalo le mabapi le go tšea karolo go thuto ya dinyakišišo tše.

Boikano bja motswadi goba mohlokomedi: .....

Lefelo Fobeni letšatšikgwedi 15 June 2022

APPENDIX D

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Boikano bja motswadi goba mohlokomedi: [redacted].....

Lefelo Mohlakong..... letšatšikgwedi ...15 June..... 2022

APPENDIX D

LETTER TO PARTICIPANT

Your permission is being sought to have you participate in this study. Your participation in the study is voluntary. The study will help learners in improving their understanding of sketching quadratic functions. All the records will be kept confidential. I also ask that you read this letter with understanding however, you will be reminded of this by the researcher.

Title of the study: **Teaching the sketching of quadratic functions online: A case of a rural school in the Mopani District, Limpopo Province**

I ..... (Full name), **agree** or **disagree** (tick one) to participate in the research study. I have fully read and understand the content of the letter concerning the participation in the research.

Learners' signature: .....

Signed at ..... On this day ..... of 2022

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Signed at Mohlakong On this day 15 of June 2022

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Signed at ...Letjeni..... On this day ..... of .....15...June..... 2022

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Learners' signature: [redacted].....

Signed at Lenyenyeni..... On this day 15 of June..... 2022

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Learners' signature: [redacted]

Signed at Mohlakong On this day 15 of June 2022

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Learners' signature: .. [redacted] .....

Signed at ..... Foboni ..... On this day ..... of ..... 15 June 2021

APPENDIX D

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Learners' signature: [redacted]

Signed at Mohlakong On this day 15 of June 2022

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Learners' signature: [redacted]

Signed at Mohlaleng On this day ..... of 15 June 2022

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Learners' signature: ... [redacted] .....

Signed at .Mohlakong..village.. On this day ..... of ...15....June..... 2022

APPENDIX E: OBSERVATION INSTRUMENT

Topic: Quadratic functions

1. The technological content knowledge to be displayed when teaching sketching of quadratic functions online.

Element of TCK	Properties	What is observed
Knowledge of technology		
Knowledge of content to be taught	a. Indication of the necessary concepts of the topic. b. Given activities reflect content taught. c. Expectations of the lesson. d. Participants' experiences with the use of technology.	
Knowledge of learners' learning	a. The use of prior knowledge for construction of new one. b. Identification of errors and misconceptions.	
Integration of technology and content	a. Technology tool is conducive for learning. b. Accessibility of activities.	

2. The technological pedagogical knowledge to be displayed when teaching sketching of quadratic functions online

Element of TPK	Properties	What is observed
Knowledge of teaching strategies	a. Learners work individually and collaborate b. Teaching strategies and use of real-life	

	situations in the lesson.	
Integration of technology and pedagogy	a. Chosen tool allows learners to collaborate. b. Technology tool is associated with the given activities.	

APPENDIX F: ETHICS CLEARANCE CERTIFICATE

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 3935, Fax: (015) 268 2306, Email: anastasia.ngobe@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING: 23 February 2022

PROJECT NUMBER: TREC/06/2022: PG

PROJECT:

Title:	Teaching the Sketching Of Quadratic Functions Online: A Case of a Rural School in the Mopani District, Limpopo Province
Researcher:	IP Kgwedi
Supervisor:	Prof. RS Maoto
Co-Supervisor/s:	N/A
School:	Education
Degree:	Master of Education in Mathematics Education

PROF P MASOKO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE

The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:
i) **This Ethics Clearance Certificate will be valid for one (1) year, as from the abovementioned date. Application for annual renewal (or annual review) need to be received by TREC one month before lapse of this period.**
ii) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee, together with the Application for Amendment form.**
iii) **PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.**

Finding solutions for Africa

APPENDIX G: PERMISSION FROM DEPARTMENT OF EDUCATION

CONFIDENTIAL

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE PREMIER

TO: DR MC MAKOLA

FROM: DR T MABILA

CHAIRPERSON: LIMPOPO PROVINCIAL RESEARCH COMMITTEE (LPRC)

ONLINE REVIEW DATE: 19th – 30th MAY 2022

SUBJECT: TEACHING THE SKETCHING OF QUADRATIC FUNCTIONS ONLINE: A CASE OF A RURAL SCHOOL IN THE MOPANI DISTRICT, LIMPOPO PROVINCE

RESEARCHER: KGWEDI IP

Dear Colleague

The above researcher's research proposal served at the Limpopo Provincial Research Committee (LPRC). The committee is satisfied with methodological soundness of the proposal.

Decision: The research proposal is granted approval

Regards

Acting Chairperson: Dr T Mabila

Secretariat: Ms J Mokobi

Date: 03/06/2022

LESSON 1

Educator: All right. Thank you for attending the class. Can we start with our lessons? .. allow me to... .. change connection. Okay, I'm connected to Y7P. Right,... last time, as I've indicated that we're having a class on sketching of quadratic functions and unmute your mic if you are answering a question and unmute your mic if you want to ask something. You can also switch off the camera. Switch off the camera. Right, okay. Last time as we were talking, I also indicated that we must first start with the definition of a function. What is a function? Remember from grade 10's work, we also did functions and different types of functions, but now I want us to focus on quadratic functions. First of all, what we need to do, are you able to see the screen. Are you able to see what is on my screen? Are you able to see what is on my screen?

Learner 2: Yes.

Educator: Okay, right. Here's a definition of a function, a quadratic function. We are saying it's a polynomial function with one or more variables with highest degree of two. Any polynomial with more than one term is which is having a highest degree or should we say a highest exponent of two then that's that polynomial is called a quadratic function. So now here if you can check, I've indicated forms of quadratic functions. Here we are saying quadratic functions can be represented in three forms, which is the first form of $y = ax^2$ *or we can have* $y = ax^2 + bx$ *or we have* $y = ax^2 + bx + c$. *So it depends on the form that they will ask you. Then if you can check on the second form, we have* bx. *But on the first form, it means* $bx + c$ *is equal to zero. That's why we can have a quadratic function of this form. And this form is called the standard form of a quadratic functions. Are we together guys?*

Learners: Yes mam.

Educator: Right, then now we have the second form, which is in this form of $y = a(x \pm p)^2 + q$. *This form here, it shows that, pardon.*

Learner 8: some are not seeing anything.

Educator: I think they are out of the lesson because they are not visible here. Can they try to reconnect? Ask them to reconnect again. I'm just going to wait for a minute. If they fail to reconnect, can they please move and join one of these two groups that are

in the lesson? Are you winning guys? Hi Learner 5, are you winning? Learner 2 or Leaner 1, can you please ask the other group to join you? Can they please join?

Learner 8: Now they are in.

Educator: All right. Now let's continue. Okay, right. I was talking about the second form to say with the second form now, what do we have is another form of quadratic function, where in this is the turning point form, we call it the turning point form, where in p and q represented a turning point, the x value and the y value of the turning point. We'll talk more about this later on. The third form, it shows intercept of the function. If you can check it's in the form of $y = a(x - x_1)(x - x_2)$ *. All this when we remove the bracket trying to find the product we will be going back to the standard form. So this is the form that we use when we are given the intercepts of a function. Seems like you're not listening guys. What are you busy with? Right. Can we move? Can we move?*

Learners: Yes.

Educator: All right. Then now, actually, the objective or the main aim of this lesson is to talk about how a *affect the quadratic functions, the influence of* a *in a quadratic functions. So here we have two forms where* a *is greater than zero. Remember,* a *here it can be zero. If* a *is zero, then we are no longer going to have a quadratic functions. So now we are looking at* a *being greater than zero. This is the shape that we expect, which is an open up shape. Are we together? And now we are saying this when* a *is greater than zero, we are going to have the turning point, which is the maximum. And when* a *is less than zero, we are going to have the turning point, which is the minimum turning point. So* a *will affect the opening up. We can have* a *changing…… we are going to increase. Then it means we might have a shape like this when* a *moves closer to the y axis. But when* a *is ….., it becomes wider and wider as* a *decreases. To go back to using the GeoGebra to the sketch, are you able to see the page of GeoGebra? Guys, are you able to see the page of GeoGebra? Learner 6: Yes.*

Educator: Hello, are you there?

Learners: Yes.

Educator: Okay, thank you. Any function here? Remember, we want to see how a *affect the quadratic function. Let's look at this function here. Now focus on the input*

part, wherein I'm typing the function. We are going to have, I'm going to use slider so that I can change and see what is happening. Look at this….. the Cartesian plane so that you can see. Right, if you can look at the function here, a *is given to be 1. That is the function which is this one. So when we have this type of a function, our graph will be like this. Can I now move, decrease the value of a? Look at this. Look at what is happening when* a *tends to be a negative number. Look at the shape. I want to show you something you can see the green line lies on what? Where's the green line? Can you tell where the green line is? When* a *is equal to zero. Can you please open your cameras? I want to see all of you. Seems like you are too quiet… Right, my question is now* a *is equal to zero. Where is the green line? Can you see the green line on the Cartesian plane?*

Learners: No

Educator: Okay, look at it. Look at the values of a*. Now* a *is 0.5 which is half. Can you see that? Can you see the sketch now? Are you able to see the sketch?*

Learners: No.

Educator: So it means you're not seeing anything.

Learner 6: Yes.

Educator: Learner 6, stop chewing in my glass. Stop chewing the gum in my glass. Can you see the graph? Can you see the parabola graph? What is it that is on your screen? Can you tell me what is it that is on your screen? Hello? What is it that is on your screen?

