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Investigating the impact of interactive simulations: A case of PhET simulators to teach algebraic functions in quintile three schools

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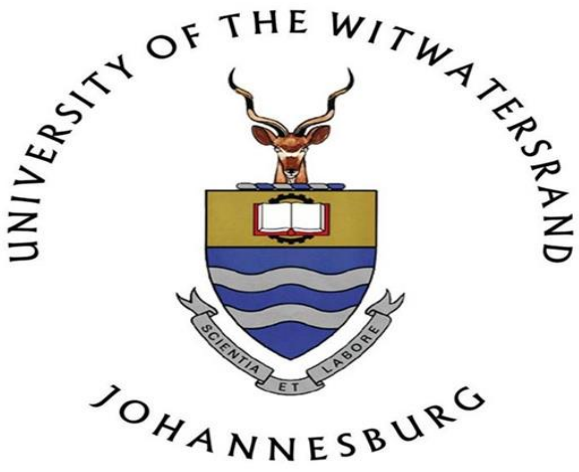
2024

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Ngubane, Nkululeko. (2024). Investigating the impact of interactive simulations: A case of PhET simulators to teach algebraic functions in quintile three schools [Masters dissertation, University of the Witwatersrand, Johannesburg]. WIReDSpace. https://hdl.handle.net/10539/44982

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Investigating the impact of interactive simulations: A case of PhET simulators to teach algebraic functions in quintile three schools.

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Protocol Number: H23/10/27

A research dissertation submitted in conformity with requirements for the degree of Master of Education at Wits School of Education

Supervisor: Dr Alton Dewa

July 2024

Declaration

I, Nkululeko Ngubane, declare that this project is my original work and has not been submitted for a degree or as part of any degree requirements previously. I certify that I have written this project myself and have acknowledged any assistance received during the research and writing process. Furthermore, I confirm that all sources and literature used in this work are properly referenced.

Signature:



July 2024

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Acknowledgements

First and foremost, I would like to express my deepest gratitude to the Almighty God for his unwavering strength and guidance throughout this journey. His blessings instilled in me the wisdom and dedication necessary to reach this point.

My sincere thanks go to my esteemed supervisor, Dr. Alton Dewa. Your patience, encouragement, and consistent support were instrumental in guiding me through this project. I appreciate your invaluable insights and advice, which significantly improved the quality of my work.

To my parents, Zandile and Praise-God Ngubane, and my sister, Aphile Ngubane, I extend my heartfelt gratitude. Your unwavering belief in me provided a constant source of motivation. I am truly grateful for your unwavering support, which has been the foundation for all my achievements. This dissertation is dedicated to you.

Abstract

This study presents a qualitative case study investigating the potential of PhET simulations to improve the teaching and learning of algebraic functions in Grade Nine classrooms in South African township schools, particularly those categorized as quintile 3. The study implements a constructivist approach, acknowledging the subjective experiences of five participating mathematics educators. The research reveals varied perspectives among educators regarding the integration of PhET into the curriculum. Some educators recognize the value of PhET's visually engaging features in enhancing student understanding of abstract mathematical concepts. However, others express concerns about limited exposure to PhET and the challenges of integrating the tool in resource-constrained environments.

Challenges identified include limited access to technology, overcrowded classrooms, and unreliable internet connections, which hinder teachers' ability to employ innovative teaching methods and promote conceptual understanding in mathematics. Additionally, broader socio-economic factors such as poverty, language barriers, and lack of parental support impact student learning. Despite these challenges, educators indicate enthusiasm for existing digital tools like GeoGebra and Google Classroom, highlighting the potential of technology to facilitate visualization and collaboration in learning environments. The study emphasizes the importance of ongoing professional development opportunities for teachers in utilizing educational technologies effectively.

The study highlights the potential benefits of PhET simulations in enhancing learner understanding and problem-solving skills in algebraic functions. However, successful implementation requires addressing teacher training needs, infrastructure limitations, and the broader socio-economic context.

Keywords: PhET simulations, Algebraic functions, Constructivist approach, township, technology.

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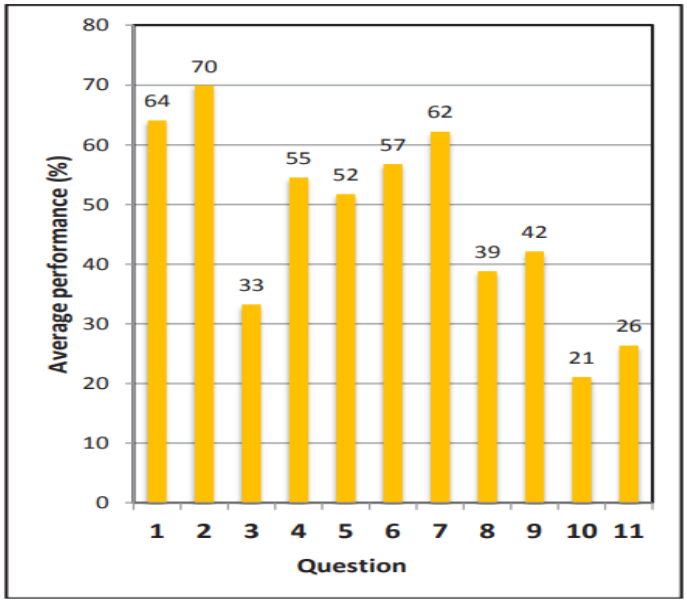
Chapter 1: Background and overview of the study

1.1 Introduction and background

Algebraic functions are one of the fundamental subjects taught in secondary school mathematics curriculum, requiring prior knowledge, and unifying mathematical disciplines. Functions are based on the study of linear functions and their graphs, which is covered in grades 7-9 senior phase. As learners progress through the Further Education and Training groups (FET) Grades 10–12, there is a progression in the content, and the examination evaluates knowledge of concepts from earlier grades. In South Africa, the National Senior Certificate (NSC) Mathematics paper 1, algebraic functions including calculus contributes between 60%-to-65%-mark allocation. These statistics alone shows that algebraic functions serve as the foundation for other mathematical ideas, and it is a skill that demands learners to use their knowledge of variables and appropriately interpret mathematical symbols. In mathematics, a function is a rule or relationship where any given input value yields a single, distinct output (Mushipe & Ogbonnaya, 2019). Functions are categorized according to their degree which is the highest exponent of the variables (for instance, $y = ax^3 + bx^2 + cx + d$) or by the type of graph the relationship produces. For example, a highest exponent of three produces a cubic function, whereas a highest exponent of two produces a quadratic function. One of the most mentioned topics in previous NSC diagnostic reports that students perform badly in are functions and calculus. The method that teachers are using when teaching functions is characterized by conversational teaching techniques or traditional methods of teaching (Mushipe & Ogbonnaya, 2019). This is a technique where teachers frequently employ conversational teaching where oral teaching dominate the lesson delivery with less illustrations, demonstration, simulations, modelling, and examples resulting in limited understanding of the concept. Majority of mathematics educators in township schools continue teaching functions using chalkboard techniques, which makes it very challenging to learners that are ‘net-generation’ (Garcia, 2020). Net-generation refers to learners that are born within technology and their lives depends entirely on the use of technology. And thus, there is a gap in pedagogical delivery, meaning net-generation learners are expecting lesson delivery that is done through use of digital technology, a language that they could understand better. On the other hand, educators are still stuck to the old methods of teaching that do not motivate and capture learners’ attention to help understand the concept taught.

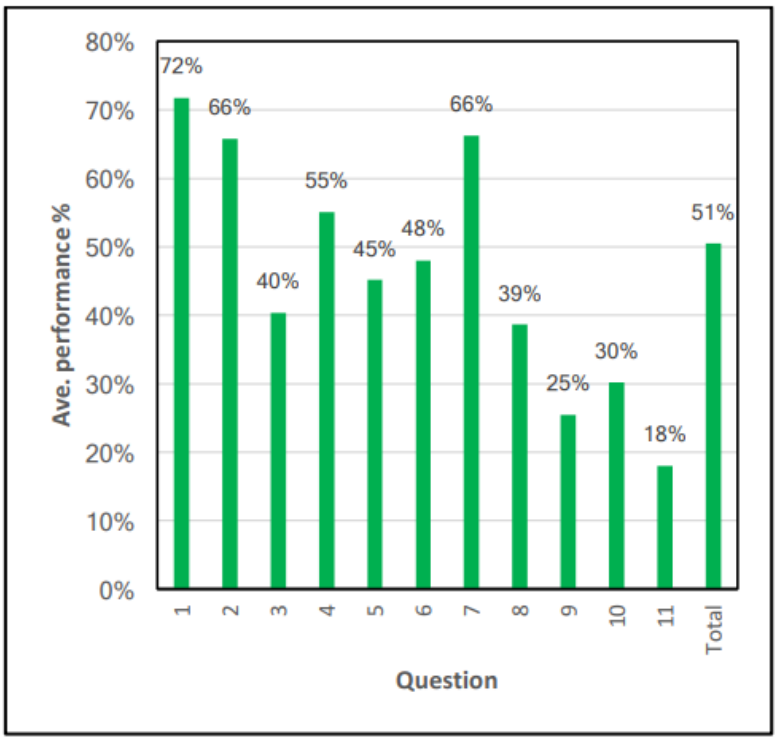
Algebraic functions could help learners in advanced mathematical reasoning, and expertise in algebraic operations as required for students pursuing occupations in science, technology, engineering, and mathematics (STEM) (Cangelosi, Madrid, Cooper, Olson, & Hartter, 2013). The

application of functions to actual, real-world problems has elevated the discussion of linear functions to the status of being the cornerstone of decision-making (Cangelosi et al, 2013). To develop workable and successful solutions, teachers may occasionally ask learners to translate real-world situations into graphs. This can be accomplished if learners have developed the mental models and schemas in linear functions that will enable them to approach such problems. Common errors and misconceptions range from incorrect Factorisation, unable to draw a sketch and write down the required answer, struggling to interpret the correct answer from the inequality, failing to label the asymptotes and the intercepts with the axes on their sketch graphs (NSC Diagnostic report, 2019; 2020; 2021).The NSC diagnostic report (2019, 2020, 2021) reports indicate average performance per question for Paper 1 and it is noted that functions and graphs and calculus questions are perfomed badly.The functions and graphs in 2019 indicate the performance of Q4 -55% and Q5- 52%, Calculus, Q7-62%, Q8-39%, Q9-42%. In 2020, Q4 -55% and Q5- 45%, Calculus, Q7-66%, Q8-39%, Q9-25%. In 2021, Q5 -77%, Q6-48% and Q7- 51%, Calculus, Q9-69%, Q10-38%, Q11-8%. Figure 1(a) to 1(c) is an exerpt that affirm the afore-mentioned statistics.



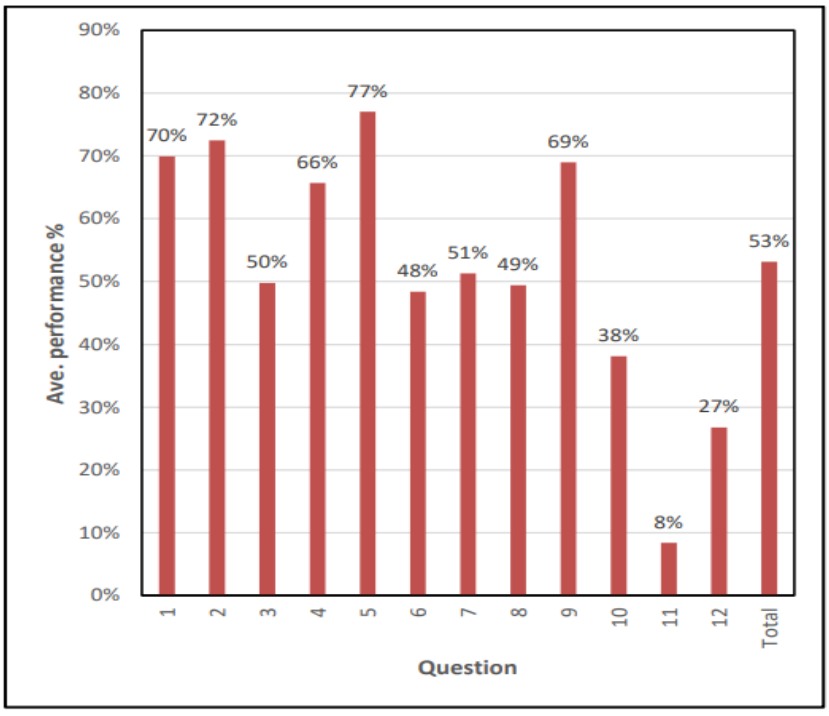
Q1	Equations, Inequalities and Algebraic Manipulation
Q2	Number Patterns & Sequences
Q3	Number Patterns & Sequences
Q4	Functions and Graphs
Q5	Functions and Graphs
Q6	Finance
Q7	Calculus
Q8	Calculus
Q9	Calculus
Q10	Probability
Q11	Probability and Counting

Figure 1(a) (*2019 NSC Diagnostic report)*



Q	Topic/s
1	Equations, Inequalities and Algebraic
2	Number Patterns & Sequences
3	Number Patterns & Sequences
4	Functions and Graphs
5	Functions and Graphs
6	Finance
7	Calculus
8	Calculus
9	Calculus
10	Probability and Counting
11	Probability

Figure 1(b) (*2020 NSC Diagnostic report)*



Q	Topics
1	Equations, Inequalities & Algebraic Manipulation
2	Number Patterns & Sequences
3	Number Patterns & Sequences
4	Number Patterns & Sequences
5	Functions & Graphs
6	Functions & Graphs
7	Functions & Graphs
8	Finance
9	Calculus
10	Calculus
11	Calculus
12	Probability & Counting

Figure 1(c) (*2021 NSC Diagnostic report)*

Based on the evidence shown in Figure 1(a) to 1(c), leaners are performing badly consistently in both Functions and calculus. It is noted that Q5 and Q11 are poorly performed. Failing to master the Functions and calculus result in ripple effect in other math topics as these are the cornerstone of mathematics. Deep understanding of algebraic functions concepts in early grades may lead to better performance in other mathematics topics as learners progress to higher grades. Many learners in quintile 3 (non-fee paying) schools have challenges in understanding the Algebraic Functions topics as educators use mono methods of teaching the concepts. Introduction of computing software in teaching algebraic functions concepts may enhance learners understanding of the problem at hand. Use of PhET Interactive Simulations may mediate solving the algebraic functions problem, as it is animated, interactive, and game-like environments, in which learners learn through exploration. To lessen the misconceptions of understanding algebraic concepts, this research proposes to use PhET simulators to grade 9 classes to concretize the concepts of algebraic functions and calculus. The objective being to use animated and interactive software to assist learners understand the concept of functions much better, and as a result this may help them perform better in functions as they progress to higher grades.

1.2 Problem statement

Learners are not performing well in Algebraic functions in Paper 1 NSC examination. The NSC Diagnostic reports (2019; 2020; 2021) reveal an average percentage mark that is less than 50% in both Functions and Graphs and calculus. According to reports, functions and graphs are one of the subjects that students find difficult. Effective teaching of functions is another challenge for many teachers as many of them are still using a conversational lesson delivery. In this day of age where there is abundance of technology, teachers can use tools such as PhET, GeoGebra and Maple calculator to enhance their teaching techniques. The senior phase of schooling (Grades 7-9) is when the foundation of functions in school mathematics curriculum is covered. Effective function instruction at the foundational level is necessary to guarantee content progression into the upper grades. In order to improve learner understanding of some topics in mathematics, including functions, several studies conducted around the world have recommended integrating graphing software to help develop the concept (Mushipe & Ogbonnaya, 2019). This study proposed the PhET simulators in Grade 9 math classes as a solution to enhance learning and understanding of algebraic functions. The PhET simulators provide the connections between real-life phenomena and the underlying concepts and seeks to make the visual and conceptual models of mathematics expert accessible to learners (Banda & Nzabahimana, 2023). This may probably motivate other educators to use these tools in their future teaching practice.

Learners are facing challenges with the algebraic representation of a linear function, which is frequently written as y = mx + c, as well as the graphical and tabular representations (Garcia, 2020). Any relationship between two variables that can be depicted as a straight line is referred to as a linear function. It is a fundamental concept in mathematics that has applications in many areas of the subject as well as in other academic disciplines and is frequently used in practical situations (Garcia, 2020). A critical turning point in students' mathematical development occurs when they learn about linear functions because it gives them their first exposure to recognizing and interpreting the relationship between two dependent variables.

One of the top priorities of the South African government is to improve mathematics education. Particularly noteworthy are the growing calls for more innovative teaching strategies, that incorporate the use of digital technologies or Information and Communication Technologies (ICT), to enhance teaching and learning (Findley, Whitacre, & Hensberry, 2017). In light of the nation's historically of low learner achievement in mathematics, this research is significant as it brings out new pedagogical approaches that are robust compared to old instructional methods (Hensberry, Moore, & Perkins, 2015). The old instructional method strategy results in learners lacking interest and developing boredom, and ultimately disliking the subject (Whitacre, Hensberry, Schellinger & Findley, 2018). To remediate the concept of functions and graphs this study proposes to implement use of Phet simulators at Grade 09 level so that as they progress to higher level the idea of the concept is better understood.

1.3 Aims of the study

- To investigate other possible intervention strategies for enhancing learners understanding and critical thinking in algebraic functions
- To alert mathematics educators about other digital tools that could be useful for teaching and learning of functions.

1.4 Objectives

1. To investigate how mathematics educators, teach algebraic functions.
2. To investigate how Phet simulators application and demonstrations enhance the teaching and learning of functions in mathematics grade 09?

1.5 Research question.

How can the use of simulators (Particularly Phet) enhance learner understanding and enhance critical thinking and problem-solving skills in algebraic functions?

Sub-questions

1. What are the current methods that teachers are using in teaching functions & graphs in quintile 3 township schools?
2. How can Phet simulators application and demonstrations enhance the teaching and learning of functions in mathematics grade 09?
3. How can Phet simulations enhance critical thinking and problem-solving skills in algebraic functions?

1.6 Significance of this study

PhET simulations are made to be user-friendly for learners, to promote inquiry-based learning, and to facilitate instruction that is learner centered. PhET simulations give students the freedom to independently investigate mathematical ideas, assess their comprehension, and get feedback within the framework of an exciting virtual environment (Whitacre et al., 2018). Before involving students in more structured activities in lessons involving PhET simulations, it can be beneficial to let them play with a simulation for a while. Learners can freely explore a simulation during the first play session, play with the controls, ask questions, find relationships, and generally get interested in and involved with the subject (Whitacre et al., 2018). This first independent task may encourage learners to take more responsibility for their learning. In addition, use of role play can help facilitate learning and making the most of learning to take place during play. The use of Phet provide a pedagogical insight on how linear functions concepts could be taught by grade 09 educators in a manner that will lay a solid foundation for learners to easily understand the topic as they proceed further to FET phase. Thus, building up and preparing learners for grade 12 final examination.

The achievement gap in mathematics education remains a persistent challenge, particularly in under-resourced township schools. These schools often struggle with a lack of up-to-date textbooks, limited access to technological tools, and various socioeconomic factors that can hinder student learning (Arifin, Nugraha, & Prasetyo, 2022). This research explores the transformative potential of PhET interactive simulations, specifically focusing on their ability to enhance the teaching and learning of linear functions in lower grades (Grades 7-9) and ultimately improve student performance in the crucial Grade 12 National Senior Certificate (NSC) examinations. Linear functions, the cornerstone of secondary school mathematics, lay the foundation for advanced mathematical concepts. Understanding slope, y-intercept, and their

graphical representations are fundamental skills required for success in higher mathematics courses. However, traditional, textbook-driven approaches can often fall short in fostering a deep conceptual understanding, especially in resource-constrained environments (Mallari & Lumanog, 2020). Here, PhET simulations emerge as a powerful pedagogical tool, offering a unique blend of interactivity, visualization, and inquiry-based learning, perfectly suited to address the specific needs of township schools.

One of the most significant advantages of PhET simulations lies in their ability to bridge the resource gap. These freely available, web-based simulations eliminate the need for expensive textbooks or specialized software (Salame & Makki, 2021). Furthermore, their user-friendly interface requires minimal technical expertise from educators, making them readily accessible even in schools with limited technological infrastructure. This democratizes access to high-quality learning experiences, ensuring that all students, regardless of their socioeconomic background, have the opportunity to engage with linear functions in a dynamic and interactive way.

PhET simulations promote a shift from passive learning to active exploration. Unlike static textbook diagrams, these simulations come alive, allowing learners to manipulate variables, observe real-time changes in graphs, and experiment with different scenarios (Findley, Whitacre & Hensberry, 2017). This fosters a deeper understanding of the relationship between the algebraic equation, its graphical representation, and the underlying mathematical concepts. For instance, the "Function Grapher" simulation allows learners to visualize how changing the slope alters the steepness of the line, while "Points to Line" enables them to explore the concept of the y-intercept by manipulating the point of intersection with the y-axis. This interactive environment empowers students to take ownership of their learning, fostering curiosity, critical thinking, and a sense of discovery.

Traditional teaching methods often rely on rote memorization and formulaic approaches. PhET simulations, however, encourage inquiry-based learning, where students actively grapple with the concepts (Banda & Nzabahimana, 2023). By posing questions and prompting exploration within the simulation environment, educators can guide learners towards formulating hypotheses, testing their predictions, and drawing their own conclusions. This process fosters a deeper understanding that goes beyond simply memorizing facts. Learners learn to analyse relationships, identify patterns, and connect mathematical concepts to real-world phenomena. According to Banda & Nzabahimana (2023), the "Linear Fit" simulation allows learners to explore the concept

of linear regression by fitting a line to real-world data sets, fostering connections between mathematics and various scientific disciplines.

The benefits of using PhET simulations extend beyond the classroom walls. These simulations provide valuable tools for personalized learning and differentiated instruction. Students can explore the simulations at their own pace, revisiting specific concepts or delving deeper into areas of interest (Bush, Webb, Kress, Yang & Perkins, 2018). This caters to diverse learning styles and allows educators to provide targeted support to students who may be struggling with certain aspects of linear functions. Furthermore, the simulations can be seamlessly integrated into flipped classroom models, where students can independently explore concepts through PhET simulations at home, freeing up valuable class time for deeper discussions, problem-solving activities, and collaborative learning experiences.