Learner 6: We see a red parabola and a blue parabola.

Educator: There is a parabola right? Yes. Can I have those who are chewing gum to stop it guys? Learner 7, what is it that you are chewing? We are in a class. Right, look at the Cartesian plane. Look at the Cartesian plane. Now I'm changing the value of . a *is the green line or the green graph now. Learner 8, where is the green line or the green graph now?*

Learner 8: is not visible can you…….

Educator: Can you see what is on the Cartesian plane now Learner 8?

Learner 8: The blue one is half.

Educator: Can you see the graph?

Learner 8: No.

Educator: Why are you sleeping? … So Learner 2 can you see the graph on this Cartesian plane? … what is it that you see on the Cartesian Plane?

Learner 2: it shows me …

Educator: Okay, what I was trying to show you is when, a *okay, when* $a = 0$. *Remember we are saying we are in a parabola, it means* a *can be zero. So when* $a = 0$ *, we are no longer having a parabola. Now, I want us to look at, yeah, my screen is not responding. We are having 10 minutes remaining of our lesson. I think when it disconnects, come back to the lesson. Are we together? Guys*

Learners: yes.

Educator: Okay, right. So now let's look at this function here. I want us to look at this function and have a function of this form $g(x)$. *Or let me say* f *this time* $f(x) = -0{,}5$ *..... We'll use this form(silent). Look at the graph that just inserted now* $-\frac{1}{2}(x-1)^2 + 1$*... A line, this is the parabola of* a. *Can you see the graph that I'm talking about? Pardon? Are you able to see the graph?*

Learners: No.

Educator: hello. Am I audible enough on that side? Yeah, I don't know, it seems the network is our biggest problem today. Eh, allow me to end this lesson. Can we login again? Can we all leave the lesson so that we start afresh? Please leave the lesson all of you.

(Connection lost)

Educator: OK. Let's just wait. Maybe it's network problem. Can you just wait a little bit? Are you able to see now? Are you able to see now? What is going on there? … Hello? Learner 2, what are you doing? You and Learner 1 what is it that you are doing? I asked you a question, are you able to see now?

Learner 8: No…

Educator: How many graphs are visible on your screen? How many graphs are visible on your screen?

Learners: ….

Educator: Pardon? How many?

Learner 1: Two graphs.

Educator: Two? Learner 5?

Learner 5: Two

Educator: Okay, right. So you can check that as a changes from a parabola, this is the shape that we are expecting when a is greater than zero, we expect an open up graph, some they call it a smile shape graph, a graph here, you can check here the value on the input bar, we have $-\frac{1}{2}$, therefore, …. a open down function or a phone shape graph. Are we together?

Learners: Yes.

Educator: Okay. Allow me to save the first part of the lesson so that we are left with less than three minutes so that we can reconnect. Allow me to save then, from there I will ask you to leave. Don't leave now. Allow me to save.

Part 2

Educator: Right. Thank you. Thank you. Can we continue where we left on? Right. Can someone share? How will we know that a is negative or a is positive in a function that has been drawn? What will determine the value of a in a drawn sketch? When the sketch is drawn of a quadratic function, how will you tell that a is negative or positive? What is it that is on the sketch that will tell you whether a is positive or negative? Yes, Learner 1. Pardon? Can we have Can I have others to mute their mic? Except Learner 1. Mute your mic. Can we have Learner 1 to give us the answer?

Learner 1: Ma'am, I get a little bit of a...

Educator: All right. I see ... In a drawn sketch of a quadratic functions, how will you know that a is positive, sorry, or that a is greater than zero or a is less than zero? How will you know by looking at the sketch? What is it on the drawn sketch that will tell you that a is greater than zero or a is less than zero. Learner 1?

Learner 1: Mam you not audible enough.

Educator: You can't hear me. Can you hear me now? Am I audible enough that side? Learner 1:Yeah.

Educator: OK, my question to all of you, but I want to start with Learner 1. How will you tell? How will you know that the a is greater than zero or less than zero in a quadratic function that is being drawn?

Learner 1: The wideness of a graph and.... Mam, repeat the question.

Educator: Yes, Learner 2, can you assist? Before I repeat, can you assist? Learner 1 mute your mic. Learner 2?

Learner 2: …...

Educator: I think we are experiencing network problem. Can you just repeat? I didn't get what you were saying.

Learner 2: … The graph will be ….

Educator: You are saying the graph will do what Learner 2?

Learner 2: Yeah …

Educator: Can you all switch off the cameras? Then I'll ask Learner 2 to repeat because still can't hear you. Yes, Learner 2.

Learner 2: When a is greater than zero, the graph will form a smile shape.

Educator: Thank you, thank you. Yeah, now I can hear you. I was struggling to hear what you were saying, but now it's clear. I think it was affected by the cameras and the other mics. Thank you. Right. Allow me to share my screen of GeoGebra. If you can check g, which is this one here in a green colour, you can see now the graph is giving us a smile shape and a is greater than zero in that case. Then we have this one with

a grey colour. On this one, we can see that a is negative half. Therefore now we have open down function or a fawn shape. Is there anyone who's having a question regarding the effect of a on a quadratic function? Any questions? I'm waiting to summarize this……. Either in all that we talked about, … graph will face up, or we are going to have …. again, what we can do, … parabola will face down. Eh …. I want us to do $f(x) = ax^2 + bx$ and type the … It might go again to obtain your own graph with $f(x)$ greater than zero. On the first one, we are not limited, but on the second one, we must have a being greater than c. If on the first one, we're having the value of b, which is one, then it means the next one, we are going to increase. We can have zero, b is zero or minus because we have to increase. It means we are moving up. If b was one, the next thing we are going to move from one upwards function. Then from there, we'll describe the transformation and to be sure what ….. you must have that. Right which is equal to $ax^2 + bx + c$ then you press enter. Can you see my screen? Are you able to see my screen, guys?

Learners: Yes.

Learner 6: Mam what if you just enter only two terms?

Educator: you not wrong as long as it represent quadratic functions. But here am entering three terms because of the given question then it depend on what is given.

Learner 6: All right.

Learner 3: So it depend on what is been asked?

Educator: Yes.

Learners: Ok.

Educator: Thank you for that. Thank you. Right. Here's our function. We just typed the function, which is $f(x) = ax^2 + bx + c$. Then now, what is it that we need to do? We need to move. If maybe you don't want this to be your function, you change it in a way that you want. But if you want to keep this as the first function, it's okay. One can say, I want to change and make it minus two. Can you see it now? Can you see my screen? Are you able to see the graph?

Learners: Yes.

Educator: Okay. Right. It means now this is my new function. This is the one that I just created, which was answering the first question. A new one. When you create a new one that will be $h(x)$ *.* $ax^2 + bx + c$*. With this new function here, … enter, I'm pressing enter. Still the same, but remember they are saying for the next question, the value of what? The value of* a*. So now we are going to change the value of* a*. Let me do this. Let me go back … again which is* $h(x)$ *equal to … All right, look at this, look at this guys. The one that facing down is the first sketch that they said, choose your own value for* a, b, c*. Are we together? Which is this one? Are we still together guys? Hello?*

Learners: Yes ma'am we can hear you.

Educator: All right. Thank you. Then this is answering the first question. When we answer the second one, this is the new function now. They are saying but with this one they're giving us the condition to say a *must be greater than zero. Can someone read the value of a on this graph of* $h(x)$*? What is the value of a on the graph of* $h(x)$*? Yes Learner 7, what is the value of* a *on the graph of* $h(x)$*? Please look at the toolbar, sorry the input bar where we type in, there is* $f(x)$ *and* $h(x)$*. So since for* $h(x)$ *we are answering the second question, where they say* a *should be greater than zero. I want you to tell me what is the value of* a *on this function?*

Learner 7: The value of a *is two.*

Educator: Thank you a *is two. So then now we are done they're saying from what you have which is* $h(x) move\ b\ and\ c$ *by increasing their values so it means now we are going to increase the value of* b *look at this* b *here it's one let's increase the value of* b *you choose any value that you want. I'm increasing* b *to be 3 now. And again, they say, please also move . I'm moving* c*, increasing* c*. I want to increase it to 2. The value of* c *is equal to 2. Look at what we have here. Can you see now the new sketch, which is* $h(x)$*? Uh-uh this 2, 1 I want 2, not 2, 1. I'm inserting the sketch for the first question. Look at the two sketch. What is it that you can tell now? What happened, actually? What is it that happened?*

Learner 3: I think the two graphs have same point of y-intercept but facing different direction.

Educator: thank you that is correct. The y-intercept is at 2. What else?

Learner 1: Mmm $h(x)$ does not have roots and the other one has two roots.

Educator: Yes the roots of $f(x)$ are real and unequal. I will explain the nature of the roots clearly on the other lesson. Any questions regarding this lesson?

Learners: No questions mam.

Educator: Ok in that case lets now go to the activity. Please copy this activity, so that you will be able to respond to this questions … ok when you done you can logout.