The ultimate goal of this pedagogical shift is to equip learners with a solid foundation in linear functions, preparing them for success in the Grade 12 NSC examinations. A strong grasp of these concepts is essential for performing well in various sections of the mathematics paper 1, including functions and graphs, and calculus. By fostering a deeper understanding and a more positive attitude towards mathematics in lower grades, PhET simulations can empower township learners to approach the Grade 12 examinations with greater confidence and a stronger skillset (Salame & Makki, 2021). Improved performance in these crucial examinations can pave the way for access to higher education opportunities in STEM fields, ultimately contributing to a more skilled and qualified workforce.

However, implementing PhET simulations effectively requires careful consideration of certain factors. Educators need to be adequately trained in utilizing these simulations effectively within their lesson plans. This training should equip them with strategies to facilitate discussions around learner observations within the simulations, address misconceptions, and connect the virtual experience to the broader mathematical framework. Furthermore, ensuring reliable internet access in township schools remains a challenge. While some simulations can be downloaded for offline use, maximizing the potential of PhET simulations necessitates addressing the broader issue of digital equity in these communities.

1.7 Conclusion

The South African education system faces a significant challenge, learners consistently underperform in the National Senior Certificate (NSC) examinations, particularly in mathematics. Alarmingly, the average mark for Functions & Graphs and Calculus falls below 50%, highlighting

a critical need for innovative teaching strategies. This study, therefore, explores the transformative potential of PhET simulations, interactive learning tools designed to bridge the resource gap and enhance the teaching and learning of linear functions, especially in under-resourced township schools. The root of the problem lies in the current teaching methods. Traditional, textbook-driven approaches often fail to foster a deep conceptual understanding of linear functions, a fundamental building block for success in higher mathematics. This is particularly concerning in township schools where students often lack access to up-to-date resources and face various socioeconomic challenges. PhET simulations emerge as a beacon of hope, offering a unique blend of interactivity, visualization, and inquiry-based learning. These freely available, web-based tools eliminate the need for expensive textbooks or specialized software, making them readily accessible even in schools with limited technological infrastructure. This democratizes access to high-quality learning experiences, ensuring that all students can engage with linear functions in a dynamic and interactive way.

Chapter 2: Literature review

1.1 Introduction

21st century high-tech software and hardware such as computers, Microsoft programs, various digital devices applications programs (e.g. YouTube, Math Software such as GeoGebra, etc.), may help to relieve pressures on teachers as they supplement the teaching by making it easier and more efficient to engage learners in more practical, relevant, and interesting lessons. In essence, these software systems, if used appropriately, can act as intervention and as extra lessons for learners. Thus, numerous literatures have proven that use of digital technologies for school learning is critical for providing learners with multiple opportunities and critical skills for striving in this information age (Mushipe & Ogbonnaya, 2019). However, most educators are still trapped in the old methods of teaching using the chalkboard. There is nothing wrong with this method, but the context at which it is practiced raise some concern. Contemporary learners are 'net-generation', and the method of teaching should somehow use some technology, the terrain that they understand better. Teachers may be doing their best to teach mathematics, however, the statistics from previous diagnostic reports (Figure 1(a) to 1(c)) does not show that there is a consistent improvement in the performance of learners in functions and its subsequent topic, calculus. To alleviate traditional mode of lesson delivery for mathematics classes, it is important to review how technology can be used in the contemporary pedagogical approaches.

1.2 Effects of Digital Technology in the Classroom

The employment of digital resources during classroom instruction can significantly improve students' academic performance and engagement with the material. According to Bengimlas (2009), in the scientific classroom, "ICT could be positive forces for a deeper understanding of the principles and concepts of science and could be used to provide new, authentic, interesting, motivating and successful educational activities" (p. 237). Furthermore, the study on mathematics conducted by Erbilgin & Şahin (2021), found that learners who learnt in a technological setting outperformed their peers who had studied the same material in a traditional classroom on examinations. "Students who learned technology-assisted algebra were more motivated to learn, had a more positive attitude towards algebra, and achieved higher academic gains" (p. 2). Erbilgin and Şahin (2021) also discovered that students who learned functions using GeoGebra were more adept in higher order thinking than those that learned the identical topic without using any graphing software. The usage of digital tools also allows for additional teaching time for an educator because these digital resources are readily available for use by the teacher. Thus, this saves both the teacher and learners a lot of time.

Improved learner outcomes may be gained when an educator strategically employs technological tools to increase learner engagement and effective communication throughout a lesson "Research studies, however, point out the need to foster teacher knowledge and practices for using technology effectively in mathematics lessons" (Erbilgin & Şahin 2021, p. 3). This will provide educators with the necessary abilities to choose appropriate computer programs to complement teaching for various mathematics topics. Integrating technology into teaching allows the net-generation to connect education to their daily lives. "An algebra curriculum that serves its students well in the coming century may look very different from an ideal curriculum from some years ago. The increased availability of computers and calculators will change what mathematics is useful as well as changing how mathematics is done" (Bokhove & Drijvers, 2010, p. 46). This implies that as times and technologies evolve, so must our ways of teaching and assessing learners. The days of chalk and talk being the best instructional technique for teaching and learning are long gone. The utilization of digital tools and powerful computer programs has the potential to significantly bridge the gap between traditional teaching techniques and what successful instruction could be for our net-generation. As a result, this research recommends that using PhET simulators from early grades may improve learners' comprehension and pedagogy of functions and graphs.

1.3 What are PhET Simulators?

At the University of Colorado (USA), Nobel Laureate Carl Wieman founded PhET Interactive Simulations in 2002, which produces free interactive math and science simulations (Garcia, 2020). The Philippine simulations aimed to engross students in a natural, game-like setting where they could discover new ideas and learn through experimentation. The abbreviation PhET stands for Physics Education Technology, but since simulations for many other subjects besides Physics are also included, the acronym becomes too limited. The PhET is a website that offers free downloads and online access to interactive computer simulations for teaching and learning physics, math, and other sciences. Since learning emphasizes interactive exploration, simulations become engaging, interactive, and game-like environments thanks to the connection between real-life phenomena and the underlying science that makes visual and conceptual models accessible to students.

The PhET project, according to (Garcia, 2020), has created over 130 interactive simulations based on research that are revolutionizing how science and math are taught and learnt. Simulations that are animated, interactive, and game-like environments allow students to learn through scientific exploration. In addition to including the visual models that scientists use, they

emphasize the connections to reality and make the invisible visible (Banda & Nzabahimana, 2023). They can be utilized in various settings, including classes, home, labs, and universities, thanks to their adaptable design. Users can use the simulators offline or online and they have been translated into more than 70 different languages. PhET simulations were designed and tested initially with college and high school students, they were found useful and entertaining for most students (Garcia, 2020). According to Whitacre et al (2018), the PhET Interactive Simulations project is addressing a significant challenge facing the nations of the world: educating the next generation of scientists, mathematicians, and engineers and raising the level of science literacy worldwide by informing and educating a wide range of people about science, math, and engineering-related issues.

One of the reasons behind the creation of PhET simulations was the recognition of the limitations of traditional teaching-based pedagogy (Astutik & Prahani, 2018). This method often presented information in a passive and decontextualized manner, failing to ignite learners' curiosity and hindering their ability to truly understand the underlying principles. As Smetana & Bell (2012) argues that learners benefit most from active engagement with the material, constructing their own knowledge through exploration and experimentation. PhET simulations were born from the vision of addressing this very need. Their creation was driven by the belief that by providing students with interactive tools and virtual laboratories, they could actively explore scientific phenomena and mathematical relationships, fostering a deeper and more meaningful understanding (Astutik & Prahani, 2018). Another factor that fuelled the development of PhET simulations was the recognition of the growing need for accessible and equitable educational resources. Traditional laboratory experiments can be expensive, require specialized equipment, and may not be readily available in all schools (Marces & Caballes, 2019). PhET simulations, being web-based and freely available, aimed to democratize access to high-quality learning experiences, regardless of a school's location or resource constraints (PhET Interactive Simulations, n.d.).

Furthermore, the increasing diversity of learning styles in classrooms posed a challenge for educators attempting to cater to individual needs. Traditional methods often struggled to effectively engage students with different learning styles, potentially leaving some learners behind (Astutik & Prahani, 2018). PhET simulations, with their diverse array of interactive features and visual representations, were designed to cater to a wider range of learning styles, allowing learners to engage with the material in ways that best suit their individual preferences (Astutik & Prahani, 2018). Figure 2 bellow illustrates some of the interactive features of the simulations:

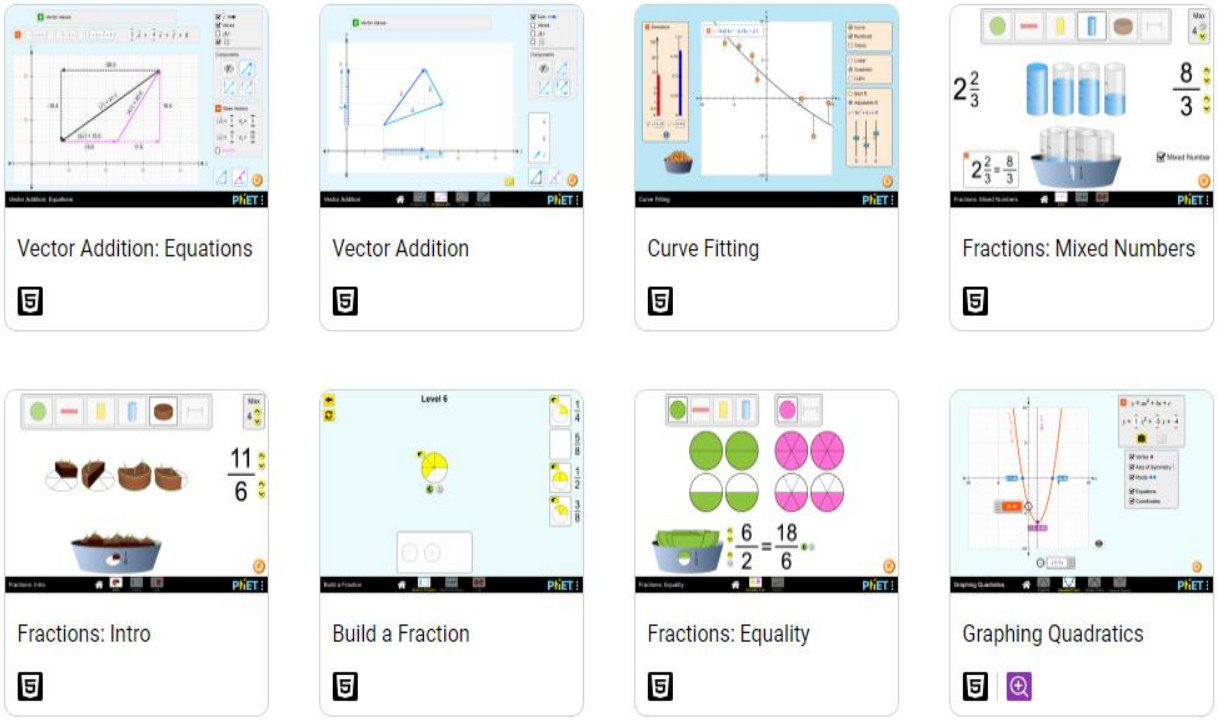


Figure 2(A)

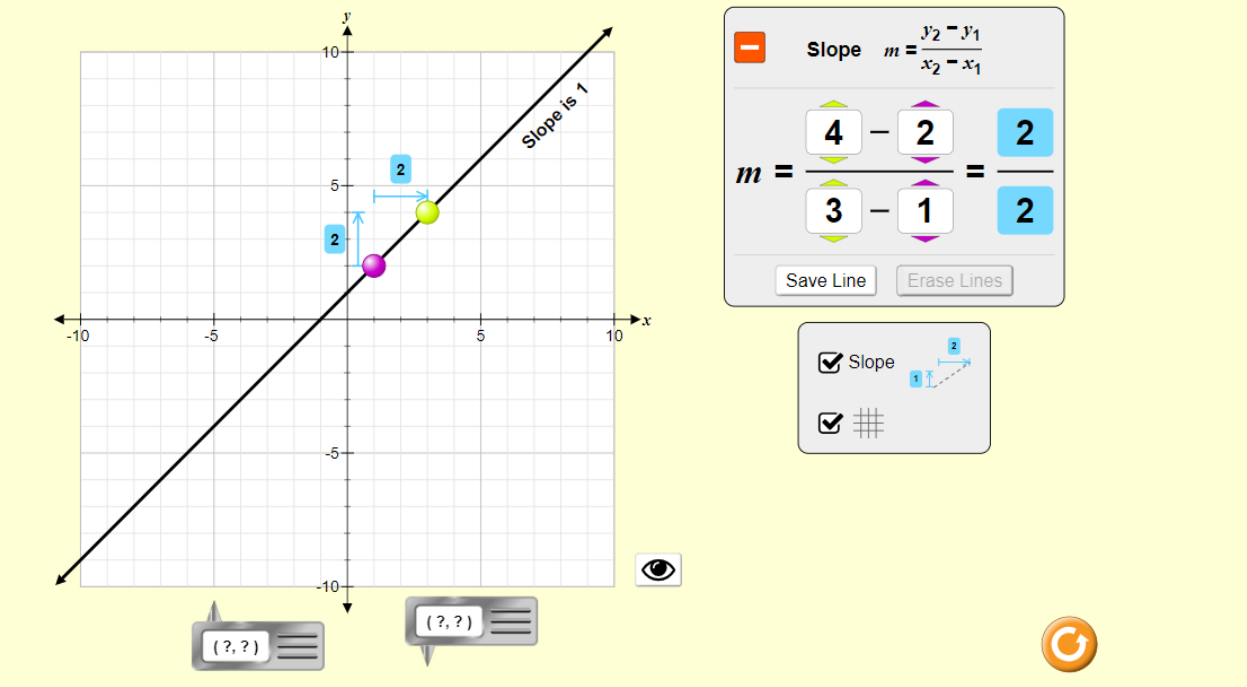


Figure 2(B)

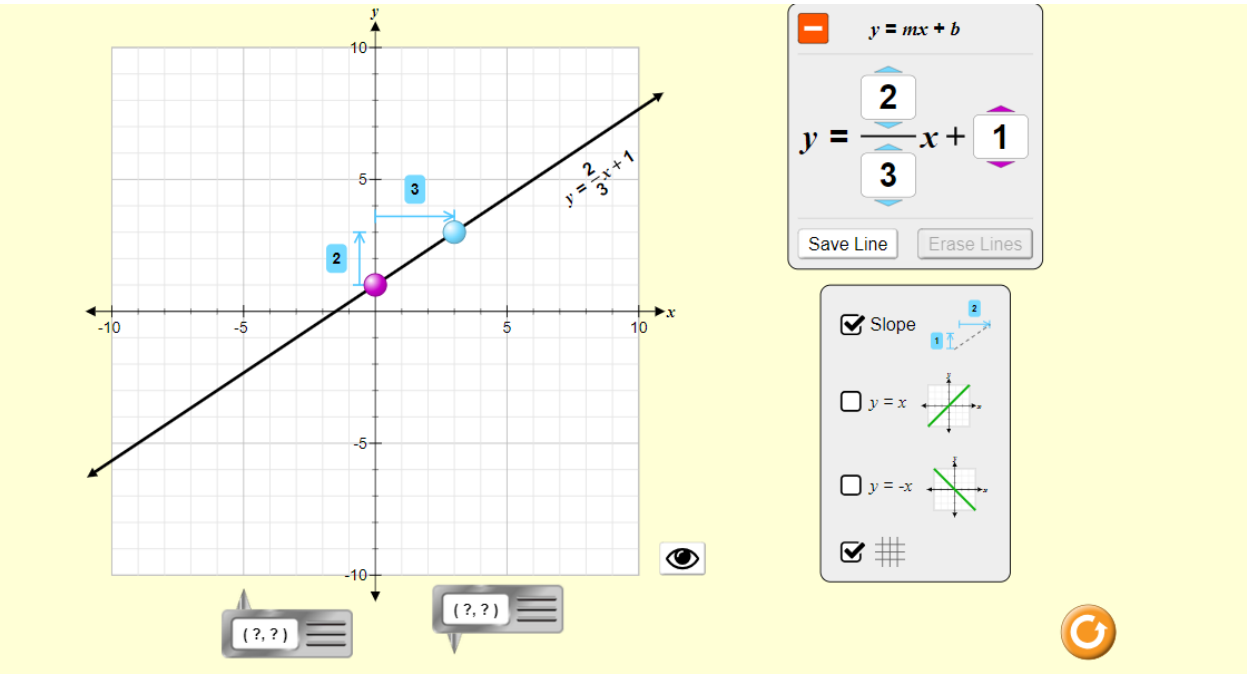


Figure 2(C)

In conclusion, the birth of PhET simulations stemmed from a confluence of concerns and aspirations in the realm of science and mathematics education. Driven by the desire to address the limitations of traditional pedagogy, promote active learning, democratize access to learning resources, cater to diverse learning styles, and leverage the potential of technology, as Marces & Caballes (2019) emphasizes that PhET simulations continue to revolutionize the way students learn and engage with science and mathematics.

1.4 Quintile ranking of schools.

South Africa has a large economic gap between the rich and the poor (Spaull, 2015). According to Graven (2014) and Letseka & Maile (2008), this imbalance has led to unequal educational chances for learners from different socioeconomic origins. According to Spaull & Kotze (2015), this educational inequality (in terms of access, performance, and resource availability) is especially visible in mathematics, a subject in which South African learners have persistently performed badly. The South African government has divided the country's public schools into five quintiles for the aim of allocating financial resources in order to address the issue of socioeconomic status and disparity in access to education (Dass & Rinquest, 2017). The

classification is based on a school's socioeconomic status, which is decided by average income, unemployment rates, and general literacy levels in the school's geographical area. Quintile 1 schools are those in the most economically disadvantaged (poorest) geographical locations, whereas Quintile 5 schools are those in the most economically advantaged (wealthiest) geographical areas (Hall & Giese, 2008). Schools in Quintiles 1–3 are non-fee-paying and get greater government support per learner than schools in Quintiles 4 and 5. Finally, there are fee-paying schools, which require less government support than schools in lower quintiles since parents can afford to pay fees. In general, it is assumed that schools in the same quintile rating should have equal socioeconomic position and standards across the nine provinces. Despite the implementation of the quintile classification of schools and the associated funding in education, one questions whether the vast disparity in academic success of learners from diverse socioeconomic backgrounds is being overcome.

The quintile system assumes a level playing field within each category. However, research by Hall & Giese (2008) suggests disparities exist even within quintiles. Schools in wealthier areas within a disadvantaged quintile might still outperform those in poorer areas within the same category due to additional community resources or parental involvement. The question remains: is the quintile system effectively addressing the vast socioeconomic disparity in mathematics achievement? While increased funding for disadvantaged schools is a positive step, it might not be enough. A multi-pronged approach is likely necessary. Curriculums that integrate real-world applications of mathematics can make the subject more engaging for students from all backgrounds (Spaull & Kotze, 2015). Additionally, investing in teacher training programs focused on effective pedagogy for diverse learners can equip educators with the skills to bridge the achievement gap (Dass & Rinquest, 2017).

Ultimately, addressing the root causes of socioeconomic inequality is crucial. Policies aimed at poverty reduction, improved access to healthcare, and community development initiatives can create a more fertile ground for learning for all students, regardless of their background. In conclusion, the socioeconomic gap in South Africa presents a significant barrier to achieving equitable mathematics education. While the quintile system represents an attempt to address this challenge, its limitations necessitate a more holistic approach. By investing in effective teaching practices, engaging curriculum design, and broader social initiatives, South Africa can move closer to ensuring all learners have the opportunity to succeed in mathematics.

1.5 Common errors and misconceptions identified in Functions grade 12 final examinations.

Several errors and misconceptions that may be significant causes leading to poor performance particularly in functions and other math topics have been documented in the NSC diagnostic reports of the previous years. It is from these reports that educators and scholars should draw some significant insights on where our pedagogical skills should be strengthened for the betterment of future NSC examinations results. Some of the issues identified by the NSC diagnostic report (part 1 content subjects) 2021 were written as follows:

> "*The algebraic skills of the candidates are poor. Most candidates lacked fundamental and basic mathematical competencies which should have been acquired in the lower grades. This becomes an impediment to candidates answering complex questions correctly*" p.186
>
> *"Candidates still confuse the domain with the range and consequently gave the incorrect answer of* $y = 2$*. Many candidates gave their answer as* $x \, \varepsilon \, R$ *. This was not accepted as it is incorrect" p.191*
>
> *"Many candidates were able to sketch the hyperbola having the correct increasing shape. However, they failed to label the asymptotes and the intercepts with the axes on their sketch graphs. They were not awarded marks for the asymptotes and intercepts with the axes because their sketches were not drawn to scale" p.191*
>
> *"In Q7.5 many candidates were unable to determine the equation of the straight line passing through K correctly. The challenge in this instance was that they were unable to establish the gradient of the line correctly. Consequently, they were unable to determine the x-coordinate of R by solving a set of equations simultaneously. Some candidates were able to calculate the equation of the line passing through K correctly but then took R to be the x-intercept of this line" P.193*
>
> *"Teachers should spend some time discussing the basic concepts of functions: all points on the x-axis have a y-coordinate of 0 and all points on the y-axis have a x-coordinate of 0. The domain is always a set of x-values and the range is always a set of y-values" p.193*

The South African Curriculum and Assessment Policy Statement (CAPS) emphasizes the development of algebraic manipulation and interpretation skills specifically designed to tackle problems related to functions. This includes calculating gradients, identifying domains and ranges, interpreting coordinates, finding intercepts, and effectively scaling, labelling, and plotting linear functions. While CAPS prescribes introduction of these concepts in grade 8 with further development in subsequent grades, issues related to grasping the fundamentals of functions persist even in higher grades, leading to difficulties with the matriculation (grade 12) function exam.

It is evident that learners struggling with algebraic manipulations and interpretations in functions will likely face challenges in related topics later in their studies. These difficulties may extend to areas like calculus, trigonometric functions, and even basic skills involving equations and solving for unknown values (Stephan, 2020). This gap in understanding presents an opportunity where simulations can be employed to reinforce these core concepts in earlier grades. By actively engaging with simulations, learners can develop a strong foundation in functions, allowing them to progress to higher grades equipped with the confidence and skill needed to tackle more complex problems (Smetana & Bell, 2012). By incorporating interactive simulations within the curriculum, educators can create a dynamic learning environment that fosters a deeper understanding of function concepts (Erbilgin & Şahin, 2021). These simulations can provide an immersive experience that allows learners to visualize abstract concepts, manipulate variables in real-time, and observe the resulting changes in graphical representations. This active engagement goes beyond traditional passive learning methods, promoting a more holistic understanding of the underlying principles.

Furthermore, simulations can cater for diverse learning styles, allowing learners to explore concepts at their own pace and through different approaches (Astutik & Prahani, 2018). This personalized learning environment empowers learners to take ownership of their learning journey, fostering a sense of agency and encouraging further exploration.

In conclusion, addressing the persistent challenges with function fundamentals requires a strategic approach that goes beyond traditional teaching methods. By strategically integrating simulations into the curriculum, educators can create an engaging and dynamic learning environment to solidify foundational function concepts. This, in turn, can equip learners with the skills and confidence necessary to excel in related mathematical disciplines, paving the way for future success in their academic pursuits.

1.6 Current methods educators use to teach functions and graphs.

The fundamental goal of education lies in fostering a transformative shift in learners' conceptual understanding of a subject, moving them from a basic grasp to a deeper, more meaningful comprehension (Stephan, 2020). To effectively facilitate this knowledge transmission, teachers must strategically adopt suitable teaching methodologies aligned with the specific objectives and learning outcomes outlined in the Curriculum and Assessment Policy Statement (CAPS) document. However, research suggests that many educators in South African township schools predominantly rely on conversational teaching or teacher-centred approaches, while neglecting the potential benefits of learner-centred strategies (Bature, 2020). This study aims to analyse the prevalent teaching methods employed in these schools, highlighting the limitations of a solely teacher-centred approach and advocating for the integration of technology-driven solutions alongside continued professional development for educators.

Within the educational discourse, discussions on the impact of various teaching strategies on student learning remain an ongoing and crucial exploration (Mascolo, 2009). Research consistently underlines the strong link between the ineffective use of teaching methods and declining student academic performance (Stephan, 2020). Teaching, as defined by Stephan (2020), is a deliberate process intended to induce positive changes in student learning outcomes. Consequently, the success of such endeavours depends upon educators' mastery of diverse teaching strategies tailored to maximize learning. While Blended Learning approaches have demonstrated promising results in enhancing learner performance (Shah & Kumar, 2019), traditional, teacher-centred methods persist in many South African township schools especially in teaching mathematics.

Teaching methods can be understood as the diverse instructional activities employed by educators to achieve specific learning objectives (Garnjost & Lawter, 2019). These methods reflect both the teachers' competencies and the overall effectiveness of the learning process. Garnjost and Lawter (2019) further highlight the ongoing quest of educators to discover innovative ways of imparting knowledge, emphasizing the diminishing effectiveness of traditional methods in the face of continuous technological advancements. Responsive teaching, tailored to meet individual learner needs, often translates to increased learning effectiveness. Digital technologies, for instance, offer the potential for immediate feedback, a valuable tool in enhancing learning outcomes.

However, the guidelines and techniques utilized by teachers to promote student learning, collectively referred to as teaching methodologies, are not uniform. These strategies are heavily

influenced by the subject matter at hand and the diverse learning styles and needs of students. To be deemed appropriate and effective, a teaching strategy must resonate with the learner's characteristics and actively foster the desired type of learning (Ali, 2019). As emphasized by Stephan (2020), the selection and design of teaching strategies should not only consider the subject matter but also take into account the inherent ways in which learners learn.

Teacher-centred instruction, characterized by the teacher as the focal point, often relegates learners to passive listening roles while demanding near-constant quietness (Sumardi, Rohman, & Wahyudiati, 2020). Such an approach fosters minimal collaboration between the teacher and the learners. As highlighted by Stephan (2020), conversational lessons place the teacher in complete control of all classroom activities, potentially leading to learner boredom and disengagement. Mascolo's (2009) research underlines the reduced likelihood of students acquiring crucial information in such settings. Since the teacher assumes sole responsibility for planning, supervising, and managing all classroom activities without actively engaging learners, the potential for knowledge absorption diminishes. This method, often prompting students to work individually, can hinder the development of communication and collaboration skills. Additionally, the monotonous nature of teacher-centred classrooms can breed student disinterest in learning, a notion corroborated by research suggesting a decline in its effectiveness in capturing and maintaining student attention (Ali, 2019). Perhaps most importantly, studies conducted by Bature (2020) reveal that a teacher-centred approach discourages students from expressing themselves and hinders their engagement in self-directed learning by discouraging them from asking questions. In essence, this method prioritizes control over fostering a dynamic learning environment.

Currently, many educators in township schools rely on a conversation-based approach, heavily focused on rote memorization of formulas and procedures for solving linear equations. Teachers present the material on the board, explain the steps involved in solving problems, and then assign practice exercises (Garnjost & Lawter, 2019). This method prioritizes teacher explanation over student exploration, leaving little room for active learning or the development of critical thinking skills. Furthermore, limited resources often restrict teachers from incorporating diverse activities or manipulatives to aid visual learners. The emphasis on memorization can be particularly disadvantageous for students who struggle with grasping the underlying concepts. As Bature (2020) highlights, teacher-centred approaches can lead to student disengagement and hinder them from asking questions or clarifying doubts.

Another prevalent method involves copying exercises from textbooks or pre-prepared worksheets. While worksheets can provide practice opportunities, their repetitive nature can become tedious and fail to address individual student needs (Ali, 2019). The lack of differentiation in these exercises can leave advanced learners bored while struggling students fall behind. Additionally, the focus on calculations often overshadows the real-world applications of linear functions, hindering learners' ability to connect the abstract concepts to practical scenarios. This disconnects between theory and application can further limit student interest and hinder their understanding of the broader value of mathematics.

While these traditional methods have a place in education, their limitations become evident in the context of under-resourced schools. Large class sizes, limited access to technology, and a lack of ongoing professional development for teachers can further exacerbate these challenges (Bature, 2020). The need for innovative approaches that cater to diverse learning styles and promote deeper conceptual understanding becomes vital.

Blended learning, which combines traditional face-to-face instruction with online learning activities, presents a promising solution. By strategically integrating digital tools into the curriculum, educators can create a more engaging and interactive learning environment for linear functions. One particularly valuable tool lies in the use of simulation games. These interactive simulations allow students to manipulate variables in real-time and observe the corresponding changes in graphical representations (Marces & Caballes, 2019). For example, a simulation could depict a moving object on a coordinate plane, with learners adjusting the slope and y-intercept to influence the object's trajectory. Such visualizations can significantly enhance a student's understanding of the relationship between the equation, its graphical representation, and the real-world context it represents.

In stark contrast to the teacher-centred approach, learner-centred instruction emphasizes the equal importance of both teachers and learners in the learning process (Ali, 2019). A defining characteristic of this approach is the increased level of interaction between learners and teachers. And these interactions can be strongly made possible by use of digital tools in the classroom, such as game like representations and interesting visualizations. Learners are actively encouraged to collaborate and engage with one another, rather than solely focusing on the teacher (Ali, 2019). Research by Stephan (2020) further indicates that this strategy fosters stronger teacher-learner communication. Numerous studies support the notion that learner-centred approaches, particularly through group projects, play a significant role in developing

students' communication and collaboration skills (Ali, 2019). Additionally, this method empowers learners to explore.

The affordability of these tools is a crucial factor in their suitability for township schools. Several online platforms offer free or low-cost educational simulations specifically designed for teaching linear functions. These resources, often developed by universities or educational NGOs, are readily available and require minimal technical expertise to utilize (Salame & Makki, 2021). Teachers can incorporate these simulations into their lessons as interactive activities, allowing students to explore concepts at their own pace and receive immediate feedback.

Blended learning should not be seen as a replacement for traditional classroom instruction. Face-to-face interaction with the teacher remains crucial for clarifying doubts, providing personalized support, and fostering critical thinking skills through discussions and problem-solving activities. The ideal scenario involves a seamless integration of both methods, leveraging the strengths of each to create a holistic learning experience for students. The current methods employed for teaching linear functions in South African township schools often fall short of fostering a deep conceptual understanding in students. Teacher-centred approaches and a reliance on rote memorization can lead to disengagement and hinder critical thinking skills. Blended learning, incorporating affordable digital tools such as simulation games, offers a promising solution.

1.7 How can Phet Simulators assist in the learning of Functions?

South Africa faces a persistent challenge in achieving consistently high matriculation results in mathematics, particularly amongst students in township schools. While CAPS outline a framework for teaching linear functions in grades 8 and 9, traditional teaching methods often struggle to effectively engage students and foster deep understanding. Thus, this research seeks to explore the potential of PhET simulations, interactive online tools, as a valuable solution to address this challenge, drawing upon research conducted both locally and internationally.

Internationally, studies highlight the effectiveness of PhET simulations in enhancing student learning across various disciplines. Salame & Makki (2021) conducted research in the USA, involving K-12 curriculum and college students using PhET simulations. Their findings indicate significant improvements in student understanding, increased engagement due to the interactive nature of the simulations, and a general appreciation for the difficulties presented. Similar positive results were reported by Puspita & Kuntjoro (2018), who observed a positive impact on students' attitudes towards science learning and their ability to grasp complex concepts. The ability of PhET simulations to introduce abstract concepts and facilitate collaborative learning is further

emphasized by Smetana & Bell (2012) and Astutik & Prahani (2018), respectively. Notably, research by Ozcan et al. (2020) confirms that the application of PhET simulations has transcended its original focus on physics education, demonstrating its effectiveness in enhancing understanding in other disciplines, including mathematics.

Studies demonstrate the measurable impact of PhET simulations on learning outcomes. Ozcan et al. (2020) found that using PhET simulations significantly improved students' understanding of the greenhouse effect, highlighting the effectiveness of simulations in enhancing learning. Similarly, Marces & Caballes (2019) observed superior results in an experimental group using PhET simulations compared to a control group relying on traditional laboratory activities. Additionally, Linog et al. (2013) concluded that PhET simulations effectively address learning competencies outlined in the K-12 curriculum and can serve as valuable substitutes in situations where real-world resources are limited.

Studies conducted within South Africa highlight the potential of PhET simulations to enhance student learning and engagement in mathematics, particularly in under-resourced contexts. Gloria and Ramnarain (2021) conducted research in diverse South African classrooms, finding that simulations "address school safety, make experiments possible when there are no apparatus, save time, improve the accuracy of results, and support independent learning" (p. 61). This supports the findings of Sylvere and Minani (2023) who observed "an improvement on students' performance in electrostatics for students taught using PhET simulations" (p. 22). These studies highlight the resourcefulness and effectiveness of PhET simulations in addressing resource limitations and fostering deeper understanding in diverse learning environments.

The success stories recounted above, originating from diverse contexts around the world, suggest a strong rationale for adopting PhET simulations within the South African CAPS curriculum. Drawing parallels with the positive outcomes observed in physical sciences education, as highlighted by Gloria & Ramnarain (2021) and Sylvere & Minani (2023), it is reasonable to expect similar benefits in the teaching and learning of functions and graphs using PhET simulations. Furthermore, Penn & Ramnarain (2019) highlight the positive impact on student autonomy, enjoyment, and ultimately, conceptual understanding in a virtual simulation environment – findings with the potential to be replicated in the context of mathematics education.

The South African context presents unique challenges, including limited resources and large class sizes. However, the affordability and user-friendly nature of PhET simulations offer a compelling solution. Numerous simulations directly address topics outlined in the CAPS curriculum for grades

8 and 9, specifically related to functions and graphs. These simulations allow students to manipulate variables, observe real-time changes in graphical representations, and gain a deeper understanding of the relationships between equations, graphs, and real-world scenarios.

The integration of PhET simulations requires careful planning and consideration. Teachers need adequate training in utilizing these tools effectively within their lesson plans, ensuring alignment with specific learning objectives outlined in the CAPS document. Additionally, addressing potential technical challenges within the classroom setting is crucial. However, the potential benefits far outweigh the initial investment. Integrating PhET simulations into the curriculum can foster a more engaging and interactive learning environment, catering to diverse learning styles and promoting independent exploration.

In conclusion, the current state of mathematics education in South African township schools necessitates innovative solutions to bridge the gap and improve matriculation results. PhET simulations, with their proven track record of success in diverse contexts and across various disciplines, offer a promising solution specifically in the teaching and learning of linear functions. By leveraging the interactive nature and affordability of these online tools, educators can create a dynamic learning environment that empowers learners to grasp complex concepts, cultivate critical thinking skills, and ultimately, achieve academic success.

1.8 Theoretical frameworks

Lev Vygotsky's (1978) concept of collectivity laid the foundation for Engeström's (1999) expanded activity theory model. This model emphasizes the social and contextual aspects of activities, addressing limitations in the classical representation of activity systems. Engeström (1999) argues for a framework that "dialectically links the individual and the social structure" (p. 19). This expanded model incorporates community, division of labour, rules, subjects, objects, and tools as its core elements (Figure 2.2). It depicts activities as collaborative endeavours, acknowledging diverse perspectives, traditions, and interactions within a community.

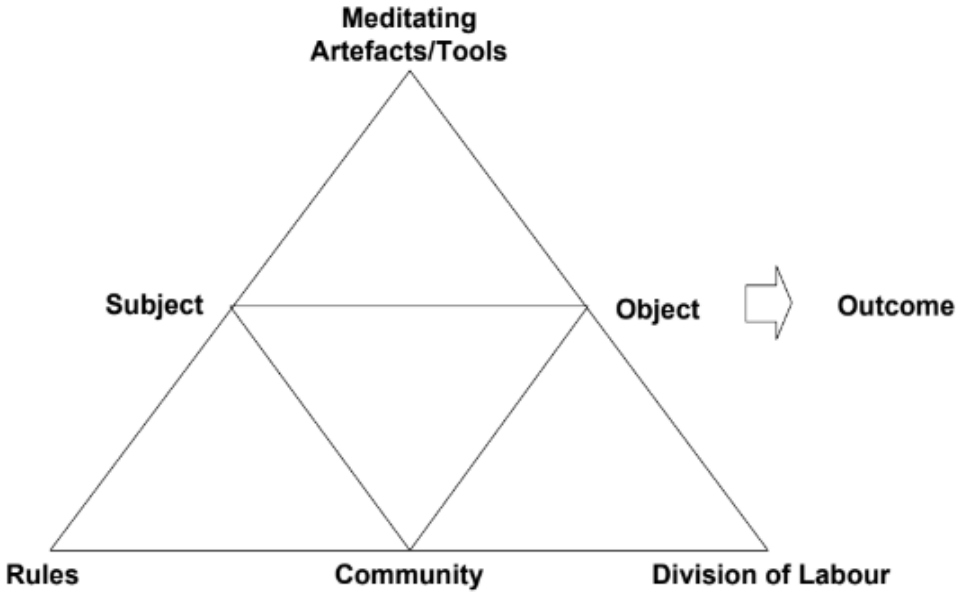


Figure 2.2: A model of an activity system (Adapted from Engstrom, 1999)

The model defines the objective of an activity as the collective goals, motives, or intentions of participants. Interactions within the activity are mediated by tools, rules, and division of labour. These elements, and their interactions, collectively constitute the activity system.

Mediation refers to the nature of relationships between participants and within the community (Mwanza & Engeström, 2005). The subjects are individuals or groups engaging in purposeful actions aimed at achieving the system's goals (Bedny & Karwowski, 2004; Jonassen & Rohrer-Murphy, 1999). The objects represent the desired outcomes or intentions of the activity (Jonassen & Rohrer-Murphy, 1999). Tools mediate the achievement of these outcomes. These tools can be physical (computers, paper) or mental (mathematical models, heuristics) (Jonassen & Rohrer-Murphy, 1999). Rules are explicit or implicit regulations guiding actions and interactions within the system (Jonassen & Rohrer-Murphy, 1999; Mwanza, 2001). The community encompasses individuals sharing the object with the subjects, representing the social and cultural context of the activity system (Mwanza, 2001). Division of labour refers to the allocation of responsibilities and roles within the community (Mwanza, 2001). Finally, the outcome is the desired result of the activity system (Bedny & Karwowski, 2004).

Engeström's (1999) model emphasizes the interconnectedness of these components. Activities are not isolated units, but rather nodes within interconnected networks, influenced by other activities (Scanlon & Issroff, 2005). Benson, Lawler, & Whitworth (2008) highlight that both internal

(subjects) and external (community) elements are mediated by tools, rules, and roles. Tools mediate the subject-object relationship, rules mediate the subject-community relationship, and division of labour mediates the object-community relationship. These components are dynamic and constantly interact, defining the activity system as a whole (Barab et al., 2002). An activity theory perspective, therefore, requires considering the interplay of all these elements in any phenomenon, such as classroom teaching and learning. Human beings rarely interact directly with the world. Throughout history, we have developed various artefacts, including Information and Communication Technologies (ICT), to mediate interactions with the world and each other, essentially to fulfil our needs. Artefacts are a hallmark of human life (Kaptelinin & Nardi, 2006). They embody successful adaptations from the past, carrying the knowledge and experience of earlier generations (Cole, 1999). They are fundamental mediators of purposeful human actions, connecting us to the present, our culture, and history (Kaptelinin & Nardi, 2006).

Physical artefacts, also known as tools or instruments, are readily identifiable due to their significant impact on daily life (Kaptelinin & Nardi, 2006). Examples include books we read, phones we use, traffic signs, and cutlery. These artefacts are deeply integrated into our daily activities. Wartofsky (1979) proposes three levels of artefacts, each influencing human activities differently. Primary artefacts directly mediate the subject-object relationship in an activity. These are the tools we use directly, such as computers, telecommunication networks, and bowls. Secondary artefacts combine primary artefacts with models of actions used to preserve and transmit skills related to their use. Tertiary artefacts contain elements of imagination, proposing potential changes to existing practices. According to Cole (1999, p. 91), "These imaginative artifacts can come to colour the way we see the actual world, acting as tools for changing current praxis. "The emphasis on tool mediation between the human mind and objectives is central to activity theory. This is because the theory recognizes the human mind's role in cultural-historical development. When development occurs, a shift from existing practices.

Studies worldwide have demonstrated the effectiveness of activity theory in transforming learning experiences. A Brazilian study by Santos et al. (2022) used activity theory to analyse how a novel teaching approach enhanced biology learning. It revealed a shift in the activity system, empowering learners to become co-creators of knowledge. Similarly, South African research by Mentz et al. (2020) employed activity theory to understand teacher perceptions of computer usage in primary schools. They found that successful integration strongly depended on aligning the tools with the activity system's goals, acknowledging teacher anxieties, and fostering collaborative learning environments.

The study explores how activity theory can guide the introduction of digital tools in South African township schools for mathematics education. Here, the object would be learners' mastery of specific mathematical concepts. The subject is the learner, while the mediating artifact is the digital tool. Rules include the national curriculum and pedagogical approaches. The community encompasses teachers, peers, and parents. The division of labour involves the roles of teachers in facilitating learning and learners in actively engaging with the tools. Potential contradictions might include limited access to technology, inadequate teacher training, or a mismatch between the software and curriculum goals. However, activity theory helps us identify and address these contradictions.

Firstly, we may consider the issue of access. One solution, as suggested by Burnett (2021) in his research on physical education in South African schools, could be to explore models where students share devices or utilize technology labs strategically. This aligns with the activity system by maximizing resource utilization. Secondly, teacher training becomes crucial. Studies by Polly, Martin & Byker (2023), highlight the importance of training that goes beyond technical skills. Teachers should understand how to integrate digital tools seamlessly into their existing pedagogical approaches, effectively bridging the gap between the tool and the intended learning outcomes. Finally, aligning the software with the curriculum and learner needs is essential. Here, community involvement becomes key. Parents and teachers can collaborate to choose tools that address specific curriculum objectives and cater to diverse learning styles. This collaborative approach strengthens the community within the activity system.

Through this activity driven approach, the introduction of digital tools becomes more than just providing learners with new gadgets. It becomes a catalyst for advanced learning. Students can move beyond rote memorization and engage with mathematics concepts in a more interactive and visually stimulating way. Imagine a student struggling with algebraic reasoning using traditional methods suddenly grasping linear principles through interactive simulations. This shift from passive learning to active engagement is at the heart of activity theory transformative potential. Furthermore, digital tools can foster collaboration within the classroom community. Learners can work together on projects using the software, promoting peer learning and communication skills. This aligns with the division of labour within the activity system, empowering learners to become co-creators of knowledge.

It is without any doubt that implementing activity theory requires ongoing evaluation and adaptation. Contradictions will inevitably arise throughout the process. However, this strategic

approach aligns perfectly with activity theory focus on development and transformation. By continuously analysing the activity system and addressing any emerging issues, educators can create a dynamic and empowering learning environment for mathematics in South African township schools.

In conclusion, Activity Theory offers a powerful lens for integrating digital tools into South African township schools. It allows us to move beyond a purely technological approach and focus on transforming the entire learning experience. By understanding the complex interplay between learners, tools, and the broader community.