LESSON 2

Educator: Okay. Let's go back to where we were. Right. Can you now see my screen?
All learners: yes.
Educator: Okay. It's good. Let's continue. As I was saying, we want to see how this p that affect the graph to move horizontally changes. Look at this one. If now our $p = -1$, what I asked before we were lost through the network. I wanted to know whether you heard me when I was explaining. Now our $p = -1$. So, my question is, when $p < 0$ the graph will shift to which direction?
Learner 2: To the right.
Educator: Yes. The graph will shift to the right. That's correct. Now, look at where it is now. It means the graph has shifted how many units to the right from the original one, which is the grey colour. The graph has shifted how many units?
Learner 3: One unit.
Educator: One unit. Then what will be the new turning point? What is the new turning point? Learner 5? Give us the turning point, the new turning point of the new graph, which is a green one.
Learner 5: 1
Educator: the turning point is 1? a point should have the x-coordinate and the y-coordinate. So, rephrase your answer.
Learner 5: $(1; 0)$.
Educator: Thank you. Right, now I'm going to shift the value of p. Allow me to change something here. Let's just use plus (+) eh. Let's look at our new graph. From the…. we have the new one, which is the green one, which is $g(x)$. Look at the given

equation. p which is what? $p > 0$ right? Hello? Are you still……Can you hear me, guys?

All learners: yes.

Educator; eish I was having a problem with my mic…….. Right, as I was saying, the value of p affect the horizontal shift of the graph. So now I want us to look at the new one, which is (x) . Can we have someone to give us the new turning point now? What is the new turning point of this graph? Learner 7?

Learners: a ese e bonale (is not visible).

Educator: It's not visible? Can you see my screen?

All learners: Yes.

Educator: Okay. Thank you. Now, I want learner 7 to give us the new turning point of $g(x)$.

Learner 7: $(-2; 0)$

Educator: thank you. Then what is the value of ? Is $p > or\ < 0$? Can we hear this from learner 3? It's $p > or\ < 0$ because we can see that the graph has shifted to the left.

Learner 3: $p > 0$.

Educator: Thank you. It's $p > 0$, which is true. And it means the graph will shift two units to right. Can you just please guys hold for a moment for me…… guys?

All learners: Yes.

Educator: Okay. It's seems like my class would be disturbed here. And as I was saying, let me stop sharing the GeoGebra page, eh we are left with less than 8 minutes. Okay. And in that few minutes that we are left with, I want to continue from where we left on now. But I want us to look at something before we continue, because it's not only p that brings changes in our function. We also have we also have a q, the effect of q on a function. We need to understand that we have a, p, q those are the parameters of a parabola that bring changes to the graph. Can you still hear me?

Continuation

Educator: Thank you. Good morning. Can you open your cameras so that I can see that how many attended this class? Unmute your camera. I want to take your register on how many attended the class. Thank you. You may unmute the cameras. So that we start with our lesson. We continue from where we left on yesterday, eh let's just

remind each other on what we talked about yesterday. Yesterday I indicated…… We talked about the value p. How p affected the graphs. Let's talk about how p affect the parabola. Are you able to see my screen? Are you able to see my screen? Please unmute your mic to respond. Are you able to see my screen?

All learners: Yes.

Educator: Okay. Yesterday we talked about how p affected the graphs. Right. So now I want us to to go back to yesterday's lesson before we move so that we connect. And yesterday I indicated that when $p > 0$. What happens to the graph?

Learner 3: The graph will shift to the left-hand side.

Educator: The graph will shift to the left-hand side with how many units? The graceful shift to the left-hand side is correct. But with how many units?

Learner 3: One units.

Educator: no. Remember $p \neq 1$ here we are just saying p is any number $p > 0$. So, how many units will the graph shift to the left?..... Okay. The graph will shift to the left with a p unit. Remember, if we are saying now our $p = 2$, it means that the graph will shift to the left. With how many units? With two units. So, it depends on the value of . So, if we generalize, we are just going to say the graph has shifted to the left with p units. Then let's look at a case where in $p\ our\ p < 0$. The graph will shift to which direction? When we have $p < 0$.

Learner 2: The graph will shift to the right hand side.

Educator: the graph will shift to the right hand side with how many units? Yes, learner 5? The graph will shift to the right with how many units?
Learner 5: With p units.
Educator: Thank you. Yes. So now that was yesterday's lesson. Can we now move to continuation of the same lesson of yesterday? Where in we engage our q, let's engage

q. How q affect the graph. Remember, we are talking about the parabola here. We are talking about the parabola. Eh I want to show you something. Just hold on. Since p affect the horizontal shift. What do you think about q? What do you think guys?

Learner 6: q will affect the vertical shift.
Educator: Thank you. q will affect the vertical shift today. Graph will shift upwards or downwards depending on the value of q and I'm trying to share my screen. I don't know what is wrong here. Just bear with me while still opening. Right, in cases where in $< 0\ and\ q > 0$. Let's look at the first one where in $q > 0$. Let's start with the first one. Look at the graphs drawn here. The first one is the original. We'll call it the basic or the original. But the $a > 0$ under this one. Can you see my screen?
All learners: yes.
Educator: Okay. I was saying let's look at the basic function where $a > 0$ and referring to $y = x^2$, right? Then look at what is there on the graph, p is added. We have the value of p, which is greater than zero. You can see from the original one, the graph has shifted to the right. Again, there is q here, remember from the standard form. Last time we talked about the three forms of a quadratic function. You still remember? Do you still remember the three forms of a quadratic function?

Learners: Yes.

Educator: Where in the first one we are referring to the standard form. The second one is when we are given the intercepts. The third one is when we are given the turning point. So, this is that form here, right? Look at the value of $= 1$. Our $q = 1$. Look at the original one. It has shifted upwards. How many units? From the basic one, it has shifted upwards with how many units? Hello? Are you still there?

Learner 6: Yes.

Educator: Okay. My question is from the basic one, $y = x^2$ to the new function that is drawn. The graph has shifted upwards. Do you agree? It's how many units upwards?
Learner 4: one unit.

Educator: it means the $q = 1$. So, since $q > 0$, it means the graph will shift upwards, not downwards. So that will tell us that if it's less than zero, then the graph will shift downwards. My document is not responding. I wanted to show you when is less than zero. Okay. Allow me to stop sharing this page and let's wait for the computer to respond. While we are waiting for the computer to respond, can we have a question from your side, guys? Any question or anything that you want to add or anything of clarity? (the class is quite) ……..
Educator: I want us to go back to the whiteboard. Okay. We talked about $< 0\ and\ p > 0$. Now let's talk about q. Let's talk about $q > 0$ when $q > 0$. We are reffering to any number which is above zero. So, what is it that you understood? As I was explaining that when > 0 , the graph will shift at which direction?

Learner 1: the graph will shift upwards.

Speaker1: The graph will shift upwards. I want to show by arrows that the graph will move upwards or let me just show, indicate in this one and the graph will shift to the right when < 0 . When $p > 0$, the graph will shift to the right with p units. All right, then. Let's go to the last one. When $q < 0$, the graph will shift at which direction? ……...

Educator: Why I'm hearing boy's voice. What happened to girls in this class? Girls, are you still in the same class?

Girls: Yes.

Educator: Okay. I want you to respond to this. When $q < 0$, the graph will shift at which direction?
Girls: downwards.
Educator: thank you. The graph will shifts downwards. You will see the original graph or the basic graph moving downwards. Right. That's all that I wanted us to have in mind. So whenever you see a graph moved from the original one or the basic one, so you should bring this in your mind whether $> 0\ or\ < 0$, meaning whether the graph is

facing up or the graph is facing down. What do you need to put in mind is now I see q if the equation is in standard form, you can also write it in this form of showing the turning point. How do you do that? By completing a square. Then, because today we are not doing the completing a square. You can also go back and revise how to complete this way, right? Allow me now to share the GeoGebra where we are going to do the drawings, now the practical part that we are going to do. Something went wrong. I don't know what is it? Okay. In that 10 minute I want us to quickly see the effect….. the input bar is not moving let's just give it time. Are you still with me, guys?
All learners: yes.
Educator: okay. Can you see my screen? The GeoGebra screen?

Learners: No. No.

Educator: Then let's wait. Let's wait. I think it will be visible…….. Are you able to see now?..... Let's I think now you'll be able to see.

All learners: yes
Sound sound

Educator: Can I have someone to mute the mic? Because there's a sound coming that side. Seems like the input bar not responding. And time is not on our side. I don't know what went wrong. Okay, guys, since we have less time, I'm going to end this lesson. Then we start again. We go through the GeoGebra before you do the activities. Are we together?

Learners: yes.
continuation
educator: okay, let's continue to the GeoGebra screen. We are still waiting for others, where are they?..... can we have others to join. Learner 5 and learner 6 am still waiting for you guys. What went wrong? Can you please join the other groups while you are still waiting to connect…….. Hello? can you hear me that side?
Learners: yes
Educator: I requested you to open the cameras. Am requesting learner 5 and learner 4 to join other groups. Learner 6 tell those two to join the other groups, stop talking.

Please guys tell them time is moving. I don't see you writing and that is my surprise. Okay let's continue. Can you all see my screen…….stop talking. Look at the tool……. The basic function we are referring to, $y = x^2$*. how it affects the graph. Ok I just inserted the……..unmute your cameras, I cant see learner 4, am waiting for learner 7's team and learner 2's team to unmute the camera. I can't see learner 4, are you in the same class with us?*

Learner 4: yes, am here.

Educator: alright thank you. Look at the left-hand side of the screen……. I will just press enter on the computer. Look at what is happening. My $p = 1\ and\ q = 1$*…….to the new one. Am I right?*

Learners: yes.

Educator: okay, when the graph shift it affects the turning point of the graph. So, looking at the new graph we are going to read the turning point. Let's first talk about the new turning point of this grey(colour) graph. What is the turning point of this graph? Yes learner 8 what is the turning point of this graph?

Learner 8: grey or green?

Educator: the grey graph……. People are busy talking and laughing in my class. Learner 8 what the……learner 3?