Table 2.1: Activity theory illustration for this work

Concepts	**Information**	**Definitions**
Subject	The teachers participate in the teaching and learning of mathematics	• Educators (Mathematics grade 09 educators and the HOD's)
Object	The object of the activity being improved matric results and deep understanding of mathematics and its concepts, particularly functions. Deeper understanding starting from early grades and progressing to higher grades.	• The object includes: • Learners participating in class activities and showing positive attention to lessons
Tools	ICT and non-ICT resources that mediate interactions between learners and the learning environment	• Digital technologies (Learning and Teaching Tools, Internet, computers, projectors, Wi-Fi, cellphone, maple software etc.) • Tools for learning and teaching, classroom infrastructure, chalkboard/white board marker, desk, seats, and so on.
Rules	Procedures and regulations that act as a mediator between the	

	subjects and their community, which encompasses the whole school.	• CAPS document as a guiding syllabus • Rules guiding algebraic functions teaching procedures
Community	The activity system's surroundings and sociocultural context	• Schools • Department of Education • Society at large
Division of labor	several roles and responsibilities cooperating to accomplish the activity's goal	• Depending on their trust level and skill, educators may share lessons. • Communities of practice and collaboration • District people

1.9 Conclusion

The literature review focuses on exploring the potential of PhET simulations to enhance mathematics education, particularly in South African township schools categorized as Quintile 3. It acknowledges persistent challenges in mathematics education, particularly in under-resourced contexts, with a specific emphasis on struggles with algebraic functions observed in Grade 12 diagnostic reports, often stemming from inadequate teaching methods in Grade 9. The literature also highlights the promising potential of PhET simulations as a tool to address these challenges. These interactive simulations offer a visually engaging and interactive approach to learning, allowing learners to manipulate variables and visualize mathematical concepts in real-time. Studies have shown their effectiveness in enhancing learner understanding across various mathematical concepts, including functions.

Moreover, the literature introduces activity theory as a guiding framework for the successful integration of PhET simulations. Activity theory emphasizes the interconnectedness of learners, tools, and the learning environment, recognizing tensions and contradictions within this system. Through the lens of activity theory, the literature suggests critically evaluating the current state of algebraic functions education in Grade 9 and identifying areas for improvement.

Chapter 3: Research Methodology

3.1. Introduction

This research delves into the experiences of educators in South African township schools (Quintile 3) as they consider the potential of PhET simulations for teaching Algebraic Functions. While participants have not used the tool in their classrooms, the study employed a qualitative case study approach (Aydin & Kaya, 2020) to explore their initial thoughts and reactions after being introduced to PhET during the interview process. This methodological choice was driven by several key considerations.

Firstly, the inherent flexibility of a case study design allowed for a rich exploration of the specific context of under-resourced township schools (Esra & Sevilen, 2021). This in-depth examination is crucial for understanding how social, cultural, and economic factors might influence learners' interactions with PhET simulations (Tomaszewski, Zarestky & Gonzalez, 2020). By focusing on these schools, the research aims to generate insights that are directly relevant to the challenges and opportunities educators face in these environments.

Secondly, the qualitative nature of the approach allows for capturing the nuanced perspectives and experiences of a purposefully selected sample of educators (Aydin & Kaya, 2020). Five participants were chosen to represent the diverse backgrounds and teaching styles present within township schools. This diversity ensures that the study captures a broad range of viewpoints and potential concerns surrounding the integration of PhET simulations.

The research utilizes semi-structured interviews to facilitate in-depth discussions about educators' prior experiences with technology in the classroom, their perceptions of PhET potential benefits and limitations, and any anticipated challenges with implementation. Additionally, observations of PhET-integrated lessons (simulated during the interviews) will provide insights into how educators envision using the tool in practice. Finally, learner-generated artifacts, such as sample work or responses to hypothetical PhET-based activities, may also be analysed in future studies to gain a more holistic understanding of how technology could potentially impact learning journeys. However, in this study particularly, learners will not be involved due to complicated processes of involving minor groups in research and time purposes, since this study is done for qualification attainment.

By employing this multifaceted approach, the study aims to move beyond simply quantifying the effectiveness of PhET simulations. Instead, it seeks to illuminate the complexities involved in integrating technology into mathematics education within Quintile 3 schools. The rich qualitative

data collected will offer valuable insights for optimizing the use of PhET simulations and creating a technology-driven learning environment that empowers both educators and learners in these under-resourced contexts. Figure 3 below shows the research map onion presenting methodology more clearly. Including research philosophy, approaches, strategies, and methods.

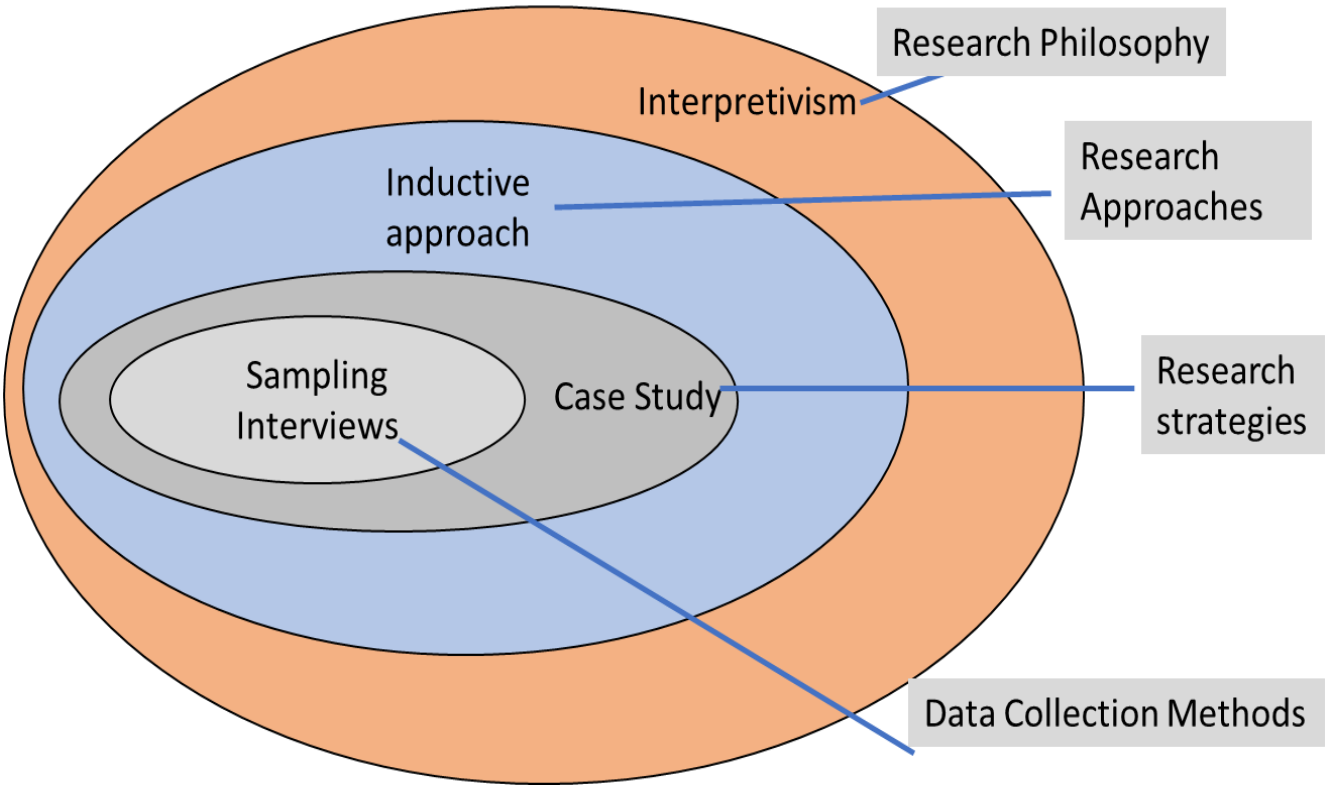


Figure: 3.1: Research Map onion

3.2. Research Methodology

This study employed qualitative case study methodologies to investigate how teachers in under-resourced schools (quintile 3) could improve their pedagogical skills for teaching algebraic functions using PhET simulations. Research methodologies encompass the various techniques and approaches used to systematically address research questions. As Mishra and Alok (2022) explain, research methodologies are the foundation for properly resolving research problems. Kothari (2017) emphasizes that research methodologies involve the scientific study of how research is conducted.

The researcher's role involved introducing the phenomenon under investigation. Research itself is defined as the systematic pursuit of knowledge or expertise on a specific subject. Pandey and Pandey (2021) describe research as a methodical inquiry aimed at expanding the existing knowledge base. This process involves collecting, organizing, and analysing information to gain a deeper understanding of the chosen topic. They further define research as "a systematic investigation or activity to gain new knowledge of the already existing facts" (p. 7). This study aimed to comprehend how teachers in quintile 3 schools, which often lack access to digital learning tools, could leverage PhET simulations to enhance their pedagogical skills for teaching algebraic functions.

Research methodologies encompass all the procedures and methods employed throughout the research process. These methods, chosen by the researcher, represent specific approaches to addressing the research question. Techniques, in turn, are derived from the chosen methods. Kothari (2017) highlights the importance of establishing a link between available data and unknown elements of the research problem to facilitate the discovery of a solution. The various tools and techniques employed throughout the research process to find solutions are collectively referred to as research methods. Pandey and Pandey (2021) categorize research methods into three main types: qualitative, quantitative, and mixed methods. Qualitative research methods involve techniques such as focus groups, individual interviews, case studies, ethnographic research, and observational research, and often utilize non-numerical data. In contrast, quantitative research methods rely on quantifiable data obtained through computational, mathematical, and statistical techniques. Mixed methods, as the name suggests, combine both qualitative and quantitative methodologies. In simpler terms, research methods encompass the tools and techniques chosen by the researcher to conduct the research, ultimately aiming to discover solutions to the research question. These methods utilize various instruments to facilitate data collection, ultimately leading to the discovery of solutions.

In this research thesis, five schools were selected to investigate the feasibility of PhET simulators for teaching algebraic functions to grade 9 learners, aiming to provide them with a strong foundation for future studies in FET classes (grades 10 to 12). The selection of township schools around Soweto in Gauteng province is rooted in a strategic educational approach. Township schools often face significant challenges, including limited resources and varying levels of teacher expertise. By choosing these schools, the study aims to address educational disparities and explore innovative teaching tools that can enhance learning in under-resourced environments. PhET simulators, known for their interactive and engaging nature, hold potential to transform the understanding of complex mathematical concepts like algebraic functions. Introducing such technology in township schools could bridge the gap between traditional teaching methods and modern educational advancements, fostering a deeper comprehension of algebraic functions among learners.

Selecting five schools ensures a diverse yet manageable sample size, allowing for comprehensive data collection and analysis. This number is sufficient to capture a variety of teaching contexts and learner backgrounds, providing a robust understanding of the simulators' effectiveness across different settings. Additionally, focusing on five schools enables detailed monitoring and support, ensuring the implementation of PhET simulators is consistent and effective. By concentrating efforts on a specific, representative sample, the study can yield meaningful insights that could be scaled to benefit a broader range of township schools, ultimately contributing to the enhancement of mathematics education in disadvantaged areas.

3.3. Qualitative method

Qualitative research stands in distinct contrast to its quantitative counterpart, delving into the complexities of human behaviour, experiences, and perceptions within specific contexts (Aydin & Kaya, 2020). While quantitative methods prioritize the collection and analysis of numerical data through statistical means, qualitative research emphasizes in-depth exploration via diverse methods such as interviews, focus groups, and observations. According to Esra & Sevilen (2021), this exploratory approach, is often conducted in natural settings, positions the researcher as the primary instrument for data collection and interpretation, drawing upon their skills and insights to navigate the intricacies of the research landscape.

The cornerstone of qualitative research lies in the generation of "thick descriptions," detailed accounts that capture the richness and nuances of everyday experiences alongside the meanings participants ascribe to them (Esra & Sevilen (2021). This methodology prioritizes capturing the

voices and perspectives of participants, offering valuable insights into their lived experiences within the natural environment where these experiences unfold. As Denzin, Lincoln & Giardina, (2006) posit, "thick description is not merely a report of events, but an interpretation of their meaning within a particular social and cultural context" (p. 189). By delving into this intricate tapestry of meaning, qualitative research fosters a deeper understanding of the "why" and "how" behind human behaviour, transcending mere observation to capture the subjective experiences that shape our actions and perceptions.

Kothari (2004) further emphasizes that qualitative research strives to equip the researcher with the target audience's perspective by facilitating immersion within their cultural context or specific circumstances. This immersive approach involves fostering direct engagement with the individuals under study, fostering a deeper understanding of their lived experiences. This direct engagement transforms the researcher into a vital data-gathering tool, acknowledging that the research outcomes can be influenced by the researcher's unique perspective and background. Creswell and Poth (2018) highlight the significance of reflexivity in this context, urging researchers to acknowledge how their own biases and experiences may shape the interpretation of the data collected. By embracing reflexivity, researchers can strive for greater objectivity and transparency within their qualitative endeavours.

Ultimately, qualitative research aspires to cultivate a deeper understanding of the human condition, fostering self-awareness not only within the participants but also within the researchers themselves. This journey of discovery transcends the mere collection of data; it is a process of mutual learning and shared exploration. As Merriam (2009) states, "Qualitative research is not just about collecting data, but about understanding the world in a new way" (p. 14). In contrast to quantitative research, which aims to verify and expand existing knowledge through the collection and analysis of data on human behaviour, qualitative research prioritizes enriching our comprehension of human experiences and the intricacies of human behaviour within their unique contexts. By delving into the subjective realities of individuals and communities, qualitative research offers a window into the complexities of the human experience, fostering a deeper appreciation for the diverse perspectives that shape our world.

3.4. Quantitative Method

Quantitative research stands as a distinct yet complementary approach to understanding the world, offering a structured and objective lens for investigating various phenomena. As Pandey and Pandey (2021) aptly describe it, quantitative research is a targeted pursuit, aiming to test

existing theories, establish factual truths, uncover potential relationships between variables, and even make predictions about future outcomes. This approach borrows heavily from the methodologies employed in the natural sciences, emphasizing objectivity, generalizability, and reliability as its core tenets. Kothari (2017) underlines the importance of these principles, highlighting how they safeguard the research process from subjective biases and ensure the findings can be applied to broader populations with greater confidence.

Mishra and Alok (2022) further refine our understanding of quantitative research by defining it as a form of social research that adheres to the principles of empirical methodology and assertions. They distinguish between what "is" and what "ought to be," emphasizing that quantitative research focuses on establishing factual realities based on observable phenomena. These realities are often expressed numerically, forming the foundation for another key aspect of quantitative research – empirical evaluations. These evaluations, as Pandey and Pandey (2021) elaborate, aim to assess the effectiveness of programs or policies against predefined standards or norms, utilizing data-driven evidence to gauge their real-world impact.

The methods employed in quantitative research are designed to ensure rigor and minimize the influence of subjectivity. This often involves the unbiased selection of participants through techniques like random sampling, ensuring that the study population is fairly represented. Additionally, standardized questionnaires or interventions are employed to control for potential variations in the data collection process. Finally, statistical techniques come into play, allowing researchers to test predetermined hypotheses about the relationships between specific variables with greater precision and objectivity.

One key distinction between qualitative and quantitative research lies in the perceived role of the researcher. Unlike qualitative approaches where the researcher acts as a primary data-gathering instrument actively involved in the research process, quantitative research positions the researcher as an external observer. This objectivity is paramount, as it minimizes the potential for personal biases or interpretations to influence the findings. Furthermore, quantitative research holds the promise of replicability, meaning that other researchers, following the same methods and procedures, should be able to arrive at similar results, reinforcing the generalizability and validity of the study (Mishra & Alok, 2022).

Quantitative research offers a valuable tool for systematically investigating and understanding the world around us. By prioritizing objectivity, generalizability, and replicability, this approach allows researchers to test theories, establish factual evidence, and uncover significant relationships

between variables. While it may differ from qualitative research in its emphasis on numerical data and standardized methods, quantitative research plays a crucial role in advancing our collective knowledge and understanding. However, this study will not adopt quantitative methods of research due to the nature of the study and time purposes.

3.5. Mixed Methods

In the ever-evolving landscape of research methodologies, mixed methods research has emerged as a powerful tool for gaining a more comprehensive understanding of complex phenomena. This approach transcends the limitations of solely qualitative or quantitative research, offering a multifaceted lens through which researchers can delve deeper and uncover richer insights.

As Nayak and Singh (2021) aptly describe, mixed methods research incorporates both qualitative and quantitative data collection and analysis, either concurrently or sequentially. This can involve gathering numerical data alongside textual information, employing diverse techniques like surveys, interviews, and observations, and subsequently utilizing both statistical and thematic analysis methods. Essentially, this research paradigm allows researchers to draw upon the strengths of both qualitative and quantitative approaches within a single study.

While some might perceive mixed methods as simply combining data collection methods, Mishra and Alok (2022) highlight the crucial aspect of data integration. This refers to the process of connecting, blending, or weaving together the qualitative and quantitative data at some point during the research journey. This integrative analysis allows researchers to identify patterns, inconsistencies, and complementary insights across the different data sets, fostering a more nuanced understanding of the research question.

The rationale behind embracing mixed methods research stems from the fundamental understanding that neither qualitative nor quantitative methods alone can fully capture the intricacies of a situation (Aydin & Kaya, 2020). Qualitative research excels at exploring subjective experiences and uncovering rich, contextual details, while quantitative research provides robust data for establishing patterns and trends. By employing both approaches, researchers create a more holistic picture, allowing them to not only quantify the "what" but also understand the "why" and "how" behind a phenomenon.

Nayak and Singh (2021) further emphasize this notion by positioning mixed methods research as a "third wave" or alternative to the traditional "paradigm warfare" that often pits qualitative and quantitative approaches against each other. This blended approach transcends these rigid

boundaries, offering a pragmatic and insightful perspective for tackling complex research questions.

Mixed methods research offers a compelling alternative for researchers seeking to gain a deeper and more comprehensive understanding of the world around them. By merging the strengths of qualitative and quantitative approaches, this approach allows for the integration and interpretation of diverse data sets, ultimately leading to a richer and more nuanced understanding of the research question at hand. As Kothari (2004) highlights the incompleteness of both qualitative and quantitative methods in capturing the intricacies of a situation, underlining the need for mixed methods research. By embracing the power of mixed methods research, we can unlock a broader and more insightful lens for exploring the intricacies of the world we inhabit.

While the strengths of mixed methods and quantitative approaches are acknowledged, they are not suitable for this particular study. Time constraints and the inherent nature of the research question necessitate a different approach. This choice does not diminish the value of these methodologies in other contexts, but simply acknowledges the limitations posed by the specific circumstances of this study.

3.6. Research Approach

This research adopted a qualitative approach due to the nature of the research question and the characteristics of the study. Firstly, the study aimed to understand a phenomenon – how educators use technology to enhance teaching and learning – from the perspective of the educators themselves. This focus on subjective experiences and lived realities aligns well with the strengths of qualitative research (Lichtman, 2023). Secondly, the study involved a small number of participants (five educators). While quantitative methods excel at analysing large datasets and uncovering generalizable patterns, qualitative research is well-suited for in-depth exploration with smaller groups, allowing for rich and nuanced insights into individual experiences (Hatch, 2023).

The specific qualitative method employed in this study was semi-structured interviews. This approach offered a balance between flexibility and structure. A pre-defined interview guide ensured the coverage of key themes while allowing participants to elaborate on their experiences and perspectives in their own words (Yoon & Uliassi, 2022). The educators were purposefully selected from a single quintile 3 township district. This specific focus allowed for a deeper understanding of the challenges and opportunities faced by educators in resource-constrained

environments, contributing to a more nuanced exploration of how technology can be leveraged for educational purposes in such contexts (Ruslin et al., 2022).

The choice of the interview location (participants' workplaces) further aligned with the qualitative approach. Conducting interviews in a familiar environment helped participants feel comfortable and at ease, potentially leading to more open and honest responses (Hatch, 2023). Additionally, introducing participants to the PhET tool during the interview facilitated the collection of immediate feedback and insights regarding its potential integration into their teaching practices.

The decision not to employ quantitative or mixed methods methodologies stemmed from several considerations. Firstly, the study did not aim to collect and analyse numerical data, but rather to capture the educators' subjective experiences and perspectives. Secondly, the limited timeframe associated with a qualification purpose study made the extensive data collection and analysis characteristic of quantitative and mixed methods research impractical within the given constraints. This study's qualitative approach, specifically the utilization of semi-structured interviews, allowed for an in-depth exploration of the educators' experiences and perspectives regarding technology integration in their teaching practices. This approach, combined with the purposeful selection of participants and interview location, facilitated the generation of rich and nuanced data that can contribute valuable insights for improving the teaching and learning of algebraic functions in resource-constrained contexts.

3.7. Research Design

Research design is about plan and structure (Nayak & Singh 2021). It involves seeking understanding and meanings between participants and information given thereof. This study is premised on a case study. Kothari (2004) defines a case study is an in-depth exploration of a specific phenomenon within its real-world context. It delves into the experiences, perspectives, and nuances surrounding a particular case, aiming to provide a rich and detailed understanding of the phenomenon under investigation. This design is particularly well-suited for this study due to its focus on:

1. Understanding educators' experiences: The study aims to understand how educators currently teach algebraic functions and their perspectives on integrating technology, specifically PhET simulations, into their teaching practices. This focus on individual experiences and subjective viewpoints aligns well with the case study method's strength in capturing the lived experiences of participants.

2. Exploring a specific context: The research focuses on educators from a single quintile 3 township district. This specific context, characterized by potential resource constraints, allows for a deeper understanding of the challenges and opportunities related to technology integration within that particular setting.

3. Examining a phenomenon within its natural environment: By conducting interviews in the educators' workplaces, the study aims to capture their experiences and perspectives within the familiar environment where they teach. This fosters a more comfortable space for open dialogue and allows participants to share their insights grounded in their everyday practices.

4. Gaining immediate feedback on a specific intervention: Introducing the PhET tool during the interviews allows for the collection of immediate feedback and insights regarding its potential feasibility and integration within the educators' existing teaching practices.

Therefore, the case study approach, with its emphasis on in-depth exploration, contextual understanding, and capturing lived experiences, provides a suitable framework for investigating the educators' perspectives on technology integration in this specific context, ultimately aiming to inform strategies for improving mathematics education outcomes.