Learner 3: $(0; 0)$.

Educator: that is the turning point. Look at the green graph now, am referring to g *Remember it has* $p\ and\ q$ *therefore…… I want you to explain what happened to the new graph which is the green graph. What happened? Yes learner 6?*

Learner 6: the graph moved left and upwards.

Educator: I think something is missing in your explanation. Yes it has shifted to left….. for someone who don't understand what is going on. Yes learner 1? Can you explain the transformation? Unmute the mic learner 1.

Learner 1: the graph has shifted left and upwards with q units.

Educator: now you know the value of q I want you to be specific.

Learner 1: 1

Educator: can you repeat what you just said? Explain what happened start from the beginning……..pardon? am failing to hear you this side.

Learner 1: the graph shift to the left and upwards with 1 unit.

Educator: the graph has shifted to the left with 1 unit and upwards with 1 unit. Your explaining what happened moving from original to new function. Are we together? Is it clear guys?
All learners: yes.
Educator: learner 4 tell us the turning point of this graph.
Continuation

Educator: good morning. Can you hear me guys? Hello? Learner 7 tell others to join those who are online, while busy trying to join let them join you so that we can start. I want you to unmute the cameras so that I can see who is absent. Okay, thank you. You may mute the camera so that we continue. Eh remember yesterday we were talking about the effect of $p\ and\ q$ *on a parabola. Today we are just going to continue from where we left on, which is the activity of that lesson. Allow me to share my screen. Network……. No no…. can you see my screen?*
Learners: yes
Educator: okay, I want us to do this activity together. Eh I will give you the opportunity to respond to this activity. Look at it. Let me read it for you. (reading from class activity) am going to give you a minute to look at these two questions and I will call one by one to present the answer. That one-minute start now, you can talk to someone next to you, you are allowed to talk to someone next to you. (Learners discussing)…… open your mic I want to hear your discussion…….. can we have learner 5 to give us the answer to the first question? Can I have the other groups to unmute their mic.
Learner 5: the turning point of the graph is $(2;3)$
Educator: $(2;3)$*? which one represent the x value and which one represent the y value….. yes learner 5 between the values that you just mentioned, which one is the x-coordinate and the y-coordinate?*
Learner 5: 2 *is the x-coordinate and* 3 *the y-coordinate.*
Educator: let me ask the other group, can we have learner 3? Do you agree with learner 5's answer.
Learner 3: yes.
Educator: are you saying the turning point is $(-2;3)$*?*
Learner 3: they are positive. Positive number.

Educator: let me ask you guys eh which one is the value of $p\ between\ 2\ and\ 3$? *Remember p affect the horizontal shift and which one is the value of* q, *remember* q *affect the vertical shift. So, what am trying to say is your answer is not correct. Yes learner 7 share with us your answer? Learner 7?*

Learner 7: $p = 3\ and\ q = -2$

Educator: okay but now what will be the turning point?

Learner 7: $(3; -2)$

Educator: it can't be. Okay. Allow me to share the GeoGebra so that we can look at the graph…….okay guys, I think while we are still waiting for GeoGebra to open eh I want to take you back to what we talked about yesterday. Eh lets go back, problem here is p (taking learners to effect of p and identifying the turning point)……..

Here we are (back to the question) this is the equation what is the correct turning point to this given equation?

Learner 8: $(2; -3)$

Educator: that is not correct. Can we have someone to give us the answer?..... are you with us……..give us your input.

Learner 1: $(-3;\ -2)$.

Educator: thank you, that is correct. The middle sign……. We going to have the graph shifting to the left and if it shift to the left it means……. Is it clear?

Learners: yes.

Educator: do we…….

Continuation

Educator: welcome back, yeah network is giving us problems everyday we just have to be patient. So, now I will go back to the activity, eh allow me to share my screen. Okay, can you all see my screen?

Learners: no.

Educator: okay lets just wait a for a moment, I think it will just popup. Let me know if you see something.

Learner 3: yeah now we can see.

Educator: okay, right before we move is there anyone who is having a question? Before we continue with the second one? Eh learner 8 we are still waiting for your answer?

Learner 8: is the h graph.

Educator: is the h graph? Lets look at the equation, yes learner 2 do you agree? Can you hear me?

Learner 2: yes mam.

Educator: do you agree to the answer?

Learner 2: no.

Educator: what is your answer?

Learner 2: its k

Educator: why are you saying is k? how can you convince someone who is saying the answer is h to agree with you?

Learner 2; because $p < 0$

Educator: $p < 0$ *correct, all the two graphs* $p < 0$ *they have shifted to the right. Continue……...pardon*

Learner 2: $q > 0$

Educator: what is q *if I may ask? What is the value of* q *if you are saying is* > 0?

Learner 2: -3

Educator: so is $-3 > 0$*?*

Learner 1: is < 0

Educator: the correct graph is k. thank you. It shift to the right with 2 uits and downwards with 3 units because when $q < 0$ *it means the graph will shift downwards. Are we together? Ist clear? Hello? Are you still there?*

All learners: yes

Educators: is there any other questions before we move to the activity that you need to write and submit?

All learners: no.

Educator: ok then, now let us move to the activity. I will give you time to copy the activity then from there you will leave the lesson and go to your laptops and sketch those graphs using GeoGebra. Can you please take down this questions and copy. While you are busy doing that let me read the activity (reading the questions on the activity). So, it means you going to do number 1 on GeoGebra and you open word document to do number 2 and 3 because you need to write down the transformation and turning point of each graph. I hope is clear. I will pose here to wait for questions…… so it means is clear?

Learners: yes

Educator: okay. Are you done copying all of you?

Learners no.

Educator: ok, I will give you few minutes to finish. Please inform me when you are done. How many are still copying?.....ohk. thank you for attending. Remember when you are done you need to email it back to me by the end of today. So you may leave the class ,thank you.

LESSON 3

Educator: Good evening once more. Guys, I think we should start. We waited for long for others to log in. Seems like they're not coming. I don't know. Maybe they are committed to something else or they will join us. Right? Remember in our previous lesson, we were talking about the effect of $p \; and \; q$ *on a parabola. And we also did the activity regarding the effect of* $p \; and \; q$*, wherein we also look at the turning point of the quadratic function. So now I want us to continue, to continue and look at the intercepts of a quadratic function. We are going to relate the intercepts with the nature of the roots. What I wanted you to understand here is, when we talk about the x-intercepts, we are referring to the roots. In other words, when we say the x-intercept, we can use the name, the roots of the equation, which we are referring to the x-intercepts. Allow me to share my screen with you. Right, we are going to look at the intercepts. The x-intercepts which are the roots of the equation and the y-intercept. When we talk about the roots, we'll be also identifying the nature of the roots. Can you all see my screen?*

Learners: Yes.

Educator: Okay. While taking notes, if maybe I move faster, you still want to copy something, please let me know.

Learner 1: mam we can't hear you

Learner 4: mam your network is cutting.

Educator: can you hear me now?

Connection lost (17 seconds)

Educator: Am back. I wonder what is happening because it seems I have been kicked out by the network again but when I check my network on this side everything seems well and ok. Can you hear me now?

All learners: yes

Educator: Right. Here are just a few sketches that I want you to just see, but we are going to do the practical part with the GeoGebra application. We are, here we are just... We are first going to start with the y-intercept. I'm going to bring you back to the grade 10 or grade 9 work, wherein you know that we need a Cartesian plane to sketch or to plot … That is why when we find the y-intercept using the calculation method, we substitute x with 0 to find the y-intercept.So here I'm just showing that at this point here on the y-axis, we have, it's the graph touches the vertical line at three. Therefore we have zero and three. That is our point. That is the y-intercept. Are we together?

Learners: Yes.

Educator: Okay. So now we are moving to, remember, a parabola will have one y-intercept. That's why we use the word intercept, not intercepts, because it's only one point that we are looking at. Then we … a parabola. Look at this. Wait a moment. Right. With a blue colour. I'm showing that this is what we call the x … of a function. So when we say it has two, it means we have two values of x and are equal. Those two are not the same … So you see now by looking at a sketch, you can describe the nature of the roots. This type of a parabola, it's having real ….. are we together?

Learners: Yes.

Educator: Okay. Look at the graph that is having one root … This is one … a point where in we have none … There are no real roots. In that case we don't have the x-intercepts. The graph will never touch the horizontal … facing down … So we can have another … Okay, okay. Can we … we are going to have the graph. Allow me to share the GeoGebra, but just hold on. Here we are. Okay, it was not responding. Can you see my screen, the GeoGebra screen?

Learners: Yes.

Educator: Okay, thank you. Right, so I'm just going to type any function. Then we talk about the y-intercept of the function, the x-intercept. You can tell me it has … real, one

root. Okay, let me try to move the graph. Alright, let's look at the graph now. Parabola or the relation or the function is $f(x) = x^2 - x - 12$. *The x-intercepts … Do we have real roots? Are the roots equal? Learner 4 is out … she will join us. Let's hope she will join us. Learner 5 give us the x …*

Learner 5: Yeah.

Educator: waiting for the answer.

Learner 5: …

Educator: Thank you. That is correct. Let's talk about the … Let's talk about the y-intercept. What is the y-intercept of this function? Yes, learner 2?

Learner 8: Learner 2 is not available. Its learner 8 who is in.

Educator: OK. Welcome, Learner 7?

Learner 7: Its negative …

Educator: Pardon?

Learner 7: Is negative 12 and 0.

Educator: The y-intercept is negative 12. Thank you, thank you, my dear. Right, so you can see that by looking at the graph drawn, we have the x-intercept, the y-intercept. In the last lesson, we talked about the turning point. So today I'm not interested on the turning point of the function. Right, let me ask this. What can you say about the nature of the roots in this graph? What can you tell me about the nature of the roots in this graph?

Learner 3: The nature of the root are real and non-real.

Educator: It can be real and non-real. Remember when you say non-real, they don't exist, they are not there. The x-values are not there. When you say non-real, you are referring to this. The x-values are not there. The graph does not touch the horizontal line. So rephrase your answer.

Learner 3: The roots are real.

Educator: How many roots do we have? ….

Learners: ……. No.

Educator: Okay. Let me do this now. Okay. We are left with eight minutes. What I'm going to do now, allow me to stop this lesson and you reconnect again. So that … you first do this. Don't leave now. Don't leave now.

Part 2

Educator: Right I wanted us to go through another function and talk about the intercepts and also describe the nature of the roots. Allow me to share the GeoGebra screen, are you able to see my screen?.

Learners: Yes

Educator: oh what I did here was to type quadratic equation with the value of $a = 1, b = 1\ and\ c = 1$. *Then we can move around with the value of a, b, c. We can just change and see what we have but now with the one we have what will be the y-intercept of this function? Do we have Learner 8 in this class? Learner 2 are you available? What is the y-intercept Learner 2?*

Learner 8: $y = 1$

Educator: thank you. Look at the diagram at this point here, this is where we call the y-intercept. That is where the graph meet the vertical line. So now do we have the x-intercept of this graph?

Learners: no.

Educator: it means the roots are what?

Learner 2: the roots are non-real.

Educator: The roots are non real. Thank you. It means the roots are non real. So you can play around with the value of b and the value of c. look at this am moving the value of a *to the left hand side, am moving* a *to negative values. Look what is happening there the graph is shifting downwards but also moving at which direction?*

Learner 3: To the right

Educator: to the right because b is less

than zero. When I move this side here I want the value of b to be zero. Lets see what will happen when b is equal to zero. Look at the graph when b is equal to zero, you can see that when b is equal to zero look at the input bar. On the left hand side of my laptop look at this side on the equation. If b is equal to zero it means the middle term is zero. It means on that equation you are going to have the first term and the last term. So if you come across any equation where you have the first term and the last term you should know that the y-intercept is aslo the value of y at the turning point. Are we together? Are you with me guys? Oh seems like ..

Part 3

Educator: thank you I was lost, did you get what I was saying?

Learners: Yes mam.

Educator: ok thank you guys for attending. Remember today we are going to continue where we left on with yesterday's lesson. Allow me to share the activity on the screen so that you can note it down. Remember how you submit you need to send it via email. Just be patient am trying to share the document with you. Can you see my screen.

Learner 4: yes we ca see the screen.

Educator: this is your activity 1 you are given this functions, what I want you to do is to create a slide to sketch a function. When I say create a slide you are going to use a, b, c. like what we did yesterday then you move the value of a, b, c to the same as what you are given on the equation. And again while you are busy moving that you must move the value of b and c such that the equation of $f(x)$ has equal roots. When we refer to equal roots we mean one root. Yesterday we did something like that where in the were no real roots then we moved b and c so that we obtained one x-intercept which was also the turning point, this is what I want you to do with number 1. 1.2. what do you notice about the y-intercept, hence determine the value of k for …. You tell us the y-intercept of the graph. Then now you will determine what should be the value of k from number 1 such that the equation has equal roots. Remember you are going to move this equation to have one root/x-intercept then after that you observe from the graph that is having one intercept you tell that oh for it to have one root it means k should be this value. 1.3. sketch any function with no real roots and identify its turning point. With 1.3 remember you will be having the first graph which is $f(x)$ 1.3 you create

another function of your own where in the function will have no real roots, in other words the graph will not touch the horizontal line. You create it the way you want it and also identify the turning point you can use the same GeoGebra app and write using the pen on the Cartesian plane, you write the turning point. You don't need to open word document you can still write on that cause is only this part of calculating or identifying the turning point. Thank you let me pause and wait for questions.

Learner 6: No.

Educator: Okay I will give you time to copy the activity and you will let me know when you are done.

Learner 1: Mam

Educator: Yes.

Learner 1: With 1.2 we didn't hear you clearly.

Educator: 1.2. remember 1.1. you will be having a function. First you enter function $f(x)$ *as it is right? But using a slider, when using slider its where in we put a, b, c like what we did yesterday if you can remember the graph we did yesterday I used a, b, c I was moving b, c along so that the graph has one x-intercept. So with 1.1. after you have identified* $a\ as -\frac{1}{2}, b\ as\ 2\ and\ c\ as -6$ *you move along with the slider so that you have a graph that is having equal roots, meaning one x-intercept. Then with number 2, what do you notice about the y-intercept with the graph that is having one x-intercept relating with the first one which is* $f(x)$*. Now after that what should be the value of k for your graph the one that is drawn to have one x-intercept. What should be k, k is a constant it means that number should be added or subtracted with 6 so that you have the graph that is having one x-intercept. I don't know if I have answered your question?*

Learner 1: yes is ok now.

Educator: Ok. Then am going to give you time to copy the activity then when you are done you can start writing … are you done copying?

Learners: …

Educator: Ok I think you are now allowed to …

LESSON 4

Educator: good morning, can you please, those who are still trying to login join others so that we can start. I can see Learner 4 and Learner 5 not yet in can you please join the other groups. I hope you had a great morning in this cold weather, unmute your camera so that I can take the attended register. Can you please unmute your camera? Can you hear me guys? Hello… can you hear me? Learner 8, Learner 1 can you hear me? Yesterday we were doing activities of previous lesson, I still have a pending submission. Learner 3 didn't submit and Learner 1 I didn't see your work, I didn't receive your email, if you have send, please re-send again yesterday's activity. Oh a day before not yesterday and again guys I will be waiting for yesterday's activity I will be waiting for you to submit today….. right… Then let's continue with our lesson for today ehhh…… I want us, allow me to share my screen. I would like us to continue on quadratic function in today's lesson's we talk about reflection along the line or reflection about the line. Here we are refering to… when we say reflection ehh… we want the mirror image of whether a function or a point. So if we are saying a reflection along a line, that line will be our mirror, so is like when standing on that mirror you see the image which is the same as you on the other side of the mirror right? So now will be looking at, I want to take you to the previous Grade where in we can start talking about reflection of a point. But is a reflection of a point..

Learner 6: mam we cant hear you….

Educator: hello… am I audible? Hello guys can you hear me?

Connection lost (10 seconds)

Educator: am back I was kicked out by network, can you hear me now? Can you hear me?

All learners: yes

Educator: ohk thank you. Right allow me to share my screen eh. let me start from the beginning because I was not audible enough you couldn't hear a word. I was saying from our previous lesson remember we are focusing on quadratic function, so in today's lesson from the same quadratic function we talked about I want us to talk about the reflection along and about the line. We are going to focus on the reflection of QF along a certain line, it might be along the y=x or y-axis or the x-axis are we together? Hello can you hear me guys?

All learners: yes..

Educator: Ok. Right so now when we say this is a reflection along the line, that line act as a mirrior. So that we can see the image of the original object or the graph. So it's like when you are standing on the mirror you see the same image as you or yourself right? So now we are saying is the reflection of a point or function or relation along a certain line. If we are saying along the line y=x. Can you see my screen? Can you see my screen guys?

Learner 1: mam we cant hear you

Educator: can you hear me now guys?

(Connection lost)

Educator: Am back now. I wonder what is happening, it seems like I have been kicked out by network again but when I check my network this side everything seems well and ok. Can you hear me now?

All learners: yes

Educator: seems like problem comes when I start sharing my other pages so I don't know. Let me know in time if you can't hear me eh which part did you hear when I was talking to you or should I start from the beginning? Hello…….. are you able to hear me?

Learner 1: yes

Educator: ohk right eh am saying on today's lesson will be talking about a reflection of a point oh sorry a reflection of QF along a line but I must take you to the lower Grade wherein we talk about the reflection of a point along the line. Here am referring to, the line act as a mirrior. Let me check if you can hear me guys. Am I still audible that side?

All learners: yes

Educator: ok thank you. Right then now if we are saying let's just give an example and we say we talk about reflection along this line, line y=x. This line is called y=x this is our function so now, looking at this line if we want a reflection along this line whether the reflection of a graph or of a point in that case it means this line will act as a mirror. This line will act as a mirror its line when standing on the mirror you see the same image as yourself.

Learner: mam you are longer audible

Educator: pardon?

Learner: you…….cut….. cut….

Educator: ok let me repeat. I was saying when we say reflection of a function or point along a line, we are referring, we are looking for the image of that point or function. So now lets look at that line that is drawn here which is y=x. Am I still audible guys? Hello can you hear me?

Learner: ……...

Educator: pardon? Hello?

Learner: …….

Educator: hello… guys can you hear me?

Sound sound sound…..

Educator: hello. Am I audible enough on that side? Yeah, I don't know seems like the network is our biggest problem today. Eh allow me to end this lesson can we login again, can we all leave the lesson so that we start afresh? Leave the lesson all of you.

continuation

Educator: I'm greeting you again, and I just hope this time network won't disappoint us. Okay. Let me just go straight to where we left. Okay. I just want to check. Can you hear me?

All learners: yes.

Educator: Are you able to see my screen?

All learners: Yeah.