3.8. Case study

Case study methodology offers a unique research lens, allowing researchers to delve into the intricate details of specific situations within their real-world context. As Hancock, Algozzine, & Lim, (2021) states that case studies are a research method that uses real-world data to investigate current issues, particularly when the lines between the issue and its surroundings are blurry. This in-depth exploration contrasts with the broader generalizations sought by other research methods, and therein lies its strength. The specific case becomes the reflection of a larger phenomenon, offering a rich tapestry of experiences and insights that may be difficult to capture through other means. This allows for a nuanced understanding of the complex interplay between various factors, as explored by Schoch (2020), who emphasizes the value of case studies in enabling researchers to understand the case, in its context, related mechanisms, and its outcomes.

One of the key strengths of this approach lies in its ability to capture the richness of individual experiences. Unlike quantitative methods, which often focus on numerical data and standardized measurements, case studies allow researchers to delve into the subjective experiences, perspectives, and emotions of individuals within a specific context. Remenyi (2022) highlights this strength, stating that case studies delve into the real-life experiences of individuals and groups,

paying close attention to their personal stories, how they understand their surroundings, and how they turn their experiences into something significant.

This focus on individual narratives becomes particularly crucial in studies that aim to understand unique or diverse experiences. For instance, in this research, where teachers from different public schools with varying resources and teaching methods were interviewed, considering the diverse backgrounds and experiences of the participants enriches the findings. This, as Remenyi (2022) points out, strengthens the credibility of the study by providing a more holistic and multifaceted view of the phenomenon under investigation. Furthermore, the inherent flexibility of case studies allows researchers to employ a diverse range of data collection methods. Interviews, observations, document analysis, and even visual aids can be used to create a comprehensive picture of the case (Schoch, 2020). This triangulation of data sources fosters a deeper understanding and enhances the validity of the research findings.

However, it is important to acknowledge that case studies are not without limitations. Critics often argue that the findings lack generalizability due to their focus on a single case as Hancock, Algozzine, & Lim, (2021) asserts. This is a valid concern, and researchers need to be transparent about the limitations and context-specific nature of their findings. However, as Schoch (2020) suggests, case studies are not meant to generalize to a larger population but rather to provide a thick description and a nuanced understanding of a specific phenomenon, contributing to a broader theoretical understanding and offering valuable insights into individual experiences.

In conclusion, case study methodology serves as a powerful tool for researchers seeking to gain a deeper understanding of complex issues within their real-world context. By delving into the unique experiences and perspectives of individuals, case studies offer valuable insights that may be difficult to capture through other means. With its flexibility and focus on individual narratives, case study methodology plays a crucial role in enriching our understanding of the diverse experiences that shape our world.

3.9. Research Paradigms in Educational Research

Research paradigms, the fundamental frameworks that guide the construction of knowledge, act as the intellectual foundation upon which specific research projects and research processes are developed (Treagust & Won, 2023). They encompass a set of fundamental assumptions about the nature of reality (ontology), the means by which knowledge is acquired (epistemology), and the appropriate methods for investigation (methodology). These two domains are closely interconnected. Our fundamental beliefs about the nature of reality shape how we approach the

investigation of it. If we subscribe to the idea of an objective, external reality, we may lean towards employing positivist methodologies in our pursuit of knowledge (Kumatongo & Muzata, 2021). On the other hand, a constructivist perspective that sees reality as shaped by our interpretations may guide us towards employing interpretive methods. This interaction underscores the vital significance of both realms in any philosophical inquiry, emphasizing that comprehending the "what" of existence is inherently linked to understanding the "how" of our knowledge about it (Treagust & Won, 2023). These interconnected elements shape the lens through which phenomena are examined in research, influencing every aspect from the formulation of research questions to the selection of data collection and analysis techniques. This process can be easily seen in figure 3.2 below:

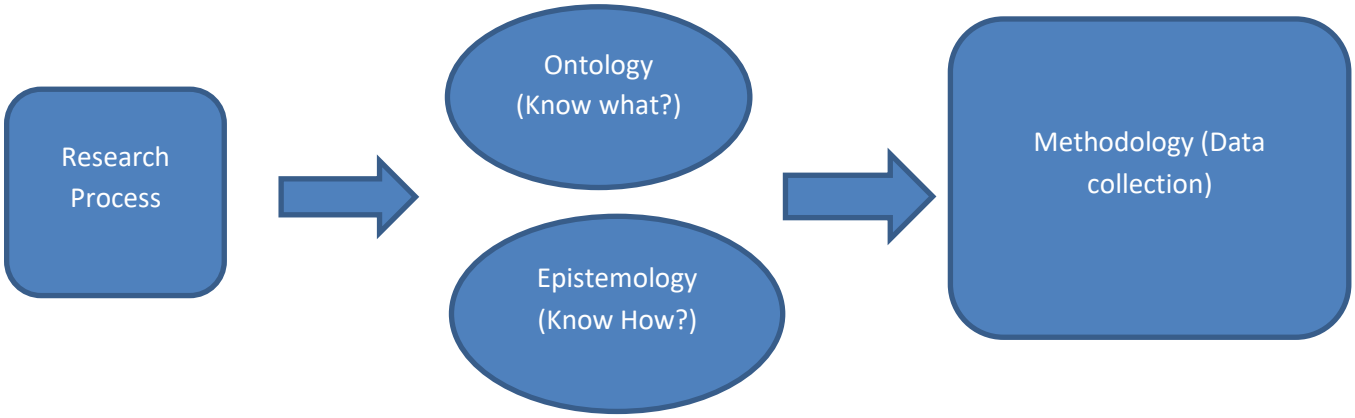


Figure 3.2: Research process

Ontology

In the realm of education, ontology emerges as a powerful tool for dissecting the fundamental nature of "things" within the learning environment (Overton et al., 2020). It delves into the core categories and structures that serve as the bedrock of educational content. This necessitates a critical examination of what constitutes knowledge itself, the dynamic between teachers and learners, and the very essence of educational phenomena. The significance of educational ontology lies in its ability to unveil the underlying assumptions and beliefs that govern our educational practices. It empowers teachers and researchers by providing a well-defined framework for explicating educational concepts like curriculum design, pedagogical approaches, and assessment strategies (Overton et al., 2020). This framework fosters clear and organized communication, enabling educators to articulate their ideas with greater precision. Furthermore, educational ontology fosters a shared language within the educational landscape, promoting a unified understanding among all stakeholders. This translates into more focused discussions, fostering collaboration and collective problem-solving. Imagine a classroom where teachers and learners operate with a common set of definitions for concepts like "understanding" or "learning." Such clarity would undoubtedly enhance communication and ultimately, the learning process.

By prompting educators to delve into the philosophical underpinnings of education, ontology ushers in a deeper understanding of the "why" behind our pedagogical practices (Pivovarova, Powers, & Fischman, 2020). This introspective journey paves the way for the refinement of educational theories, methods, and frameworks. As a result, we can move beyond a purely

pragmatic approach to education and begin to build a system rooted in a robust philosophical foundation. This, in turn, fosters better teaching and paves the way for more effective learning experiences for students.

Ultimately, educational ontology serves as a catalyst for positive change. By fostering a deeper understanding of the fundamental nature of learning, it empowers educators to create a more effective and impactful learning environment (Pivovarova, Powers, & Fischman, 2020). It fosters collaboration and clear communication, ultimately leading to a more robust and well-defined educational system. As (Ahlin, 2019) proclaimed that, education is not preparation for life, however education is life itself. Through the lens of ontology, we gain the tools necessary to refine and enrich this very essence of life – the life of learning.

Epistemology

Epistemology in education is all about understanding how we learn and know things in the context of teaching and learning (Mbhiza, 2021). It's like a philosophy that looks at questions about what knowledge is, where it comes from, and why we believe in certain things. In education, epistemology explores how we learn, the ways we get knowledge, and how we decide what's considered valid knowledge. Teachers often think about how students learn, the role of personal experiences in learning, and how beliefs connect to evidence. Considering epistemology in education is really important because it helps shape how teachers teach, how curriculum is made, and how assessments are done. Knowing how people build, get, and confirm knowledge helps teachers choose the best ways to teach (Mbhiza, 2021). Also, epistemology makes educators think about the goals of education and how knowledge is shared in the classroom, leading to a more thoughtful and detailed approach to teaching and learning.

In the realm of paradigms, two primary models often serve as initial reference points: positivism and interpretivism. Positivism, grounded in objectivity and generalizability, posits a singular, external reality that can be objectively studied through quantitative methods (Overton et al., 2020). Further asserts that, Positivism is grounded in the core conviction of an objective, external reality that exists independently of human perception. Accordingly, knowledge is derived from the impartial observation and measurement of this reality through quantitative methods. Research in positivism is guided by statistical analysis and hypothesis testing, with the aim of uncovering generalizable laws and universal truths (Khatri, 2020). In this approach, researchers aspire to maintain neutrality and detachment, minimizing subjectivity and personal bias in their pursuit of understanding. In contrast, interpretivism advocates for a subjective, meaning-making reality

shaped by human experiences and interpretations. Knowledge is born out of comprehending and interpreting individual experiences and social interactions through qualitative methods (Khatri, 2020). Tools such as narrative analysis, interviews, and ethnography are employed for investigation, with the goal of capturing the richness and context-dependent nature of lived experiences. In this paradigm, researchers recognize their own subjectivity and strive to engage with participants in a dialogical manner.

Positivism

In the educational landscape, positivism has carved a unique niche, advocating for a scientific foundation in understanding and improving educational practices (Pugacheva et al., 2020). Its core principle revolves around the acquisition of knowledge through observable and quantifiable evidence. In simpler terms, positivists believe that true knowledge stems only from what we can directly observe and measure.

This translates to the educational sphere through the emphasis on rigorous, scientific methods like controlled experiments and data-driven research. The objective is to unearth unbiased truths about teaching, learning, and the effectiveness of various instructional approaches (Pugacheva et al., 2020). This data-centric approach offers several advantages. Firstly, it encourages the pursuit of objectivity, minimizing researcher bias that can skew findings. Secondly, by collecting precise and quantifiable data, researchers can identify patterns and connections within the complex educational system. This reliance on verifiable evidence enhances the trustworthiness and replicability of research findings, laying a solid foundation for educational discourse.

Furthermore, positivism champions the notion of cause-and-effect relationships. This perspective encourages educators to embrace evidence-based methodologies that demonstrably improve learning outcomes. By grounding educational decisions in validated evidence, positivism fosters the development of effective teaching practices and robust education policies (Mbhiza, 2021). In essence, it provides a structured framework for approaching educational inquiry, advocating for a scientific lens to refine pedagogical approaches and ultimately, enhance learning outcomes.

However, this study deviates from the positivist approach due to its emphasis on individual experiences and diverse perspectives. Positivism, by its very nature, prioritizes objectivity, quantification, and the pursuit of a single, measurable truth (Khatri, 2020). This often leads to the dismissal of subjective experiences as potential biases, hindering researchers from gleaning valuable insights gained through immersion in the research setting. In this way, the positivistic emphasis on objectivity can inadvertently exclude valuable nuances and subjective

interpretations that are crucial for comprehending the complexities of individual experiences within the educational context. While the study benefits from a nuanced understanding of individual narratives, it does so by venturing beyond the boundaries of the strictly positivist approach.

Interpretivism

Interpretivism in education is a way of thinking that focuses on understanding and explaining the meanings people attach to their experiences in school (Pugacheva et al., 2020). It is unique from positivist way of thinking because it highlights that knowledge is based on personal viewpoints and the situation. Interpretivism recognizes that everyone brings their own ideas, beliefs, and values to their time in school, affecting how they see and understand things. In education, interpretivism encourages using methods like talking to people, observing, and looking at documents to explore what students, teachers, and others think and feel (Pivovarova, Powers, & Fischman, 2020). One good thing about interpretivism in education is that it helps capture the complexity and depth of human experiences in learning. It values each person's voice and their unique situation in education, giving us a better understanding of how personal and social factors affect teaching and learning. Interpretivism also supports exploring different cultures, helping researchers and educators appreciate diverse perspectives and creating a more inclusive and thorough view of education (Pivovarova, Powers, & Fischman, 2020). Overall, interpretivism in education gives us a complete and detailed way of looking at the many meanings and situations in educational settings.

Paradigms serve as frameworks that highlight the crucial role of perspective in shaping our understanding of the world, emphasizing that the lenses we choose significantly impact both our observations and interpretations (Pugacheva et al., 2020). The choice of a particular paradigm not only influences what we observe but fundamentally molds the knowledge we construct and the truths we assert. In the execution of this research, an interpretivist approach was deliberately chosen. The decision to adopt an interpretivist methodology extends beyond a simple rejection of quantitative methods or an affirmation of subjectivity. Instead, it represents a conscious and purposeful commitment to prioritize the comprehension of human sense-making and the contextual realities associated with the utilization of digital technologies to enhance the teaching and learning of mathematics (Mbhiza, 2021). This approach underscores the recognition that human experiences, perceptions, and meanings are essential considerations in investigating the intricate interplay between technology and education, providing a nuanced and holistic understanding that quantitative methods alone might not capture.

Within the realm of this study, the interpretivist paradigm is the most relevant approach due to its fundamental alignment with the very nature of qualitative data. It posits that social reality is subjective and constructed through individual meaning-making. Thus, according to this research, participants are homogeneous, meaning that there are all Grage 9 math educators, coming from the same district and from the same quintile in a Township environment. Qualitative research methods like interviews, observations, and focus groups directly capture these subjective experiences, making interpretivism a natural fit. Unlike positivism, which seeks an objective reality, interpretivism embraces subjectivity as a strength, allowing researchers to delve into the rich tapestry of individual perspectives.

Interpretivism emphasizes on the understanding of meanings that participants ascribe to their experiences and the contextual factors shaping those meanings (Pugacheva et al., 2020). Qualitative data, often textual and descriptive, is saturated with these meanings and contextual nuances. Through interpretive analysis, researchers can uncover the "why" behind behaviors, motivations, and social phenomena, offering deeper insights than positivist approaches focused on quantifiable "what's". In addition, interpretivism recognizes the interconnectedness of various aspects within a social phenomenon. Qualitative research, through its in-depth exploration, naturally lends itself to this holistic understanding. By piecing together individual narratives and experiences, researchers can develop a comprehensive picture of the phenomenon in a study, capturing the complexities that might be missed by more reductionist approaches. Therefore, the interpretivist paradigm, with its emphasis on subjectivity, meaning, context, and holism, finds fertile ground in qualitative research and is favorable in this research. Its core principles resonate with the nature of qualitative data, allowing researchers to unlock the rich insights hidden within participants' experiences and interpretations.

3.10. Research paradigms in relation to this research.

This research delves into the world of educational technology integration from the unique perspective of educators themselves, adopting a qualitative research paradigm. This paradigm aligns with the study's interpretivist approach, emphasizing subjective experiences and individual interpretations, which stand in contrast to the positivist perspective that prioritizes objectivity and quantifiable data.

Ontologically, the research acknowledges the existence of multiple realities and the subjective nature of knowledge. Educators' experiences with technology integration are not singular truths waiting to be discovered, but rather interpretations shaped by their individual backgrounds,

teaching styles, and the specific context of their school environment. This aligns with the interpretivist understanding of reality as socially constructed and open to multiple interpretations.

Epistemologically, the study embraces a constructivist approach, acknowledging that knowledge is co-constructed through interaction between the researcher and the participants. Semi-structured interviews serve as the primary tool for this co-construction. While the researcher asks pre-defined questions to explore key themes, the participants actively shape the meaning and understanding of technology integration through their responses and narratives.

The rationale behind the qualitative approach can be further understood by examining the research question itself. Aiming to understand how educators utilize technology for teaching and learning, the study delves into the subjective experiences and lived realities of individual educators. This inherently subjective focus aligns with the strengths of qualitative research method, which excels at exploring complex phenomena from the perspective of the individuals involved. Additionally, the limited number of participants, purposefully selected from a specific context (township district), aligns with the qualitative approach's suitability for in-depth exploration with smaller groups.

The choice of semi-structured interviews further reinforces the qualitative nature of the research. This method strikes a balance between providing structure through pre-defined questions and allowing for flexibility in capturing participants' unique experiences and perspectives in their own words. The interviews themselves were conducted in the educators' familiar workplaces, ensuring a comfortable and safe environment that could potentially lead to more open and honest responses.

In conclusion, this research project's qualitative paradigm, characterized by its interpretivist approach, constructivist epistemology, and the use of semi-structured interviews within a specific context, allows for a nuanced understanding of educators' experiences with technology integration. This understanding can provide valuable insights for improving the teaching and learning of algebraic functions in resource-constrained environments, highlighting the potential of qualitative research in educational contexts.

3.11. Population and sampling.

Every research endeavour begins with clearly defining the population and the sample. The population, as highlighted by Stratton (2021), represents the entire group of individuals or entities that share the characteristics relevant to the research question. Bhardwaj (2019) further clarifies

that this serves as the source from which the sample – a subset of the population – is drawn. In this study, the population encompasses grade 09 mathematics educators who teach in quintile 3 schools. However, due to practical limitations and the qualitative nature of the research, not all educators from this population will participate.

Selecting the appropriate sampling technique is crucial for ensuring the validity and generalizability of research findings. Sampling, as described by Berndt (2020), is a deliberate process of choosing individuals from a larger population to participate in the study. Ideally, the chosen sample accurately represents the characteristics and diversity of the entire population. There are two main categories of sampling methods: probability sampling and non-probability sampling.

In probability sampling, every member of the population has a known and equal chance of being selected for the study (Bhardwaj, 2019). This ensures that the sample is unbiased and representative of the entire population, allowing for generalizations to be drawn back to the population. Common examples of probability sampling include simple random sampling, where every individual has an equal chance of being chosen through a random selection process, and stratified sampling, where the population is divided into subgroups (strata) based on specific characteristics, and then individuals are randomly selected from each stratum.

In contrast, non-probability sampling techniques rely on the researcher's judgment to select participants based on specific criteria relevant to the research question. This approach is often preferred in qualitative research, where the aim is to gain in-depth insights from specific individuals rather than generalize findings to a larger population (Obilor, 2023). Purposive sampling, also known as judgmental sampling or selective sampling, is a commonly used non-probability technique. In this method, the researcher intentionally chooses participants based on specific characteristics deemed to be informative for the study. A non-probability sampling approach will be utilized to determine participants who will form part of the study from one district with quintile three schools in Gauteng province.

Random sampling approaches will not be used in this investigation. As previously stated, the study selects participants by non-probability sampling. The sample procedure that was employed in the research was a purposive sampling. Purposive sampling, also known as judgmental or selective sampling, is a non-probability sampling technique where researchers intentionally choose participants based on specific criteria or characteristics relevant to their study (Obilor, 2023). Unlike random sampling, where every member of the population has an equal chance of

being selected, purposive sampling relies on the researcher's judgment to select the most informative participants.

3.12. Rationale for Selecting Five Participants in this Study.

The decision to select five participants in this study employing purposive sampling rests on several key considerations. These includes:

1. **Qualitative Research Focus:** This study adopts a qualitative approach, aiming to explore the lived experiences and perspectives of educators regarding technology integration in their teaching practices. Qualitative research often benefits from smaller sample sizes, allowing for deeper engagement with individual participants and the generation of rich, nuanced data. As Casteel & Bridier (2021) emphasizes that the strength of qualitative research lies in its ability to gather rich, descriptive details about how individuals live and what they go through.

2. **Resource Constraints:** Conducting qualitative research, particularly when involving interviews and in-depth analysis, often requires significant time and resources. Selecting a smaller sample size allows for a manageable workload within the constraints of the study, ensuring thorough data collection and analysis while maintaining the quality and depth of inquiry.

3. **Saturation Point:** In qualitative research, the concept of saturation point refers to the point at which additional data collection no longer yields new insights and instead produces repetitive information. Selecting five participants allows for an in-depth exploration of the phenomenon while keeping in mind the potential for reaching saturation, where further data collection might not contribute significantly to understanding.

4. **Informative Participants:** Utilizing purposive sampling, the research focuses on selecting information-rich participants who possess relevant experiences and perspectives. The five educators selected likely represent diverse teaching styles, approaches to technology integration, and experiences within the specific context of quintile 3 schools. This diversity offers valuable insights into the complexities of technology integration in such environments.

5. **Data Management and Analysis:** While qualitative data analysis is often rich and insightful, managing and analysing large amounts of data can be time-consuming and challenging. Selecting five participants ensures a manageable volume of data that allows

for thorough and detailed analysis, enabling the researcher to effectively draw meaningful conclusions from the collected information.

In this study, the choice of non-probability sampling through purposive sampling and a sample size of five participants is based on the qualitative nature of the research, resource constraints, the concept of saturation point, the selection of information-rich participants, and the need for effective data management and analysis. Selecting a smaller sample size, while not allowing for generalizability to the entire population, enables a deeper exploration of the lived experiences and perspectives of the chosen educators, ultimately contributing valuable insights into the complexities of technology integration in the specific context of quintile 3 schools.

3.13. Instruments

The instrument that was utilized in this study was semi-structured interviews with five mathematics teachers from quintile 3 township schools. An interview is roughly characterized as a two-person contact on a certain occasion, with one acting as an interviewer and the other as an interviewee. Thus, an interview is described as an '*inter-view*', which is a discussion between two people over a common theme or issue (Adeoye-Olatunde & Olenik 2021). In general, an interview is a type of conversation between two or more persons (the interviewers and the interviewees) during which questions are asked in order to elicit information from the interviewees. According to Magaldi and Berler (2020), the interview is a part of countless approaches of human connection. Conversations allow us to get to know other people, learn about their lives, feelings, and hopes, and gain a better understanding of the worlds in which they live. According to Ahlin (2019), a semi-structured interview is an exploratory interview. He goes on to say that the semi-structured interview is normally based on a guide and is centered on the major issue that gives a general pattern. Furthermore, Mahat-Shamir, Neimeyer, and Pitcho-Prelorentzos (2021) suggest that, despite the topical trajectories supplied prior to the interview, the semi-structured interview allows a researcher to dive deep for a finding. As indicated earlier, this study only focused on semi-structured interviews to gain raw and authentic knowledge about participants' experiences in the use of Phet simulators, in environments where there are few available digital devices.