Educator: Thank you. Right. Eh from the previous Grade we talked about ... From the previous lesson ... Sorry we talked about the effect of $p \; and \; q$ *and we did an activity for that. So on today's lesson, I want us to talk about the reflection of a point or the reflection of a quadratic function. Actually, we are going to focus more on the reflection of a quadratic function, but I have to take you back to the previous grade and talk about the reflection of a point. This reflection will be a reflection along a certain line. It might be the line called* $y = x$*, which is just the straight line, or it might be the x-axis or the y-axis line. Am I audible enough? Can you hear me, guys? Hello. Are you able to hear me?*

All learners: No.

Educator: But it means you can hear my voice now. So I wanted to check. Did you get me when I was referring to a reflection of a point. Can you hear me now? Hello. Can you hear me?

All learners: yes

Educator: ok. Right. And you're able to see my screen.

All learners: Yes. Yes.

Educator: Okay. As I was saying with the reflection of a point. Let's look at what is being sketched here. This line here is a line called the $y = x$ *line. Are we together? And then we also have the y-axis, which is the vertical line of the Cartesian plane. We also have the x-axis, which is the horizontal line of the Cartesian plane. Right now. Let's look at the point A which is written as the original point. Can you see this point? Can you see the point I'm referring to?*

All learners: yes

Educator: Okay. So when we talk about the reflection of point A along a certain line, we are just talking about the mirror image. It's like when you're standing in a mirror, then you see another image the same as you on the other side of the mirror. So even here we'll be looking at but if we can check that the image is looking at you and even you, you are looking at that side. So here we'll be looking at A as our original point the coordinates of A it's $(-1; 2)$ *you can note down. The coordinate of A the original point is* $(-1; 2)$*. So, if we wanted a reflection of this point along the line,*$y = x$ *it means the reflection point will be this one here. Look at the new point. This is the reflection of this point. And look at the coordinates of this point. Who can tell me the coordinates of the point that is the reflection of the original one along* $= x$ *. What are the coordinates of this point, which is the reflection of A along the line* $y = x$*. I indicated the coordinates of A, the original point. It's* $(-1; 2)$*. So now we have the reflection of this point along the line* $= x$ *, which is another point here that I'm pointing here. This is another point. So what I want. Now I want you to give me the coordinates of this point. Remember I gave you the coordinates of the original point? Now I want you to give me the coordinates of this point. Reading from the Cartesian plane, read from a Cartesian plane. What is the x value? What is the y value?*

Learner 6: $(2; -1)$

Educator: Thank you. What was the coordinate of the original point? What did I say about the coordinates of the original point?

Learner: $(-1; 2)$*.*

Educator: Then the reflection one is?

Learners: ……..

Educator: All right. You have written this down?

Learner: yes.

Educator: look at the two points that we just talked about. What happened when you related a two points. Looking at the second one, we compare with the first one. What can you say? What happened? What has been done there to obtain the second one.

Learner 6: We didn't……...

Educator: pardon. Yes learner 6?

Learner 6: a rea lekwa (we did not hear you)

Educator: Okay. Let me repeat the question. The coordinates of the original point we talked about, it's $(-1;2)$*. The coordinates of the point that is the reflection along* $y = x$*. The coordinates are* $(2;-1)$*. Did you hear me on that?*

All learners: Yes.

Educator: Okay. I'm saying look at the two points. And tell me what happened from the original one to the second one. Okay. Right. If we can look at what happened today. On the first point, the original point, $x = -1\ and\ y = 2$*. The second one, the values swapped. In a way that now the* $x\ value$ *becomes the* $y\ value$*. The* $y\ value$ *becomes* $x\ value$*. Are we together, guys?*

All learners: Yes.

Educator: Okay. Thank you. So now we are done with the reflection along $y = x$*. Let's look at the reflection of the original point along the y-axis. The y-axis is the vertical line. So we have original point with the coordinates* $(-1;2)$*. And what are the coordinates of this point here, which is the reflection along the y-axis. Here, the one that I'm pointing what are the coordinates? What are the coordinates of this point? Can you see the point that I'm pointing?*

All learners: yes

Educator: Then what are the coordinates of this point?

Learner 5: $(1:2)$*.*

Educator: $(1:2)$*. Thank you. Note down, note down. The first one is*$(-1:2)$*. And now we are saying that the coordinates of a point that is the reflection along the y axis is* $(1:2)$*. Looking at this point, the reflection along the y-axis. What can you say about the coordinates? What happened to the coordinates?*

Learner: swapped. Swapped. They swapped.

Educator: swapped? What is it that is being swapped there?

Learner 1: The x value is now……

Educator: pardon. Learner 1?

Learner 1: the x value is now positive.

Educator: Thank you. Only the x value is changing, right? Hello? Can you hear me, guys?

All learners: Yes.

Educator: yes. Only the x value is changing. So, in other words, the reflection along the y axis affects the only x. There is no swapping here. It only affects the x. If x is negative it will turn positive. If x is positive, it will turn negative? That's how it affects the x value. Well, let's lastly, we have the reflection along the x-axis, the horizontal line. We are still going back to the original point. The original point is $(-1:2)$ *that are the coordinates of the original point. So, look at this. This point is a reflection along the x-axis of the original point, along this line, the horizontal line, which is the x-axis. So what are the coordinates of this point, which is the reflection along the x-axis?*

Continuation

Educator: I'm back again. Yeah. Can you hear me that side?

All learners: yes.

Educator: eish yeah this network today. It's not doing us a favour. Okay. Let me go back to presenting. Tell me if you can see my screen. The one I opened before…. Can you see my screen?

All learners: Yes, ma'am.

Educator: Okay. Right before I got kicked out by network, I wanted you to give me the coordinates of this point, which is the reflection of the original one here along the horizontal line, which is the x-axis. What are the coordinates here?

Learner 6: $(-1:-2)$.

Educator: Okay. Thank you. Compare the coordinates of this point here with the original one and tell me what happened. The original one, remember, it's $(-1:2)$. *The new one here you have* $(-1:-2)$.

Sound sound

Educator: pardon. Learner 1? Hello. Can you hear me, guys? Hello. I'm back, guys. I'm back. Eh can we have someone to share what happened when you related the two points? Learner 1? Oh I talked to learner 1, can I hear learner 8? What happened?

Learner 8: ke kgopela lr repeat question akea lekwa gabotse (can you please repeat the question I did not hear you well)

Educator: did you note down the coordinates? I want you to tell me what happened from the original one to this point.

Continuation

Educator: Okay. Allow me to share the screen. Are you able to see what is on my screen?

All learners: Yes.

Educator: So, let's go back to the GeoGebra and use the app. Okay, allow me to do this practically and observe what is happening there give me a moment for it to open. Right. Let's look at what we have here are you able to see the GeoGebra screen?

Learners: Yes.

Educator: okay. Am going to go to the toolbar on top here. Look at the toolbar. Okay, allow me to do this. On the toolbar I'm going to choose this one here number 3 from the last. Then reflection about a line. Now I'm going to indicate the same point we talked about. Look at the point. Now are you able to see the point?

Learners: Yes.

Educator: okay. We want the reflection of this point along the line. So this is what we are going to do. We click the point. Then we click the point of reflection. Oh, let me do this….. So, I'm going to look out for the reflection of this point along the x-axis. Then I'm going to click the line that is….. Then you can see what will happen. You click what you are looking at, and which line you want the object to reflect along. So, I clic k A as a point then, I want A to reflect along the x-axis. Then I will click the line which is called the x-axis then this is the new point. So now let's look at the original point the coordinates you indicated is $(-1;2)$ *right? So now my question is moving from the original point to the point that is the…….What happened to the coordinates? Are we still having the same coordinates? If not, what happens? In other words, I want to know if a point is reflecting along the y-axis, what is it that is being affected? Learner 1? We are saying that new coordinates. Yeah. Sorry the coordinates of the original point is* $(-1;2)$ *and the coordinates of a point that reflected along the y-axis is* $(1;2)$. *I'm Sure you're noting this down the original point the coordinates is* $(-1;2)$. *This point that is the result of reflection along the y-axis the coordinates are* $(1;2)$. *So reflecting along the y-axis, affect what? What are the impact of this reflection? Learner 1, can you hear me?*

Learner 1: Yes.

Educator: give us the answer.

Learner 1: The sign of the x value changed.

Educator: The sign of the x value changed. It means it affects only the x value. (lesson disturbed for few seconds). Right. Thank you. Allow me to share the screen. Right guys are able to see my screen.

Learner: Yes.

Educator: So now you can see. You can see that from the original point to the one that has been reflected along the y-axis only the x value is been affected. The y value hasn't changed only the x value. So, lets look at…..

Learner 4: Yes.

Educator:….. which is the reflection along the x-axis. What are the coordinates here guys? Learner 8 give us the coordinates for this point which is the reflection along the x-axis. Learner 8? Can you hear me

learner 8: Yes.

Educator: yes, can you please give me the coordinates now. Learner 8 what is the x value and the y value at this point?

Learner 8: $(1; 2)$.

Educator: right? Thank you. So now I want us to look at what is being affected moving from the original one to this one here. What is it that has been affected moving from this point to the new one? What changed? Can someone help because seems learner 8 is quiet, what changed guys which coordinate has been affected by the reflection along the x-axis.

Learner 6: the y value.

Educator: the y value has been affected so you can see that if the reflection is along the x-axis only the y value it's been affected by changing the sign, I'm sure you're noting this down reflection along the x-axis, the y value will change to negative. The reflection along the y-axis, the x value is the one that is affected. Then, it will change and become negative. So, look at this when I say it will change remember, here we were having -1*, then it means is* $-(-1)$ *therefore, it will change it to* $(+1)$*. The value which was negative becomes positive. That is why now we have* 1 *here . Is it clear? guys too much? Hello!*

All learners: Hello

Educator: allow me to write this equation sorry yeah look at this line, which is called $y = x$. *The grey line. I want to, I want ……along this line. Let us see what will be the new point. Look at the point. Can you give the coordinates of this point of reflection? Hello……Pardon.*

Learner 3: $(2; -1)$

Educator: correct let's compare the two points ……..the original one. What has been affected here, or what happened? Just note this coordinates down the original one is $(-1; 2)$. *Those are the coordinates, the new point I* $(2; -1)$. *Look at the two points say something. Learner 5? What ist that you can say about the two points. Learner 5, are you still there? Yeah. Hello.*

Learners: Yes.

Educator: please give us the answer now

Learner 5: the y value is been affected.

Educator: it's been affected how?.....what is happening here is the x value becomes the y value. The y value becomes the x value that's how reflection along the line $y = x$ *affect the coordinates? The coordinates have been swapped. Ist clear?*

Learners: yes

Educator: it means now we can look at functions. Reflection of quadratic functions along the y-axis, x-axis and $y = x$ *line.*

Continuation

Educator: good afternoon.

Learner: good afternoon mam.

Educator: Yes, thank you guys thank you let's continue a putting in mind what happened. Can you just hold on for a moment I just want to attend to something that came. Okay, Thank you. Yes, I was addressing issue of Mathematics competition on Friday. Sorry about that, right last time eh we ended up a talking about the reflection of a point along the few lines which is the x-axis, y-axis and $y = x$. *Today I want us to talk about to look more into details on the reflection, sketching the parabola, which might be the reflection along the x-axis or along the y-axis or along the line* $y = x$. *Allow me to share my screen with you. Let's just wait for a moment it will pop up. Right can you see my screen?*

Learners: yes

Educator: Okay, thank you right now, let's look at the original graph, this is just an example of the types of graphs to expect when you talk about the reflection along certain lines. Let's look at the original one which was sketched is $y = -x^2 + 6x - 5$ *is the pink colour when looking at the graph, is the pink one. Okay, looking at the graph, we are referring to the pink one as the original graph. Okay, So now, if we can check in each graph is being labelled whether that is the reflection along the y-axis. But now just observe, look at the turning point of the graphs according to their reflections and we also have a grey line which is the line* $y = x$*. The maroon one which is along the x-axis, the reflection of the pink one along the x-axis. Then we also have the blue one, which is the reflection of the pink one along the line* $y = x$*. And we have the purple graph, which is the reflection of the pink one along the y-axis. Are you still with me?*

All learners: Yes

okay. So right now we are going to do this practically so on GeoGebra.

Can we now create this function and see it? Eh okay, let me stop sharing. Now let's go to GeoGebra. If you have a question, please don't hesitate to ask. Eh can you see my screen?

All learners: Yes.

Educator: can you see the GeoGebra screen?

All learners: Yes.

Educator: okay. Now, let's type that function they're saying we should have this type of function. Eh the typing bar it does not respond. Let's have $f(x) = a(x - p)^2 + q, a < 0. we\ choose\ a = -2$*. We should make sure that our* $a < 0$*. And this is the function that you just created. Maybe you play around you change the value of* p*. This is the new value of* p*,I want to change it to* -2*. Right. This is the function. Are you still with me guys?*

All learners: Yes.

Educator: Okay, here's the function. Yeah. I will be moving from the question to GeoGebra and from GeoGebra to the question. Okay, allow me to stop sharing this page and go to the question, and let's see if we have captured everything correctly. You created this function, where $a < 0$ *that one we did. Let's move to number 3. Explain what you observed when the quadratic function you created in number 2 reflected along the y-axis. Then it means we must sketch the graph that reflect along*

the y-axis first from there, then we can explain what we just observing there. Eh okay, I'm gonna stop sharing this one here and going back to the GeoGebra they say is the reflection along the y-axis then let's check. We want to this. Look at the toolbar. Look at the toolbar. I choose this one, which is about the reflection about the line. Not about the point, so I will choose the first one which is reflection about a line. Are you able to see guys? can you see?

All learners: Yes.

Educator: okay, right on the toolbar on to then we just choose this one. We click on it. Then it will show options to choose from. We want the reflection of a parabola along or about in line…….. We click the original function, which is our $f(x)$. *We want this* $f(x)$ *to reflect along which line? Hello? We want* $f(x)$ *to reflect along which line?*

Learner 4: x-axis

Educator: ah ah guys it means you are not noting this down. Along the y-axis, then this is the new graph now can you see it?

All learners: yes.

Educator: You go to the toolbar you select reflect about line, then from there you click the graph that you are interested in, and you click the line that is reflecting along. Let me go back again and start afresh. Okay. going for reflection. I choose the first option from there I click the $f(x)$ *which is my parabola that is reflecting along the line y-axis then…….. Clicking* (x) *. Then the new function will be sketched. Can you see that? Are you still with me guys?*

All learners: Yeah.

Educator: So now we can talk about the same graph reflecting along the certain line. You just click the function after or using the toolbar you click the function, then we want it to reflect along the x-axis. Here I am, clicking on their x-axis. Then this is the new graph which is the reflection of $f(x)$ *along the x-axis. Is it clear?*

All learners: yes.

Educator: Okay, thank you. Any question? So, it means understand everything that's why you don't have questions? Learner 8 do you have a question?

Learner 1: mam lere graph ya bobedi (mam you say the second graph) ……...

Educator: I can hear you guys. Hello? Yes I'm listening…. Learner 1?

Learner 1: graph ya go lebelela godimo e tlile bjang (how did you manage to get the graph that is facing up)?

Educator: This second graph from the original. This one is the reflection of the original one along the x-axis. I will go back again. Look at the curser as it moves. Are we together?..... on the reflection that's why it's……. I want I'm just adding this, is not part of that question. I'm just adding we want the reflection of this $f(x)$ along the x-axis, which is the horizontal line. So, what I'm going to do is to click the graph you see now the graph is being highlighted. Then it means I'm choosing $f(x)$ to reflect along the x-axis, which is the horizontal i'm clicking anywhere on the horizontal line and there is a graph now. Did I answer your question?

Learner 1: Yes.

Educator: Okay, any other question? Okay, if there are absence of questions, remember the question was saying explain what you have observed, let's look at the two graphs. We are left with 10 minutes. Let's look at the graph. This is the original one, this is the reflection, what is it that you are observing? Look at the two graphs nicely and share what is it that you are observing. Guys let's talk you can't be just quite like this

Learner 6: the turning point……...

Educator: I couldn't hear you learner 6

Learner 6: the turning point of the original graph is now positive.

Educator: You can't just say the turning point is positive. Talk about the coordinates. What do you mean when you say the turning point is positive. A turning point is made up of the x-coordinate and the y-coordinate, right?

Learners: Yeah.

Educator: that's why, I'm saying talk about the coordinates

Learner 6: the coordinate of x changed and y also changed.

Educator: Is the value of y at the turning points changed?

14:57:01 What is the value of y at the turning point for this graph, the original one?

Learner 3: the turning point is one

Educator: And what is the value of y…….. learner 3?.....

What is the value of y at the turning point of the new graph? Learner 7?

Learner 7: 1 and 3.

Educator: No. what is the value……. I want to the value of y. When you say 1 and 3

Learner 7: it's a 1

Educator: it's 1, so you can check observing the reflection you can see that y has not changed along the reflection of y-axis, y hasn't changed. We talked about this. The

turning point hasn't changed if you can look at it. Y is still 0 even on this one on the intercepts y is still 0 and x is a certain number here. So, observing this reflection, we can see that the graphs still have same y-intercept, which is at -7. Only the value of x has been changed on the turning point x has changed to positive on the turning point, from negative value to positive value. That's what we are observing and we can see that the y value still the same only the x values have changed now to positive values. Are we together, guys?

All learners: Yes

Educator: okay, and we are left with 4 minutes. I'm going to a flesh the activity that you are supposed to do so that you can start writing the activity and make sure that you submit. Let me go back and share the activity with you. Here is the question.

You can do screenshot on this…. Ok you can logout.

TRANSCRIPTION OF DATA FROM INTERVIEWS

LEARNER 1

Educator: What did you find interesting when using GeoGebra to sketch quadratic funtions?

Learner 1: It doesn't take time because I just type only.

Educator: What is it that you did not like about using GeoGebra to sketch quadratic functions?

Learner 1: Sometime you type wrongly, and think that you typed correctly then you get confused.

Educator: In sketching quadratic functions using GeoGebra which steps did you take?

Learner 1: Unable caps lock for small letters, type and press shift for brackets. Other features were easy as they were on the GeoGebra.

Educator: What were your challenges when being assessed online?

Learner 1: Internet connection was poor.

Educator: In your experience, was the online assessment fair and effective for your learning? Explain.

Learner 1: Yes. Because when you teach online is better than when you are using chalkboard. The online is better no disturbance and is beautiful. In online class we are able to ask questions, because in class we are afraid to ask.

Educator: Compared to the past, how do you think using GeoGebra improved your knowledge of sketching quadratic functions?

Learner 1: It helps on graph reflection because in normal class I was not able to understand. It helped a lot.

Educator: Would you recommend use of GeoGebra to other learners? Why?