3.14. Data Analysis

The most important aspect of any research is data analysis. Data analysis is the summarization of acquired data. It entails interpreting data acquired through analytical and logical reasoning to find patterns, correlations, or trends (Lester, Cho, & Lochmiller, 2020). According to Popenoe, Langius-Eklöf, Stenwall, and Jervaeus (2021), data analysis is the process of cleaning, altering,

and processing raw data in order to extract actionable, relevant information that allows us to make informed decisions. The technique reduces the risks associated with decision-making by offering relevant insights and statistics, which are frequently displayed as charts, graphics, themes, tables, and graphs. Thematic analysis was used to analyze the data in this study.

Thematic analysis is a data analysis process that involves searching over a data collection for, identifying, interpreting, and reporting recurrent patterns (Braun & Clarke, 2023). It is a strategy for describing facts, but it also requires interpretation in the processes of choosing codes and developing themes (Thompson, 2022). Thematic analysis is distinguished by its ability to be employed within a wide range of theoretical and epistemological frameworks, as well as to be applied to a wide range of study questions, designs, and sample sizes (Xu, & Zammit, 2020). Thompson (2022) claims that theme analysis can be used as a standalone analytic tool as well as a foundation for other research methods. When attempting to comprehend experiences, thoughts, or behaviors throughout a data set, thematic analysis is an appropriate way of analysis (Xu, & Zammit, 2020). Themes, as opposed to mere summaries or categorizations of codes, are deliberately built patterns (or meanings) derived from a data set that address a research topic (Braun & Clarke, 2023). Furthermore, depending on the researcher and the nature of the data, themes might be developed inductively or deductively.

The inductive method, like a detective gathering clues, immerses the researcher in the data. They meticulously code and analyze the information, allowing themes to emerge organically (Braun & Clarke, 2023). This bottom-up approach lets the data speak for itself, potentially uncovering unexpected insights. Conversely, the deductive method starts with a pre-existing theory or framework (Braun & Clarke, 2023). The researcher acts as a mapmaker, actively searching for evidence to support or challenge their initial ideas. They code the data with specific themes in mind, creating a top-down analysis. While efficient for confirming existing theories, it might miss unforeseen patterns. Ultimately, the choice between these methods depends on the research question. However, both approaches can answer the question, depending on how they are utilized. In this research, deductive approaches will be utilized to analyze data or to formulate themes.

3.15. Ethical Considerations

In general, trustworthiness means how much someone, or something can be relied upon. In this context, trustworthiness focuses on determining the reliability and trustworthiness of data. This relies on the methods used during the research process, including the research design, data

collection, and data analysis, despite any challenges faced. According to Lichtman (2023), qualitative researchers emphasize dependability, credibility, and confirmability as criteria to ensure the rigor of qualitative findings. Credibility involves having confidence in the truth of the findings, and qualitative researchers can achieve this through peer examination, triangulation (using different methods like interviews and observations), time sampling, and other approaches. Confirmability assesses whether findings can be confirmed by other researchers, while dependability considers the stability of findings over time.

In this study, the university where the research was conducted provided ethical approval for this study (attached in 'appendix A'). The ethics application was completed and submitted to the ethics committee. After obtaining the ethical clearance certificate, another application was submitted to the department of education to acquire access to schools to conduct the study (GDE letter attached in 'Appendix B'). Participants were provided consent forms to fill out in order to recognize their involvement in the study. Participants were informed that their involvement in this study is voluntary and that they may withdraw at any time if they so desire, and that their contribution will be kept confidential, and their identity will remain anonymous. Plagiarism score is also attached in 'Appendix C'.

In this research, data was carefully looked at, making sure not to let the researcher's personal opinions or likes and dislikes affect the analysis. Participants were picked based on how much experience they had as teachers while they were working. This was done to make sure that the information received was trustworthy, as teachers were supposed to know well about what the research was about and can provide valuable information based on experience.

3.16. Conclusion

This qualitative case study explored the feasibility of introducing PhET simulations (PhET) into the teaching and learning of algebraic functions in Grade Nine classrooms within quintile 3 township schools. The research employed a constructivist approach, acknowledging the subjective experiences and interpretations of the five participating educators. Data collection occurred through semi-structured interviews conducted within the teachers' working environments. This approach fostered a sense of comfort and familiarity, potentially leading to richer and more detailed responses. Thematic analysis of the interview transcripts identified key themes that emerged from the educators' perspectives.

The findings from this research illuminate the potential benefits and challenges associated with integrating PhET simulations into the mathematics curriculum.

Chapter 4: Data presentation and analysis

4.1 Introduction

The effective presentation of data lies at the core of successful communication in today's information-saturated world. With the increasing prevalence of quantitative analysis and statistical research across diverse fields, the ability to present data in a clear, concise, and meaningful manner has become essential for a wide range of stakeholders, from decision-makers to researchers and the general public (Aguas, 2022). The way data is presented can significantly impact its interpretation, comprehension, and ultimately, its utility. Transforming raw data into comprehensible formats, such as charts, graphs, tables, and narratives, is a crucial skill that facilitates the extraction of valuable insights and enhances the accessibility and impact of information (Aguas, 2022). In this era of data-driven decision-making, mastering the art of data presentation is not simply a desirable skill, but a fundamental requirement for effective communicating knowledge and driving informed actions across various disciplines. This exploration will delve into the key principles, methods, and tools employed in effective data presentation, highlighting its crucial role in the successful communication of information in today's data-rich landscape.

4.2 Data presentation

In recent years, the integration of digital technologies into mathematics education has become an increasingly important aspect of pedagogical practices globally. In South Africa, where educational disparities and challenges persist, leveraging digital technologies in mathematics teaching presents both opportunities and obstacles for educators. This research explores the challenges and advantages that mathematics teachers in South Africa may encounter when incorporating digital technologies into their teaching methods (particularly Phet simulators).

In conducting this study, five township educators teaching in quintile 3 South African schools were interviewed. All teachers interviewed had more than three years' experience in the field, this was done to ensure validity of the comments provided. All teachers came from five different schools in a single township. Gender selection was random as it was not expected to contribute to the validity of the data. All educators were interviewed in different times and dates in their schools of work. All educators were selected from the district to ensure that there was no conflict of interests between the researcher and the participants. In coding of the data and naming of the participants to ensure confidentiality, participants were named in an alphabetical order using pseudo naming. Teacher, one named TA1; second teacher named TB2; third teacher named TC3; fourth teacher named TD4; and the fifth teacher was named TE5. This can be seen in Table 2.1 below:

Table 4.1. Participants pseudo names

School number	Teacher code
1	TA1
2	TB2
3	TC3
4	TD4
5	TE5

Five participants were interviewed about their use of PHET simulators for teaching algebraic concepts. Their insights were gathered regarding their utilization of PHET simulators for the instruction of algebraic concepts, yielding a spectrum of viewpoints concerning the efficacy of this pedagogical tool. One participant, identified as TA1, having employed PHET simulators within the context of instructing physical science, articulated a perspective affirming the simulations' efficacy by elucidating their capacity to furnish visual representations and facilitate interactive manipulation of fundamental algebraic principles, thereby rendering abstract concepts more tangible and comprehensible. This sentiment was reiterated by participant TB2, who underscored the value of PHET simulations in accommodating diverse learning needs through the provision of customizable difficulty levels and instructional scaffolding, thereby enabling educators to tailor instructional experiences to the unique requirements of individual students. Conversely, participant TD4 expressed reservations regarding the integration of PHET simulators into teaching practices, citing a lack of familiarity with the tool compounded by an absence of digital resources within their educational setting. However, they acknowledged the potential advantages of digital technology in the broader domain of mathematical instruction. Participant TD4, whose proficiency with digital technologies was noted to be limited, articulated apprehensions pertaining to the integration of software-based instructional tools, citing concerns related to the potential for instructional disruptions stemming from technical glitches and the requisite acclimation period necessitated for educators to familiarize themselves with the tool. On the other hand, participant TE5 underlined the importance of leveraging technology in pedagogical practices while advocating for comprehensive training initiatives aimed at equipping educators with the requisite proficiency to effectively integrate technological tools into instructional contexts.

During data collection, the following themes stood out:

- Learner Performance in Linear Functions

- Method of teaching Functions
- Digital tools used for enhancing Functions.
- Status of PHET simulators among Grade 9 Educators

4.2.1 Learner Performance Linear Functions

In mathematics, a linear function refers to a specific type of function that can be represented by a straight line when plotted on a Cartesian coordinate system. Formally, a linear function is a mathematical expression of the form:

$f(x) = mx + c$, where:

- $f(x)$ represents the output or dependent variable,
- x represents the input or independent variable,
- m represents the slope of the line, which determines the rate of change or steepness of the line,
- c represents the y-intercept, which is the point where the line intersects the y-axis.

The key characteristic of a linear function is that the rate of change in the dependent variable with respect to the independent variable is constant, resulting in a straight-line graph. Linear functions are fundamental in various areas of mathematics and have many practical applications in fields such as physics, economics, engineering and more. Despite the simplicity of the equation, participants revealed a heterogeneous state of affairs about learner understanding of linear functions. TD4 mentioned that learners perform better in linear functions compared to quadratic, hyperbolic and exponential functions. This is what TD4 mentioned,

> *"Generally, learners are doing well in this concept. They can tell the gradient and where the graph cuts the y-axis. However, challenge begins when the function is quadratic".*

TE5 echoed similar sentiments about the learner performance in linear functions. TE5 noted that there are several factors that contribute to making linear functions more easily understood by learners. These include visual representation where linear functions can be graphically represented as straight lines on a coordinate plane. This visual representation helps learners to intuitively grasp concepts such as slope and y-intercept. In addition, linear functions often model real-world relationships such as distance vs. time, cost vs. quantity, or temperature vs. time. Relating linear functions to everyday scenarios helps learners understand their practical significance and relevance. Furthermore, the algebraic structure of linear functions is relatively

simple, typically involving basic operations such as addition, subtraction, multiplication, and division. This simplicity makes it easier for learners to manipulate equations and solve problems. TE5 remarked,

> *"The presence of linear graph enables leaners to intuitively grasp concepts such as slope and y-intercept. They can have a sense of real-world model such as distance vs. time, cost vs. quantity, or temperature vs. time……. linear functions are relatively simple, as they involves basic operations such as addition, subtraction, multiplication, and division….. helping them to understand and solve equations".*

On the contrary, not all participants agree that their learners perform well in algebraic functions. TA1 mentioned that linear functions can pose challenges to many learners due to abstract concept of mathematical equations and symbols can be challenging for some learners to grasp initially. Understanding the relationship between variables and the concept of a function itself can require a shift in thinking for some students. TA1 mentioned multiple challenges that they have observed during the teaching and learning of linear functions. These included graphing, misconceptions, algebraic manipulations and interpretation of word problems. They asserted that, while the graphical representation of linear functions can aid in understanding, interpreting graphs accurately and understanding concepts such as slope and intercepts can be difficult for some learners, especially if they struggle with visualizing abstract concepts. They also asserted that learners may develop misconceptions about linear functions if not explained deeply, such as equating "linear" with "straight" or assuming that all linear relationships have positive slopes. Addressing and correcting these misconceptions can be crucial for developing a deeper understanding of linear functions. Understanding the general properties and characteristics of linear functions, such as the concept of a constant rate of change or the behavior of parallel and perpendicular lines, can be challenging for learners who struggle with abstract mathematical concepts. And manipulating algebraic expressions and solving equations involving linear functions can be challenging for some learners, especially if they struggle with basic algebraic concepts such as combining like terms, distributing, or solving equations. TA1 remarked:

> *"while the graphical representation of linear functions can aid in understanding, interpreting graphs accurately and understanding concepts such as slope and intercepts can be challenging. Multiple misconceptions and errors arise from interpreting word problems and converting them to graphs. Algebraic*

manipulations also become a critical problem for some of the learners, especially when they have to find the intercepts".

The participant highlights the limitations of using graphical representations alone to teach linear functions. While graphs can be helpful for visualization, they may not be sufficient for students to fully grasp concepts like slope and intercepts. The insight also emphasizes the challenges students face in interpreting word problems and translating them into graphs, as well as their struggles with algebraic manipulations, particularly when finding intercepts. This suggests a need for a more multifaceted approach to teaching linear functions that combines visual representations with explicit instruction, practice with word problems, and targeted support for algebraic skills.

4.2.2 Method of teaching Functions

Teaching linear functions effectively involves a blend of approaches. Foundational understanding starts with visualizing graphs and exploring how changes in slope and intercepts affect their shape. Interactive activities can engage learners, like plotting points from equations or sketching graphs based on descriptions. Next, delve into translating word problems into equations, emphasizing key phrases that denote slope and intercepts. Practice with diverse word problems helps solidify this crucial skill. Utilize graphing calculators or dynamic software to visualize real-time changes as students manipulate equations, reinforcing connections between algebraic operations and graphical behavior. Address the hurdle of algebraic manipulations by breaking down steps, providing clear explanations, and offering scaffolded practice. Recognizing misconceptions is key, so use of formative assessments to identify and address individual challenges to ensure a solid foundation for students to build their algebraic fluency. In addition. effective teaching encourages exploration, fosters connections, empowering students to confidently navigate the world of linear functions.

In South African township schools particularly quintile 3 schools, teaching algebraic functions at the Grade 9 level faces a multitude of challenges that go beyond the inherent complexities of the topic itself. Participants mentioned that limited access to technological resources hinders visualization and interactive learning, making abstract concepts like slope and intercepts even more difficult to grasp. TE5 mentioned that they are teaching algebraic functions using the traditional method as they do not have access to technological resources.

"We use traditional methods of teaching algebraic functions. Textbooks and chalkboard is the main instructional modes we use. Even though the other

schools now use technology such interactive whiteboards and smartboards, we do not have them here in our school".

The same sentiment was echoed by TD4 who mentioned that they do not have access to digital technologies.

"We used to have smartboards in our classrooms, and they have since stopped working and the department of education is not coming on board to repair them. Thus, our teaching is predominantly chalk and talk".

TA1 further mentioned that despite that they were rudimentarily exposed to digital technologies in their school, these devices have overlived their life span and are presenting a lot of technical glitches that are beyond their knowledge, forcing them to be teaching mathematics using tradition methods.

"We were once provided with tablets but there are presenting a lot of challenges. Their charging system is no longer working properly, and some are no longer switching on. On top of that, we as educators do not have knowledge to deal with technical fault of these tablets. The department is not making a follow up on the status of these devices. Instead of wasting time fixing technical glitches, we have decided to park these devices aside and use the traditional method of teaching".

The presented transcripts paint a stark picture of the resource constraints faced by mathematics teachers in South African township schools. These educators highlight a reliance on traditional methods, primarily textbooks and chalkboards, due to the absence of newer technologies like interactive whiteboards and smartboards, further hindered by lack of repair or replacements. Even attempts at incorporating tablets were thwarted by malfunctioning devices and inadequate technical support, leading to frustration and a return to traditional methods.

Some participant made some remarks that most learners come from low socioeconomic background and hence such things as poverty and language barriers contribute to weak foundational skills in mathematics, creating hurdles in understanding symbolic manipulation and equation solving. TA1 mentioned that their school is located in low socio-economic environment.

Learners have challenges in accessing digital technologies because most of their parents are not working. This presents a challenge in trying to teach using technology.

> *"Our learners come from low socioeconomic backgrounds. Even if we are interested in using digital devices such as smart phones, not all learners have them. In addition, the school on its own, is facing challenges to buy WIFI so that the learners and staff can log in to search some information" TA1.*

The issue of low socioeconomic background has great implications on learners particularly in understanding mathematics languages. Learners are predominantly using their mother tongue even in the classroom. This affects their mathematical vocabulary.

> *"These learners are predominantly speaking their indigenous languages and hence it affects them in understanding mathematical vocabularies. If the school had access to technological devices, we were going to use them to help learners understand what we are talking about. But due to lack of these technologies, we do not have an option but to use traditional methods"TE5.*

The combined testimonies by the two participants paint a stark picture of the challenges faced by mathematics educators in South African township schools. The participants highlight three key hurdles: socioeconomic limitations, linguistic barriers, and lack of technological resources. The learners' low socioeconomic backgrounds create an uneven playing field. Not all learners have access to smartphones, crucial for utilizing digital learning tools. This digital divide exacerbates the educational gap, leaving some learners further behind. Additionally, the school's lack of Wi-Fi further restricts access to online resources and information, hindering the exploration of diverse learning methods. In addition, the participants raised the challenge of linguistic barriers. Many learners predominantly speak their indigenous languages, creating difficulties in understanding mathematical vocabulary and concepts taught in English. This language barrier limits their ability to fully engage with the material and participate effectively in the classroom. Furthermore, the absence of technological devices poses a significant obstacle. The participants expressed their desire to utilize technology to enhance understanding and engagement but are forced to rely on traditional methods due to resource constraints. This limits the use of interactive tools, simulations, and visualizations that could potentially make abstract concepts more accessible. These experiences reveal the complex and interconnected challenges faced by mathematics educators in under-

resourced township schools. Addressing these challenges requires a multi-pronged approach that considers providing equitable access to technology, incorporating multilingual teaching strategies, and utilizing alternative, low-tech methods to engage learners and bridge the learning gap.

All five (5) participants expressed concern about their class sizes. They all mentioned that large class sizes often restrict personalized attention and opportunities for practice, leaving many learners struggling to grasp key concepts.

> *"I am teaching five classes and on average there are 50 learners per classroom. With this number and the pressure of time, it is a challenge to focus on individual attention". [TE5]*
>
> *"The classes are too large in general, inhibiting teachers to have fully engaged lessons. In addition, as teachers we cannot manage to give practice activities daily and mark them". [TC3]*
>
> *Due to the large class size, learners tend to make noise and disturb others. And generally, they are difficult to manage. Even if you give them some activities in groups, not all participate. [TB2]*
>
> *I think we give these learners less practice in the form of both formative summative assessments. It is a challenge on the teacher to mark and provide adequate feedback to learners' individual needs in a form of weekly assessments due to the large size of the classes. [TA1].*

The participants paint a worrisome picture of the challenges presented by large class sizes in their educational setting. The overarching concern is the impossibility of providing individualized attention, as highlighted by statements like "*it is a challenge to focus on individual attention*" and "*less practice in the form of both formative summative assessments*." This lack of personalized support can hinder learner engagement and understanding, especially when combined with the pressure of time mentioned ("*pressure of time" and "weekly assessments*"). Furthermore, large classes seem to create issues with classroom management, evident in comments about noise, difficulty managing groups, and lack of learner participation ("*learners tend to make noise*," "*difficult to manage*," and "*not all participate*"). This chaotic environment can further impede effective learning. The participants also expressed their inability to effectively assess learners progress, with remarks like "*we cannot manage to give practice activities daily and mark them*"

and "*challenge...to mark and provide adequate feedback*." This lack of timely and individualized feedback limits learners' ability to identify and address their weaknesses, ultimately hindering their academic progress. These transcripts reveal a multitude of interconnected challenges arising from large class sizes, jeopardizing both the quality of instruction and student learning. Addressing these issues requires systemic solutions, including reduced class sizes, increased teacher support, and innovative teaching strategies that can cater to diverse learning needs even in crowded classrooms.

The current curriculum, while emphasizing application, might inadvertently prioritize procedures over conceptual understanding, leading to rote memorization and difficulty transferring knowledge to diverse problem types. The conditions prevalent in South African township schools often hinder effective teaching and learning, particularly in subjects like mathematics. The Curriculum and Assessment Policy Statement (CAPS) document emphasizes the importance of teaching mathematics conceptually, focusing on understanding rather than mere procedural knowledge. However, several issues mentioned by participants also contribute to teachers resorting to procedural teaching methods. TD4 further mentioned that:

> *"Overcrowded classrooms make it challenging for us to provide individualized attention and foster conceptual understanding among learners. With large class sizes, teachers often resort to rote learning and procedural teaching to cover the curriculum within limited time constraints."*

TE5 raised the same sentiment of rote learning as a result of inadequate resources in their schools. Lack of essential teaching materials such as textbooks, instruments, calculators, technology and more were mentioned as some of the contributing factors.

> *"Inadequate resources and infrastructure further exacerbate the situation. Our schools often lack essential teaching materials, such as textbooks, manipulatives, and technology, which are crucial for facilitating conceptual understanding in mathematics. Without these resources, teachers may rely more on procedural methods that require minimal materials."*

Additionally, TA1 further mentioned that socio-economic factors such as lack of access to internet, parents not being informed about school content, and thus not involved in children schoolwork; and many other economic factors lead to learners not having a deep understanding of

mathematics as they lack support outside of the classroom. It was also mentioned that learners even struggle with completing HomeWorks as a result of lacking support.

> *"Socio-economic challenges prevalent in township communities can impact students' readiness to engage with mathematics conceptually. Factors such as poverty, language barriers, and lack of parental support can hinder students' ability to grasp abstract mathematical concepts, leading teachers to focus more on procedural methods that students can memorize without fully understanding*."

The challenging conditions in South African township schools, including overcrowded classrooms, resource constraints, and socio-economic factors, often compel mathematics teachers to prioritize procedural teaching over conceptual understanding. Addressing these systemic issues is crucial for promoting effective mathematics education aligned with the principles outlined in the CAPS document.

Teacher training and support remain crucial, yet inadequate training on effective approaches to teach abstract concepts and address diverse learning needs can exacerbate existing challenges. In South African schools, the integration of technology in teaching mathematics is crucial for enhancing student engagement, promoting conceptual understanding, and preparing learners for a technologically driven world. However, the lack of adequate teacher training in utilizing technology effectively can result in poor mathematics outcomes. Teachers in South African schools, especially those in underserved areas like townships, have limited exposure to technology themselves. They may not be familiar with the latest educational software, online resources, or interactive tools available for teaching mathematics. Without proper training, teachers may struggle to incorporate technology into their lessons in meaningful ways, resorting to traditional, less effective teaching methods. TD4 asserted:

> *"Even if we may have access to technology, some of us lack the skills and knowledge to use it effectively in the mathematics classrooms. Integrating technology requires more than just knowing how to operate the devices; it involves understanding how to select appropriate tools, adapt curriculum materials, and design interactive activities that enhance mathematical learning. Without specialized training, we may feel overwhelmed or uncertain about how to leverage technology to support our teaching goals".*

The rapid pace of technological advancements means that even teachers who received training in the past may find themselves outdated in their knowledge and skills. Continuous professional development opportunities are essential to keep educators abreast of emerging technologies and best practices for integrating them into mathematics instruction. However, such opportunities are often limited in South Africa, particularly in townships and under-resourced areas.

TB2 asserts that:

> *"Schools in affluent urban areas or private institutions tend to have better access to technology and resources, as well as teachers who are more proficient in using them. As a result, students in these schools receive a more enriched mathematics education compared to their peers in underserved communities, widening the achievement gap. Hence, some of us we teach in township schools but our children school in private schools."*

Addressing the issue of poor mathematics results in South African schools requires comprehensive efforts to improve teacher training in technology integration. This includes providing ongoing professional development opportunities, equipping teachers with the necessary resources and support, and fostering a culture of innovation and collaboration within the education system. By investing in teacher training in technology use, South Africa can work towards improving mathematics outcomes for all learners and bridging the digital divide in education.

4.2.3 Digital tools used for enhancing Functions.

Algebraic functions form a cornerstone of secondary school mathematics, unlocking crucial applications across various STEM fields. However, their abstract nature often presents challenges for learners, particularly in resource-constrained environments like South African townships. Digital tools offer promising avenues to enhance the teaching and learning of algebraic functions in these contexts. In South Africa, as in many parts of the world, the effective teaching and learning of algebraic functions pose significant challenges. However, with the advent of digital technology, there exists a plethora of tools and resources that can aid township mathematics educators in overcoming these obstacles. While the South African curriculum emphasizes the integration of technology in mathematics education, the landscape of digital tools for teaching algebraic functions at Grade 9 level remains complex and nuanced. Examining commonly used tools requires navigating diverse contexts, resource availability, and teacher comfort levels. GeoGebra stands out as a popular choice due to its free, open-source nature and its ability to visually represent graphs, points, and lines.

Four out of five participants showcase GeoGebra effectiveness in enhancing visualization and understanding of linear functions, particularly slope and intercepts. However, limitations in internet access and teacher training can hinder its full potential. Two educators (TA1 and TC3) mentioned that in some of their lessons they make means to get projectors in their classrooms to use GeoGebra to help save teaching time and to allow visualization of multiple graphs.

> *"GeoGebra helps me a lot when I have to teach graphs, drawing multiple graphs on a chalkboard presents multiple challenges, and wastes a lot of teaching time. I use GeoGebra for teaching all algebraic functions and trigonometric graphs. After I have taught all the graphs and showed all the differences from stretching graphs to shifting graphs both horizontally and vertically. I then show them how to draw it on their exercise books."* TA1

> *"I've noticed a significant improvement in my students' understanding of algebraic functions since integrating GeoGebra into our lessons. The interactive visualizations have helped them grasp abstract concepts more effectively. One smartboard in the school is working, normally I project my computer screen on it for my teaching. It is my tool for teaching linear graphs in grade 9. It is easy to use and saves time for drawing manually."* TC3

These comments highlight the practical advantages of using GeoGebra in the classroom, particularly in teaching graphs and algebraic functions. In the first comment from TA1, the teacher emphasizes the challenges of drawing multiple graphs on a chalkboard and the time-consuming nature of manual graphing. By utilizing GeoGebra, they can efficiently teach various algebraic and trigonometric graphs, demonstrating concepts such as stretching and shifting. After introducing these concepts using GeoGebra's interactive visualizations, the teacher then transitions students to draw the graphs manually in their exercise books, reinforcing their understanding. In the second comment from TC3, the teacher echoes the sentiment of improved student understanding due to GeoGebra's interactive visualizations. They specifically mention using a smartboard to project GeoGebra from their computer screen, making it a valuable teaching tool for linear graphs in grade 9. By leveraging technology in this way, the teacher not only enhances students' comprehension but also saves time that would otherwise be spent on manual drawing. Both comments highlight GeoGebra's efficacy in streamlining the teaching process, improving learner understanding, and maximizing instructional time, ultimately enhancing the overall learning experience in the classroom.

On the other hand, two other educators expressed their interest in incorporating GeoGebra into their classrooms, recognizing its potential benefits for enhancing student learning experiences. However, they lamented the lack of necessary equipment hindering their implementation efforts. TB2 educator stated, "I'm aware of GeoGebra, and I'm eager to integrate it into my lessons to enrich my students' understanding of mathematical concepts." TE5 educator echoed this sentiment, saying, "GeoGebra seems like a fantastic tool, but unfortunately, we lack the essential equipment to use it effectively in our classrooms." Both educators emphasized the absence of functional smartboards and the lack of personal computers and projectors as significant barriers to adopting GeoGebra.

The unavailability of such technological resources underlines the disparities in educational infrastructure, particularly in township communities. These limitations not only restrict educators' ability to leverage innovative teaching methods but also deprive learners of valuable learning opportunities. Without access to tools like GeoGebra, learners may miss out on interactive and engaging learning experiences that could deepen their understanding of mathematical concepts. Addressing these infrastructure gaps is crucial to ensuring equitable access to quality education and empowering both educators and learners to thrive in the digital age. It is evident that digital tools can transform a learning environment, making it easy for both teachers and learners to enjoy the lesson and to foster deep understanding of the concepts.

The integration of online learning platforms has become increasingly prevalent in educational settings, with educators leveraging these resources to enhance their teaching practices and enrich student learning experiences. The five interviews with educators revealed a common reliance on online platforms for various aspects of their teaching endeavours. Each educator acknowledged the utility of online learning platforms, whether for personal preparation or for supplementing classroom instruction. As TE5 educator noted, "I often turn to online learning platforms to enhance my understanding of complex topics before presenting them to my students." This sentiment reflects a broader trend among educators who recognize the value of online resources in strengthening their own knowledge and skills.

Moreover, the use of YouTube platforms, such as Khan Academy and other educational channels, emerged as a prominent feature in the teaching practices of all five educators interviewed. These platforms offer a wealth of instructional videos covering a wide range of subjects, making them valuable tools for both educators and learners. As TC3 educator explained, "I frequently utilize YouTube lessons to supplement my teaching materials and provide students with alternative

explanations of algebraic concepts." This approach not only diversifies instructional methods but also caters to different learning preferences, ensuring that all learners have access to quality educational content.

Interestingly, two educators, TA1 and TC3, highlighted their use of projected YouTube lessons as a means of enhancing student understanding of algebraic functions. By projecting these videos in the classroom, educators can leverage multimedia resources to provide dynamic and engaging explanations of mathematical concepts. This approach not only reinforces classroom instruction but also offers learners opportunities for reinforcement and review. As TA1 educator articulated, "I find that projecting YouTube lessons allows me to provide students with a unique perspective on algebraic functions, supplementing traditional teaching methods with multimedia resources."

The widespread adoption of online learning platforms, particularly YouTube, underlines the growing importance of digital resources in contemporary education. These platforms offer educators a versatile toolkit for delivering dynamic and engaging instruction, catering to diverse learning styles and preferences. However, it is essential to recognize that access to such resources may not be uniform across all educational contexts. Addressing disparities in technology access and digital literacy is crucial to ensuring equitable access to quality education for all students.

During the interview it was also noticeable that two young educators TA1 and TC3 appeared to be highly knowledgeable about the use of digital tools and they also emphasized that they learnt most of these skills at the university where they attended. They both delved into the feasibility of leveraging online collaboration tools such as Google Classroom, Microsoft Teams, and Zoom in the context of mathematics education. First and foremost, the educators highlighted the accessibility and ease of use as key factors contributing to the feasibility of these online collaboration platforms. TA1 educator remarked:

> *"Google Classroom provides a user-friendly interface that simplifies the process of sharing resources and assignments with students, irrespective of their technological proficiency."*

This sentiment was also echoed by TC3 that:

> "*Microsoft Teams offers seamless integration with other Office applications, making it convenient for both educators and students to navigate and utilize various tools within a familiar environment*."

Moreover, both educators emphasized the potential of online collaboration tools to facilitate personalized learning experiences and cater to diverse learning needs. TA1 participant articulated, "*Zoom's breakout room feature can enable us to group students based on their proficiency levels or learning preferences, allowing for targeted instruction and peer collaboration."* Similarly, TC3 highlighted, "Google Classroom's ability to provide instant feedback on assignments can enable us to offer timely support and interventions to students who may require additional assistance."

Furthermore, the educators emphasised the value of synchronous and asynchronous communication features offered by these platforms in promoting active engagement and fostering a sense of community among students. "*Through Microsoft Teams' chat and discussion channels, students can engage in meaningful discourse, share insights, and collaborate on problem-solving tasks outside of the traditional classroom setting,*" remarked TC3 educator. TA1 added on this insight by mentioning that, "*Zoom's real-time interaction capabilities can enable us to conduct live polling, quizzes, and interactive whiteboard sessions, thereby enhancing student participation and understanding*."

However, educators mentioned certain challenges and considerations associated with the implementation of online collaboration tools in mathematics education, including digital equity issues, privacy concerns, and the need for comprehensive professional development. As TA1 educator aptly stated, "*While these platforms offer immense potential, it's crucial to address disparities in access to technology and ensure equitable learning opportunities for all students*." The same challenge was raised by TC3 by saying that: "*While I am highly knowledgeable about digital tools that I can use in my classroom to enhance learning, however, I have never been able to use any of the collaboration tools in my current school. I was only able to apply these tools in the private school where I was once employed while I was still a student at the university*".

The insights gleaned from the perspectives of township mathematics educators underline the feasibility and transformative potential of online collaboration tools such as Google Classroom, Microsoft Teams, and Zoom in enhancing mathematics education. By leveraging these platforms effectively, educators can create dynamic learning environments that foster collaboration, engagement, and personalized learning experiences for all students, thereby paving the way for academic success and empowerment in the digital age.

In conclusion, it is evident from the interviews that digital tools offer diverse learning pathways and cater to individual learning styles, allowing educators to personalize instruction and address

the needs of all students effectively. Despite the challenges, digital tools have the potential to revolutionize the teaching and learning of algebraic functions in South African townships. By addressing access barriers, promoting digital literacy, and fostering collaboration, educators can harness the power of technology to enhance mathematical understanding and empower their learners for success in the digital age. However, concerted efforts are needed to overcome implementation challenges and ensure that all learners have equal opportunities to thrive. Implementing these tools requires addressing issues of access, providing adequate teacher training, ensuring inclusivity, and promoting responsible digital citizenship. Through collaborative efforts between educators, policymakers, and technology providers, the power of digital tools can be harnessed to bridge the educational divide and empower township learners to excel in mathematics.

4.2.4 Status of PHET simulators among Grade 9 Educators

The insight collected from the five educators about the status and potential of Phet simulators in township schools raised numerous striking positions. The findings revealed a critical lack of awareness regarding Phet simulations, highlighting the need for targeted interventions to bridge this gap and unlock the pedagogical benefits of this technology. Strikingly, only one educator amongst the five participants expressed any knowledge of Phet simulations. This sole individual had encountered the tool during school workshops but had not yet integrated it into their teaching practice. The other four educators were entirely unfamiliar with Phet simulations, indicating a significant knowledge absence among participants about this potentially valuable resource.

> *"I have interacted with Phet simulators in one of physical sciences workshops at the district, the tool seemed so useful and engaging. And has a potential of developing our learners understanding of functions and graphs in a playful and interesting way."* TA1

> *"I have been taught multiple technologies that we can use to teach mathematics such as GeoGebra at the university. However, they never introduced us to Phet simulators. Phet looks like a fun and easy to use tool, and it seems to promote a playful learning environment, that can help learners to develop a conceptual understanding of functions." TC3*

> *"I am a fast-learning individual, from this demonstration of Phet I have gained a deep understanding of the tool, and I am highly willing to apply it into my lessons.*

However, the availability of digital resources in my school may limit me from being able to implement the tool". TB2

"I am highly fascinated by the tool, especially because the tool can be utilized offline if there is no availability of internet connection. I am looking forward to downloading the tool and try using it for my lessons. However, I may need to request for a computer and a projector from the principal". TD4

The interview extracts shed light on the reasons behind the educators' limited exposure to PhET simulators. One recurring theme was the lack of information and resources available to teachers in township schools. Participants mentioned limited access to professional development opportunities specifically focused on technology integration in mathematics education. Additionally, the constraints of overcrowded classrooms and limited access to technology infrastructure were cited as contributing factors.

After demonstrations, the educators expressed a generally positive outlook on the potential of Phet simulations. They acknowledged the potential benefits of the tool in enhancing student engagement, promoting visual learning, and fostering deeper conceptual understanding of mathematical concepts. TE5 educator remarked, "*It sounds like a valuable tool that could make learning math more interactive and engaging for students."*

However, concerns were raised regarding the feasibility of implementing Phet simulations effectively in the context of township schools. Educators highlighted the challenges associated with large class sizes, limited access to computers and internet connectivity, and the potential need for additional training and support to utilize the tool effectively.

Based on the findings of the interviews, the following three recommendations are proposed to bridge the knowledge gap and explore the feasibility of Phet simulations in township mathematics education. The first one is to target professional development of educators. The stakeholders must organize workshops specifically focused on introducing Phet simulations to township mathematics educators. These workshops should provide hands-on training on utilizing the tool, integrating it into lesson plans, and addressing potential challenges in the classroom environment. The second recommendation is resource development. Stakeholders must create localized resources and materials that cater to the specific needs and contexts of township schools. This could include translated user guides, lesson plans tailored to the South African curriculum, and offline versions of Phet simulations for use in schools with limited internet access. And the third

recommendation is to implement pilot programs. Stake holders and school management teams must implement a pilot program in a select number of township schools to test the feasibility and effectiveness of using Phet simulations in the classroom. This program should involve ongoing monitoring, evaluation, and feedback collection from both educators and students to inform adjustments and future implementation strategies.

While the current state of awareness regarding Phet simulations in township mathematics education is concerning, the potential benefits of the tool cannot be ignored. By addressing the knowledge gap through targeted interventions and developing contextually relevant resources, Phet simulations hold the potential to transform the teaching and learning of mathematics in township schools, fostering a more engaging and effective learning experience for students. By acknowledging the challenges and working collaboratively with educators, stakeholders can unlock the potential of this technology and contribute to improved mathematics education outcomes in townships.

4.3 Data Analysis

Data analysis in qualitative research involves the systematic examination and interpretation of qualitative data to uncover meaningful patterns, themes, and insights. It aims to make sense of the rich, descriptive data gathered through methods like interviews, observations, or textual analysis. The process typically begins with the collection of raw data, which is then organized, coded, and analysed to identify recurring themes or categories. Techniques such as content analysis, grounded theory, or narrative analysis may be employed depending on the research design and objectives. The primary goal of data analysis is to generate findings that are grounded in the data itself, offering a deeper understanding of the phenomenon under study. It often involves iterative cycles of coding and categorizing data to refine interpretations and ensure the reliability and validity of findings. Data analysis is crucial for identifying patterns, outliers, and relationships within the data, thus providing a foundation for further exploration through thematic analysis or other analytical approaches.

In qualitative data analysis, arriving at themes involves a process of uncovering the underlying meaning and interconnected patterns within the data (Braun & Clarke, 2023). This process is often iterative and involves familiarization, coding, and theme development (Gale et al., 2013). In other words, thematic analysis, is a specific method of data analysis within qualitative research. It involves identifying, analysing, and reporting patterns (themes) within data that are relevant to the research question or objectives. Themes are patterns of meaning that emerge across data sources and reflect the shared experiences, perspectives, or phenomena under investigation

During familiarization, the researcher immerses themselves in the data by repeatedly reading and reviewing transcripts, notes, or other qualitative materials (Braun & Clarke, 2023). This initial immersion allows for the identification of tentative codes, which are labels or keywords assigned to capture specific concepts or ideas within the data. These codes are then refined and organized, potentially merging or dividing them as patterns become clearer. Through continued analysis and comparison, the researcher seeks to identify recurrent themes, which are abstract concepts that capture the essence of the data (Gale et al., 2013). These themes should be coherent, internally consistent, and distinct from one another, offering a deeper understanding of the phenomenon under investigation. By critically reflecting on the data and the relationships between codes, researchers can arrive at a rich and nuanced understanding of the participants' experiences, perspectives, and meanings.

4.4 Three main themes emerged

Theme 1: Challenges of Teaching Mathematics in Resource-Constrained Environments

The challenges faced by mathematics teachers in resource-constrained environments have been a recurrent theme in recent literature. Researchers highlight the significant impact of limited access to technology on the teaching and learning of mathematics in such settings. For instance, a study by Smith et al. (2023) examined the experiences of mathematics teachers in underserved schools and found a consistent lack of technological resources, including interactive whiteboards, smartboards, and functional tablets. In addition, a study by Warrington et al. (2023) conducted in rural schools in developing countries found that a lack of resources, including technological resources, significantly impacted the quality of mathematics education. Teachers in these settings often face overcrowded classrooms, limited access to teaching aids, and insufficient time for individualized instruction, leading to a reliance on traditional teaching methods that may hinder conceptual understanding (Aydin & Kaya, 2020). The absence of these tools hindered teachers from employing dynamic visualizations and interactive activities in their pedagogies. Overcrowded classrooms exacerbate these challenges, as discussed in the transcripts. In a study conducted by Banda & Nzabahimana (2023), the authors emphasized the difficulties teachers face in providing individual attention and catering to diverse learning needs in overcrowded classrooms. The limitations in resources and time often lead teachers to resort to rote learning and procedural teaching methods, impacting students' ability to engage with conceptual understanding.

Furthermore, the impact of poverty, language barriers, and lack of parental support on student learning was acknowledged in the transcripts. Bature (2020) explored the intersectionality of these

factors and their cumulative effect on hindering students' engagement with mathematics. The language barriers, and lack of parental support on student learning due to socio-economic factors affect learners' educational outcomes. These factors not only affect students' engagement but also influence teachers' instructional approaches and their ability to address diverse learning needs effectively. The study underlines how these challenges push teachers toward traditional methods of lesson delivery, making it imperative to address not only the technological limitations but also the broader contextual constraints.

Theme 2: Potential of Technology in Enhancing Linear Function

Recent literature has recognized the potential of technology in enhancing the teaching of linear functions. The participants revealed positive experiences with existing technologies such as Phet, GeoGebra, and Google Classroom. A study by Bingimlas (2009), delved into the impact of incorporating these tools into mathematics classrooms, highlighting their role in facilitating visualization, saving time, and simplifying resource sharing. The positive experiences with Phet simulations, GeoGebra, and Google Classroom have sparked enthusiasm among mathematics teachers to explore new technological tools. This is consistent with the findings of a survey conducted by Erbilgin & Şahin (2021), which indicated a growing interest among teachers in adopting and integrating technology to create engaging learning environments and promote conceptual understanding of linear functions.

The positive experiences with technology highlighted in this theme are consistent with recent literature emphasizing the potential of educational technology to enhance mathematics instruction. For instance, a meta-analysis by Mushipe & Ogbonnaya (2019) demonstrated that the use of digital tools, such as dynamic geometry software like GeoGebra, can improve students' understanding of linear functions and promote problem-solving skills. Moreover, the interest among mathematics teachers in exploring new technologies aligns with studies advocating for professional development opportunities focused on integrating technology into mathematics teaching (Ali, 2019). Research suggests that effective use of technology tools, such as Phet simulations, can create interactive learning environments that foster conceptual understanding and engage students in meaningful mathematical explorations (Astutik & Prahani, 2018).

Teachers expressed a strong desire for learning and using new technologies such as Phet, emphasizing the potential of such tools for creating interactive and student-centered learning environments. The literature suggests that fostering a culture of continuous exploration and

integration of technology in mathematics education can contribute significantly to enhancing the understanding of linear functions.

Theme 3: Need for Teacher Training and Support

The need for teacher training and support in utilizing educational technology is a recurring theme in the literature on mathematics education. The need for teacher training and support in utilizing technology for mathematics education is a crucial theme in recent research. Contemporary studies have highlighted the importance of ongoing professional development programs that provide teachers with the necessary skills and knowledge to integrate technology effectively into their teaching practices (Bingimlas, 2009). The lack of training on specific technologies, as highlighted in the data presentation, has been identified as a drawback among mathematics teachers. In a study by Erbilgin & Şahin (2021), it was revealed that while some teachers received exposure to tools like GeoGebra during their teacher training, they lacked training on tools such as Phet simulators.

This underlines the importance of continued professional development opportunities for mathematics teachers to stay updated on the latest technological tools and their pedagogical applications. The challenges faced in utilizing even simple technologies like PowerPoint and Microsoft suite applications, due to limited access to computers, projectors, and reliable internet connections, were also noted. A study by Aydin & Kaya (2020) emphasized the need for improved infrastructure and technical support within schools to empower teachers in effectively integrating technology into their mathematics instruction.

Additionally, the challenges faced by teachers in utilizing technology due to infrastructure limitations, such as inadequate access to computers and reliable internet connections, underline the importance of addressing broader systemic issues in educational settings. Investments in improving infrastructure and providing technical support within schools are crucial to ensuring equitable access to technology-enhanced learning opportunities for all learners.