Learner 1: Yes, because when you sketch in your book there are many mistakes.

Educator: What advice would you give to other learners when using GeoGebra to sketch quadratic fucntions?

Learner 1: When you sketch graph on a GeoGebra learners must relax and focus to avoid making mistakes.

Educator: What would you recommend to teachers for improvement when assessing you through GeoGebra to sketch quadratic funtions?

Learner 1: They must allow us to use GeoGebra when we sketch graphs.

LEARNER 2

Educator: What did you find interesting when using GeoGebra to sketch quadratic funtions?

Learner 2:

Educator: What is it that you did not like about using GeoGebra to sketch quadratic functions?

Learner 2:

Educator: In sketching quadratic functions using GeoGebra which steps did you take?

Learner 2:

Educator: What were your challenges when being assessed online?

Learner 2:

Educator: In your experience, was the online assessment fair and effective for your learning? Explain.

Learner 2:

Educator: Compared to the past, how do you think using GeoGebra improved your knowledge of sketching quadratic functions?

Learner 2:

Educator: Would you recommend use of GeoGebra to other learners? Why?

Learner 2:

Educator: What advice would you give to other learners when using GeoGebra to sketch quadratic fucntions?

Learner 2:

Educator: What would you recommend to teachers for improvement when assessing you through GeoGebra to sketch quadratic funtions?

Learner 2:

LEARNER 3

Educator: What did you find interesting when using GeoGebra to sketch quadratic funtions?

Learner 3:

Educator: What is it that you did not like about using GeoGebra to sketch quadratic functions?

Learner 3:

Educator: In sketching quadratic functions using GeoGebra which steps did you take?

Learner 3:

Educator: What were your challenges when being assessed online?

Learner 3:

Educator: In your experience, was the online assessment fair and effective for your learning? Explain.

Learner 3:

Educator: Compared to the past, how do you think using GeoGebra improved your knowledge of sketching quadratic functions?

Learner 3:

Educator: Would you recommend use of GeoGebra to other learners? Why?

Learner 3:

Educator: What advice would you give to other learners when using GeoGebra to sketch quadratic fucntions?

Learner 3:

Educator: What would you recommend to teachers for improvement when assessing you through GeoGebra to sketch quadratic funtions?

Learner 3:

LEARNER 4

Educator: What did you find interesting when using GeoGebra to sketch quadratic funtions?

Learner 4: Am I understood everything you were doing and the graph were simple I understand how to sketch the graph.

Educator: What is it that you did not like about using GeoGebra to sketch quadratic functions?

Learner 4: There is nothing that I did not like.

Educator: In sketching quadratic functions using GeoGebra which steps did you take?

Learner 4: I take how to see the coordinates and how to see the reflections in the graph. What I liked was how it reflect and how I understood.

Educator: What were your challenges when being assessed online?

Learner 4: My challenges was to understand what I was learning online and I saw that learning online was better than face-to-face because we were given many examples.

Educator: In your experience, was the online assessment fair and effective for your learning? Explain.

Learner 4: Yes because I understand everything and what I learned about that is I did not face bad challenges. I understand the most learning online and I think learning online is better than face-to-face.

Educator: Compared to the past, how do you think using GeoGebra improved your knowledge of sketching quadratic functions?

Learner 4: Using GeoGebra learning online I did not face anything bad, everything was possible. It make me understand everything so learning this GeoGebra online comparing with my past was simple for me.

Educator: Would you recommend use of GeoGebra to other learners? Why?

Learner 4: Yes because GeoGebra is something that is possible while learning online. is not that tough when you learn online because is more suitable for our mind and to understand everything. I would like to recommend other learners to learn online and understand simple.

Educator: What advice would you give to other learners when using GeoGebra to sketch quadratic fucntions?

Learner 4: Is to take their time and focus on doing GeoGebra when they are learning. They should focus and take notes in online class.

Educator: What would you recommend to teachers for improvement when assessing you through GeoGebra to sketch quadratic funtions?

Learner 4: That they should teach us online as I understood the most when I was learning GeoGebra. I understand so much and I have improved.

LEARNER 5

Educator: What did you find interesting when using GeoGebra to sketch quadratic funtions?

Learner 5: Sketching quadratic functions using GeoGebra was easy than doing in the book because in the book you start by drawing a table.

Educator: What is it that you did not like about using GeoGebra to sketch quadratic functions?

Learner 5: There was nothing that I didn't like because I saw that it was easy than doing in the book.

Educator: In sketching quadratic functions using GeoGebra which steps did you take?

Learner 5: Sketching quadratic function using GeoGebra I used the GeoGebra….I used the quadratic functions for sketching the graphs in the GeoGebra.

Educator: What were your challenges when being assessed online?

Learner 5: I had no challenges it was easy when doing classes online.

Educator: In your experience, was the online assessment fair and effective for your learning? Explain.

Learner 5: Yes it was fair and effective because it was something different than doing in the class. It was something that was new and we do with technology.

Educator: Compared to the past, how do you think using GeoGebra improved your knowledge of sketching quadratic functions?

Learner 5: Using GeoGebra improved my knowledge because since back then quadratic functions I was not understanding them but doing those classes online when the time goes on I did understand some of them. And I did differentiate shape.

Educator: Would you recommend use of GeoGebra to other learners? Why?

Learner 4: Yes because using GeoGebra is easy than doing in the books, you have to start by doing a table for your graph.

Educator: What advice would you give to other learners when using GeoGebra to sketch quadratic fucntions?

Learner 5: I will give them to ask for help if they don't know how to start by sketching quadratic functions using GeoGebra from teachers or other learners who know about it.

Educator: What would you recommend to teachers for improvement when assessing you through GeoGebra to sketch quadratic funtions?

Learner 5: Recommend them to help us know the laptops and help us to sketch the graphs with GeoGebra in the laptops than drawing in the books.

LEARNER 6

Educator: What did you find interesting when using GeoGebra to sketch quadratic funtions?

Learner 6: When I was plotting the graphs it showed that when a is negative it goes down and when a is positive it goes up.

Educator: What is it that you did not like about using GeoGebra to sketch quadratic functions?

Learner 6: Is when I write the values then result to wrong graph.

Educator: In sketching quadratic functions using GeoGebra which steps did you take?

Learner 6: I use the y…… the y…..

Educator: What were your challenges when being assessed online?

Learner 6: I did not have any challenges.

Educator: In your experience, was the online assessment fair and effective for your learning? Explain.

Learner 6: Yes it was fair because it helped me to know the functions and also what we have been doing in class, I understand some of the functions we have been doing in class.

Educator: Compared to the past, how do you think using GeoGebra improved your knowledge of sketching quadratic functions?

Learner 6: It improved on ploting functions of GeoGebra and other functions.

Educator: Would you recommend use of GeoGebra to other learners? Why?

Learner 6: Yes. Because it is helping you how to draw the functions.

Educator: What advice would you give to other learners when using GeoGebra to sketch quadratic fucntions?

Learner 6: I will advise them to use the method that they know so that their graphs are perfect.

Educator: What would you recommend to teachers for improvement when assessing you through GeoGebra to sketch quadratic funtions?

Learner 6: I will recommend them to continue with our online lessons even if we are done.

LEARNER 7

Educator: What did you find interesting when using GeoGebra to sketch quadratic funtions?

Learner 7:

Educator: What is it that you did not like about using GeoGebra to sketch quadratic functions?

Learner 7:

Educator: In sketching quadratic functions using GeoGebra which steps did you take?

Learner 7:

Educator: What were your challenges when being assessed online?

Learner 7:

Educator: In your experience, was the online assessment fair and effective for your learning? Explain.

Learner 7:

Educator: Compared to the past, how do you think using GeoGebra improved your knowledge of sketching quadratic functions?

Learner 7:

Educator: Would you recommend use of GeoGebra to other learners? Why?

Learner 7:

Educator: What advice would you give to other learners when using GeoGebra to sketch quadratic fucntions?

Learner 7:

Educator: What would you recommend to teachers for improvement when assessing you through GeoGebra to sketch quadratic funtions?

Learner 7:

LEARNER 8

Educator: What did you find interesting when using GeoGebra to sketch quadratic funtions?

Learner 8: The reflection graphs.

Educator: What is it that you did not like about using GeoGebra to sketch quadratic functions?

Learner 8: Nothing because it will help you when you are having a real class.

Educator: In sketching quadratic functions using GeoGebra which steps did you take?

Learner 8: Steps of showing that the coordinates of the graph are negative or positive.

Educator: What were your challenges when being assessed online?

Learner 8: Data and network connection.

Educator: In your experience, was the online assessment fair and effective for your learning? Explain.

Learner 8: Was fair because it will help you to practice.

Educator: Compared to the past, how do you think using GeoGebra improved your knowledge of sketching quadratic functions?

Learner 8: By showing that $a > 0$ or $a < 0$. And if $a > 0$ the graph will have a sad shape and if eh…. If $a > 0$ the graph will have a smile shape and if $a < 0$ the graph will have a sad shape.

Educator: Would you recommend use of GeoGebra to other learners? Why?

Learner 8: Yes. Because it will help them.

Educator: What advice would you give to other learners when using GeoGebra to sketch quadratic fucntions?

Learner 8: To help the knowledge that if $a > 0$ you will see a smile shape and if you don't see a smile shape it means is a wrong graph.

Educator: What would you recommend to teachers for improvement when assessing you through GeoGebra to sketch quadratic funtions?

Learner 8: To have more learners in her/his class.