4.5 Discussion

Phet Simulators have been extensively utilized for teaching algebraic functions, offering interactive and engaging pedagogical methods that enhance learners' understanding. For instance, research by Banda & Nzabahimana (2023) demonstrates the effectiveness of Phet simulators in facilitating conceptual understanding of algebraic functions through dynamic

visualizations and hands-on exploration. By allowing learners to manipulate variables, observe graphical representations, and experiment with different scenarios, Phet Simulators promote active learning experiences that deepen comprehension and promote problem-solving skills. In the South African context, where resource constraints and diverse learning needs are prevalent, the pedagogical methods employed with Phet Simulators can be particularly beneficial. Integrating Phet Simulators into mathematics instruction in South African schools can address the challenges of overcrowded classrooms and limited access to traditional teaching aids by providing virtual environments where students can actively engage with algebraic functions (Garcia, 2020). Additionally, Phet Simulators offer flexibility in accommodating diverse learning styles and language backgrounds, making them well-suited for addressing the needs of a diverse student population (Gloria & Ramnarain, 2021). Through teacher training programs and collaborative initiatives aimed at enhancing technology integration in education, South African educators can effectively leverage Phet Simulators to promote conceptual understanding and mathematical proficiency among learners in their classrooms.

In South African township schools, where resource constraints and limited access to technology are prevalent particularly quintile 3 schools, the utilization of Phet simulators in teaching algebraic functions presents both opportunities and challenges. The potential benefits of Phet simulators, such as interactive visualizations and engagement-enhancing activities, align with the need to promote conceptual understanding among learners (Garcia, 2020). Phet simulators offer a powerful platform to enhance learners' cognitive domain in understanding functions by providing dynamic visualizations and interactive activities that engage students in active learning processes. Through hands-on exploration and experimentation with virtual models, learners can develop a deeper conceptual understanding of mathematical concepts related to functions (Özcan et al., 2020). For example, students can manipulate variables, observe graphical representations, and analyze the effects of different parameters on function behavior in real-time, fostering critical thinking and problem-solving skills (Mushipe & Ogbonnaya, 2019). Furthermore, the interactive nature of Phet simulators encourages students to construct their own knowledge through inquiry-based learning, leading to higher levels of cognitive engagement and retention (Graven, 2014). By immersing students in virtual environments where they can explore mathematical concepts in a hands-on manner, Phet simulators promote active learning experiences that stimulate higher-order cognitive processes such as analysis, synthesis, and evaluation (Ali, 2019). Thus, Phet simulators serve as valuable tools for increasing learners' cognitive domain in understanding

functions, enabling them to develop a robust conceptual framework and problem-solving proficiency in mathematics.

However, the challenges associated with resource limitations and infrastructure deficiencies, as highlighted in the challenges of teaching mathematics in resource-constrained environments theme, may hinder the effective implementation of Phet simulators in these settings (Warrington et al., 2023). To address these challenges and enhance learner understanding of mathematics, several strategies need to be implemented. Firstly, comprehensive teacher training programs should be designed to equip educators with the necessary skills to integrate Phet simulators into their teaching practices (Mallari & Lumanog, 2020). These programs should focus on pedagogical approaches that leverage the interactive features of Phet simulators to facilitate active learning and conceptual exploration. Additionally, efforts to improve infrastructure and provide technical support within schools are essential to ensure reliable access to technology (Polly, Martin & Byker, 2023). Collaborative initiatives involving government agencies, educational institutions, and community stakeholders are crucial for addressing systemic barriers and promoting equitable access to quality mathematics education in South African township schools (García et al., 2021). Through a combination of teacher training, infrastructure improvements, and collaborative efforts, the effective use of Phet simulators can play a significant role in enhancing learner understanding of algebraic functions and promoting mathematical proficiency in South African township schools.

Incorporating an activity system, adapted from Engeström (1999), into teaching algebraic functions using Phet simulators involves creating a structured learning environment that fosters collaborative engagement and active participation among learners. According to research by (Mwanza, 2001), this approach emphasizes the interconnectedness of various elements within the learning context, including tools, rules, community, division of labor, and outcomes. In this context, Phet simulators serve as the primary tool for exploration and experimentation, allowing learners to manipulate variables and observe graphical representations of algebraic functions in real-time. The rules of engagement are established through clear instructions and guidelines provided by the teacher, promoting focused inquiry and problem-solving activities. The classroom community functions as a collaborative learning space where learners share ideas, collaborate on tasks, and provide peer support, fostering a sense of belonging and collective ownership of learning outcomes. Additionally, the division of labor involves assigning roles and responsibilities within group activities, promoting equitable participation and skill development among students. Ultimately, the outcomes of this activity system encompass not only the acquisition of conceptual understanding and problem-solving skills but also the development of collaborative and critical-

thinking abilities essential for mathematical proficiency in the South African context (Engeström, 1999).

In the context of teaching algebraic functions using Phet simulators in South African township schools, four (4) components of the Activity System theory are particularly suitable and important. These components include tools, rules, community, and division of labor (Engeström, 1999).

1. **Tools**-Phet simulators serve as the primary tool for exploration and experimentation in learning algebraic functions. These interactive software platforms provide students with dynamic visualizations and manipulative capabilities to engage with mathematical concepts in a hands-on manner (Banda & Nzabahimana, 2023). In resource-constrained environments, where access to traditional teaching aids may be limited, Phet simulators offer an accessible and versatile tool for enhancing conceptual understanding and problem-solving skills among students.
2. **Rules** - Clear instructions and guidelines provided by the teacher establish the rules of engagement within the learning environment. In the context of using Phet simulators, teachers set expectations for student behavior, task completion, and collaboration during exploration activities (Bedny & Karwowski, 2004). Establishing clear rules ensures that students understand their roles and responsibilities, promoting focused inquiry and effective use of the simulator to achieve learning objectives.
3. **Community** - The classroom community plays a crucial role in facilitating collaborative learning experiences among students. In South African township schools, where students come from diverse backgrounds and may face various socio-economic challenges, fostering a supportive and inclusive learning community is essential (García et al., 2021). Through collaborative activities facilitated by Phet simulators, students have opportunities to share ideas, collaborate on tasks, and provide peer support, creating a sense of belonging and collective ownership of learning outcomes.
4. **Division of Labor** - Assigning roles and responsibilities within group activities promotes equitable participation and skill development among students. In the context of using Phet simulators, teachers can assign specific tasks to individual students or groups, such as data collection, analysis, or presentation (García et al., 2021). By distributing tasks based on students' strengths and interests, teachers promote active engagement and collaborative problem-solving, enhancing the overall effectiveness of using Phet simulators for teaching algebraic functions in South African township schools.

By incorporating these components of the Activity System theory, teachers can create a structured and supportive learning environment that maximizes the potential of Phet simulators to enhance conceptual understanding and mathematical proficiency among students in South African township schools.

4.6 Responding to the research question

1. What are the current methods that teachers are using in teaching functions & graphs in quintile 3 township schools?

The current methods employed by teachers in teaching functions and graphs in quintile 3 township schools primarily revolve around traditional instructional approaches supplemented by limited technological resources. Teachers often rely on rote learning and procedural teaching due to challenges posed by overcrowded classrooms, limited access to technology, and resource constraints (Gloria & Ramnarain, 2021). In the absence of interactive whiteboards, smartboards, or functioning tablets, teachers face difficulties incorporating dynamic visualizations and interactive activities into their lessons. Additionally, factors such as poverty, language barriers, and lack of parental support impact learner engagement with conceptual understanding, further reinforcing the use of traditional teaching methods. Despite positive experiences with available technologies like Phet simulators, GeoGebra, and Google Classroom, teachers lack comprehensive training on these tools and face challenges in utilizing them effectively due to infrastructure limitations and technical constraints within the school environment. Therefore, while there is an interest among teachers in exploring new technologies for teaching functions and graphs, the current methods predominantly reflect traditional pedagogical approaches constrained by the realities of the quintile 3 township school context.

2. How can Phet simulators application and demonstrations enhance the teaching and learning of functions in mathematics grade 09?

Phet simulators application and demonstrations can significantly enhance the teaching and learning of functions in Grade 9 mathematics. By providing dynamic visualizations and interactive activities, Phet simulators engage students in hands-on exploration of algebraic concepts, fostering a deeper understanding of functions (Banda & Nzabahimana, 2023). Through manipulation of variables and observation of graphical representations in real-time, students can actively experiment with different scenarios, promoting critical thinking and problem-solving skills. The interactive nature of Phet simulators encourages inquiry-based learning, where students construct their own knowledge through exploration and experimentation (Findley, Whitacre &

Hensberry, 2017). Moreover, collaborative activities facilitated by Phet simulators promote peer interaction and knowledge sharing, fostering a supportive learning community (Garcia, 2020). By integrating Phet simulators into mathematics instruction, teachers can create engaging learning experiences that cater to diverse learning needs and promote conceptual understanding of functions among Grade 9 students in South African township schools.

3. ***How can Phet simulations develop critical thinking and problem-solving skills in algebraic functions?***

Phet simulations offer a dynamic and interactive platform that fosters the development of critical thinking and problem-solving skills in the context of algebraic functions. By allowing students to manipulate variables, explore graphical representations, and observe cause-and-effect relationships in real-time, Phet simulations engage learners in active inquiry and experimentation (Garcia, 2020). Through hands-on exploration of mathematical concepts, learners are encouraged to analyze data, make connections between different mathematical representations, and apply mathematical reasoning to solve complex problems (Findley, Whitacre & Hensberry, 2017). Furthermore, Phet simulations provide learners with immediate feedback on their actions, enabling them to assess their understanding and revise their strategies accordingly (Hensberry, Moore & Perkins, 2015). By promoting a process-oriented approach to learning, Phet simulations encourage learners to think critically, evaluate evidence, and develop systematic problem-solving strategies essential for success in algebraic functions. Therefore, Phet simulations serve as a valuable tool for developing critical thinking and problem-solving skills in the context of algebraic functions, fostering deeper conceptual understanding and mathematical proficiency among learners.

Response to the Main Research Question

How can the use of simulators (Particularly Phet) enhance learner understanding and develop critical thinking and problem-solving skills in algebraic functions?

The use of simulators, particularly Phet simulations, can enhance learner understanding and develop critical thinking and problem-solving skills in algebraic functions through their interactive and dynamic nature. Phet simulations provide learners with opportunities for hands-on exploration, allowing them to manipulate variables, observe graphical representations, and analyze cause-and-effect relationships in real-time (Arifin, Nugraha, & Prasetyo, 2022). By engaging in active inquiry and experimentation, learners develop a deeper conceptual

understanding of algebraic functions and their properties. Furthermore, Phet simulations promote critical thinking by encouraging learners to analyze data, make connections between different mathematical representations, and evaluate evidence to solve complex problems (Banda & Nzabahimana, 2023). Through immediate feedback and iterative exploration, learners refine their problem-solving strategies and develop systematic approaches to tackle algebraic problems (Gloria & Ramnarain, 2021). Overall, the use of Phet simulations as simulators in teaching algebraic functions fosters a process-oriented approach to learning, promoting both conceptual understanding and the development of critical thinking and problem-solving skills among learners.

4.7 Conclusion

The study found that teachers have different opinions about using PhET in their teaching. Some think PhET can help learners understand tricky mathematics ideas better because it's visually interesting. But others worry because they haven't used PhET much and think it's hard to use in schools with few resources. There are some big obstacles, like not having enough technology, classrooms being too full, and the internet not working well. These factors make it hard for teachers to try new ways of teaching and for learners to understand mathematics better. Also, factors like being poor, not speaking the language well, and not getting enough help from parents make it tough for learners to learn. But even with these problems, teachers like using other digital tools, like GeoGebra and Google Classroom. They think these tools can help learners see things better and work together. The study says teachers need to keep learning about how to use technology well to help learners learn better.

Chapter Five: Conclusions, Limitations & Recommendations

5.1 Conclusion

This qualitative case study delved into the feasibility of integrating PhET simulations (PhET) into the teaching and learning of algebraic functions in Grade Nine classrooms within quintile 3 township schools. Employing a constructivist approach, the research acknowledged the subjective experiences and interpretations of the five participating educators.

Findings revealed a nuanced picture regarding the potential and challenges associated with using PhET for this purpose. Educators like TA1 recognized the value of PhET's visual representations and interactive features in enhancing student understanding of abstract concepts. They described a scenario where students could manipulate variables within the simulations, observe the corresponding changes in graphical representations, and gain a deeper grasp of the relationships between variables and functions. This aligns with research by Banda & Nzabahimana (2023) who demonstrated the effectiveness of PhET simulations in facilitating conceptual understanding through dynamic visualizations and hands-on exploration.

However, the study revealed concerns and challenges. Educators like TD4, with limited exposure to PhET and working in resource-constrained environments, expressed apprehension about integrating the tool. Their concerns resonated with studies by Smith et al. (2023) and Warrington et al. (2023), highlighting the pervasive issue of limited access to technology in underserved schools. This lack of resources can manifest in overcrowded classrooms, limited access to traditional teaching aids like whiteboards and projectors, and unreliable internet connections. Consequently, teachers often resort to rote learning and procedural teaching methods, hindering students' ability to engage with conceptual understanding (Aydin & Kaya, 2020). The absence of technology further exacerbates this issue by limiting the opportunities for incorporating dynamic visualizations and interactive activities into lessons.

Furthermore, findings from the interviews highlighted the broader socio-economic context that can impact student learning. Educators alluded to the challenges posed by poverty, language barriers, and lack of parental support. These factors align with research by Bature (2020) who emphasized the intersectionality of these factors and their cumulative effect on hindering students' engagement with mathematics. These challenges not only affect students' engagement but also influence teachers' instructional approaches and their ability to address diverse learning needs effectively.

Despite these challenges, a glimmer of hope emerged from the findings. Participants expressed positive experiences with existing digital tools like GeoGebra and Google Classroom. This

enthusiasm aligns with studies by Bingimlas (2009) and Erbilgin & Şahin (2021) who found that technology can facilitate visualization, save time, and simplify resource sharing, fostering a growing interest among teachers in adopting technology to create engaging learning environments.

The findings also emphasized the need for ongoing professional development opportunities for teachers to stay updated on the latest educational technologies and their pedagogical applications. This aligns with research by Bingimlas (2009) who highlighted the importance of training programs in equipping teachers with the necessary skills to integrate technology effectively. The challenges faced in utilizing even basic technologies, as noted in the interviews, underline the need for improved infrastructure and technical support within schools (Aydin & Kaya, 2020). Furthermore, collaborative initiatives involving government agencies, educational institutions, and community stakeholders can be instrumental in addressing systemic barriers and promoting equitable access to quality mathematics education in South African township schools (García et al., 2021).

Looking beyond the immediate challenges, the potential benefits of PhET simulations for enhancing learner understanding and developing critical thinking and problem-solving skills in algebraic functions are compelling. By allowing students to manipulate variables, observe graphical representations, and experiment with different scenarios in real-time, PhET simulations promote active learning experiences that deepen comprehension and develop problem-solving skills (Mushipe & Ogbonnaya, 2019). This aligns with the Activity System theory proposed by Engeström (1999), which emphasizes the interconnectedness of various elements within the learning context, including tools, rules, community, division of labour, and outcomes. In this context, PhET simulators serve as the primary tool, fostering hands-on exploration and experimentation. Teachers establish clear rules and expectations, promoting focused inquiry and effective use of the simulator. The classroom community becomes a collaborative learning space where students share ideas, collaborate on tasks, and provide peer support. Finally, the division of labour within group activities ensures equitable participation and skill development. By incorporating these components, teachers can create a structured and supportive learning environment that maximizes the potential of PhET simulations.

Furthermore, PhET simulations cater to diverse learning styles and can potentially bridge the language barrier. This is particularly relevant in South African township schools with a diverse student population (Gloria & Ramnarain, 2021). The interactive and visual nature of PhET

simulations can provide alternative pathways to understanding concepts that may be initially challenging to grasp through traditional methods.

5.2 Limitations for this study

This qualitative case study explored the feasibility of integrating PhET simulations into the teaching and learning of algebraic functions in Grade Nine classrooms within quintile 3 township schools. While the research yielded valuable insights, several limitations are important to consider when interpreting the findings.

- The study's scope was confined to a small sample size of five educators due to time constraints from a limited geographical area. This restricts the generalizability of the findings to the broader population of quintile 3 township schools in South Africa. The experiences and perspectives of the participating educators may not represent the entire spectrum of challenges and opportunities within these schools. A larger and more geographically diverse sample could provide a more comprehensive understanding of teacher experiences with technology integration in this context.
- Due to time factors the study relied solely on semi-structured interviews, limiting the researchers' ability to directly observe classroom practices and student interactions with PhET simulations. While the interviews provided valuable teacher perspectives, it is important to acknowledge the potential for bias or misrepresentation. Educators may not always accurately recall their practices or may present them in a more favourable light. Including classroom observations or student focus groups could have provided a more holistic perspective on the potential and challenges of using PhET simulations.
- Due to time factors the research did not explore the long-term sustainability of integrating PhET simulations into the classroom environment. The study focused on initial feasibility, but the ongoing challenges of maintaining access to technology, ensuring technical support, and providing ongoing teacher training were not fully addressed. Investigating these factors would be crucial for understanding the long-term viability of using PhET simulations in resource-constrained settings.

In conclusion, while the qualitative case study provided valuable insights into the potential of PhET simulations for teaching algebraic functions in quintile 3 township schools, the limitations discussed above highlight the need for further research with a broader scope and more robust methodologies. Future studies should consider including larger and more diverse samples, incorporating classroom observations and student perspectives, and exploring the long-term

sustainability and cultural relevance of technology integration initiatives in these resource-constrained contexts. By acknowledging these limitations, researchers can gain a more comprehensive understanding of the opportunities and challenges associated with using PhET simulations to enhance the teaching and learning of mathematics in South African township schools.

5.3 Recommendations

Building upon the valuable insights gleaned from this qualitative case study on PhET simulations and the teaching of algebraic functions in quintile 3 township schools, several key recommendations can guide future research endeavours. By addressing the limitations identified and expanding the scope of inquiry, researchers can gain a more comprehensive understanding of PhET's potential and develop strategies for successful integration within these resource-constrained environments.

- Firstly, to enhance the generalizability of findings, future research should strive for a broader and more geographically diverse sample of schools and educators. This could involve collaborating with educational authorities to identify schools across different provinces in South Africa, ensuring representation from various demographics within the quintile 3 township school category. By including a larger and more diverse sample, researchers can capture a wider range of experiences and perspectives, leading to a more generalizable understanding of the challenges and opportunities associated with integrating PhET simulations in these contexts.
- Secondly, future studies should consider employing a mixed-methods approach that combines qualitative and quantitative data collection techniques. While the current study relied solely on semi-structured interviews, incorporating classroom observations could provide valuable insights into how educators utilize PhET simulations in practice. In addition, pre- and post-tests for learners could gauge the impact of PhET integration on their understanding of algebraic functions. This triangulation of data would offer a more holistic picture of the potential benefits and challenges associated with using PhET simulations.
- Thirdly, investigating the pre-existing technological fluency of participating educators would be crucial. Future research could include surveys or questionnaires to assess educators' comfort level with using technology in general and their familiarity with specific educational technology tools. Understanding these baseline skills would allow researchers to tailor professional development initiatives more effectively. Training programs could be

designed to address specific skill gaps and equip educators with the necessary knowledge and confidence to integrate PhET simulations effectively into their teaching practices.

- Investigating the long-term sustainability of PhET integration initiatives is crucial. Future research could explore strategies for overcoming challenges related to technology access, technical support, and ongoing teacher training. This might involve investigating partnerships with educational technology companies to provide ongoing support and infrastructure upgrades in participating schools. Additionally, exploring the potential of open-source educational technology alternatives and offline versions of PhET simulations could offer solutions for schools with limited internet connectivity. By investigating these aspects, researchers can develop a more sustainable framework for integrating PhET simulations in resource-constrained settings.

In conclusion, due to time constraints caused by degree attainment purposes of this study, multiple potentials of the study were not reached. Thus, by addressing the limitations of the current study and incorporating the recommendations outlined above, future research can significantly contribute to our understanding of how PhET simulations can be effectively integrated into the teaching and learning of mathematics in South African township schools. By employing a broader scope, mixed-methods approaches, and a focus on long-term sustainability and cultural relevance, researchers can develop evidence-based recommendations and strategies for harnessing the potential of PhET simulations to provide equitable access to quality mathematics education for all learners in these underserved communities.

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Appendix A (Wits Ethics Approval letter)

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Ngubane

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H23/10/27**
PROJECT TITLE	Investigating the impact of interactive simulations: A case of Phet simulators to teach algebraic functions in quintile-three schools
INVESTIGATOR(S)	Mr N Ngubane
SCHOOL/DEPARTMENT	Wits School of Education/
DATE CONSIDERED	20 October 2023
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	25 January 2027

DATE 26 January 2024 **CHAIRPERSON** (Professor J Watermeyer)

cc: Supervisor : Dr A Dewa

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **A SIGNED COPY** returned to the Secretary electronically. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure be contemplated from the research procedure as approved I/we undertake to submit an amendment of the protocol to the Committee. **I/we agree to completion of a regular progress report. For Minimal and Low Risk studies, this is due annually on 31 December. For Medium and High Risk studies, this is due twice annually on 30 June and 31 December.**

Signature 31,01,2024 Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix B (GDE Permission letter)

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	**22 January 2024**
Validity of Research Approval:	**08 February 2024– 30 September 2024** **2024/528**
Name of Researcher:	**Ngubane N**
Address of Researcher:	**2090 Mabalane Street**
	Soweto
Telephone Number:	**083 9234364**
Email address:	**1471556@students.wits.ac.za**
Research Topic:	**Investigating the impact of interactive simulations: A case of Phet simulators to teach algebraic functions in quintile three schools.**
Name of University:	**Wits**
Type of qualification	**Masters**
Number and type of schools:	**5 Secondary Schools**
District/s/HO	**Johannesburg Central**

Re: Approval in Respect of Request to Conduct Research

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

22/01/2024

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

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

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

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

Kind regards

.....

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

DATE: 22/01/2024

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

Appendix C (Plagiarism Score)

Masters Project N Ngubane final _TunItin.docx

ORIGINALITY REPORT

9%	7%	5%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

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2	fastercapital.com Internet Source	1%
3	aut.researchgateway.ac.nz Internet Source	1%
4	Melody Mushipe, Ugorji Iheanachor Ogbonnaya. "Geogebra and Grade 9 Learners' Achievement in Linear Functions", International Journal of Emerging Technologies in Learning (iJET), 2019 Publication	1%
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