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Exploring the Integration of Mobile Learning Applications among Secondary Level Mathematics Students

A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE EDUCATION DEGREE IN MATHEMATICS

BY

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APPROVAL FORM

The undersigned confirms that they have supervised and recommended to Bindura University of Science Education for acceptance the dissertation titled '**Exploring the Integration of Mobile Learning Applications among Secondary Level Mathematics Students.**'

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DECLARATION : PLAGIARISM

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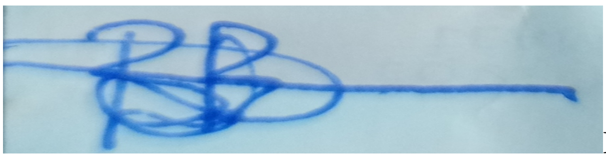
Signature  Date 16/10/24

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Abstract

This research examines the integration of mobile learning applications (apps) in mathematics education within rural Nyanga, Zimbabwe, with the goal of improving school mathematics learning amid significant educational challenges. Employing a mixed-methods approach, the study collected qualitative data through interviews with a sample of ten mathematics teachers and twenty students from Nyanga, uncovering their perceptions, experiences and challenges associated with using applications such as GeoGebra, Kahoot!, Mathway, Photo Math, DragonBox and Desmos. Quantitative data were gathered through pre-test and post-test assessments to measure the impact of these applications on students' academic performance and conceptual understanding. Pre-test and post test scores were analysed using pared sample t-test and qualitative data was analysed thematically.

The findings reveal that mobile learning applications notably enhance student engagement, deepen their conceptual understanding and boost motivation. Teachers leverage these tools for visualizing complex concepts, administering quizzes and providing step-by-step solutions. Despite these benefits, the study identifies several critical barriers, including unreliable internet connectivity, limited access to devices and frequent power outages. Additionally, teachers report a lack of structured training and technical support as significant impediments to maximizing the potential of mobile learning tools. To address these challenges, the study recommends investing in robust technological infrastructure, developing applications tailored to local needs and implementing comprehensive professional development programs for educators. This study provides valuable insights for policymakers, educators, and stakeholders, offering actionable recommendations to improve the integration of educational technology in resource-constrained settings.

DEDICATION

This work is dedicated to my wife Biningu Praise Tatenda and Daughter Ariella Mutsawashe.

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CHAPTER 1

THE RESEARCH PROBLEM

1.0 Introduction

The rapid integration of mobile learning applications in education has transformed traditional teaching methods, offering new avenues for enhancing student's problem solving skills. This chapter explores the significance of mobile learning applications in secondary school mathematics education, focusing on its potential to improve students' engagement and understanding. By examining current trends the chapter sets the stage for investigating how mobile learning applications can be effectively utilised in secondary school mathematics education, to foster a deeper comprehension of mathematical concepts. The research aims to identify the benefits and challenges of incorporating these technologies, providing insights for educators and policy makers.

1.1 Background to the study

The advancement of technology has revolutionized various aspects of education globally, with mobile learning emerging as a prominent method for delivering educational content. In the context of mathematics education, mobile learning applications offer innovative opportunities to engage students, enhance learning experiences and promote the development of critical skills such as problem-solving (Attewell and Savill-Smith, 2004).

In Zimbabwe, like many other countries, the education sector faces challenges such as limited resources, large class sizes and disparities in access to quality education, particularly in rural areas (Chigona et al., 2017). However, with the increasing availability and affordability of mobile devices and internet connectivity, there exists a potential avenue to address some of these challenges and improve the quality of education (UNESCO, 2017).

Nyanga, located in the Eastern Highlands of Zimbabwe, is characterized by its rural setting and diverse socioeconomic conditions. Chikoko and Mapolisa (2019) are of the opinion that despite efforts to improve educational outcomes in the region, students in Nyanga, particularly in secondary schools, continue to encounter difficulties in mastering mathematics concepts and applying problem-solving strategies effectively ultimately affecting their results.

Given these challenges and the potential of mobile learning technology in helping students master mathematical concepts, there is a pressing need to explore the integration of mobile learning applications in mathematics education in Nyanga. By leveraging on mobile devices that are increasingly prevalent among students, educators have the opportunity to enhance the teaching and learning process, cater for diverse learning needs and foster the development of essential mathematical skills (Sharples et al., 2019).

Through a comprehensive exploration of the integration of mobile learning applications in Nyanga's secondary schools, this research endeavours to contribute to the ongoing discourse on technology-enhanced learning in mathematics education and inform future educational practices and policies in Zimbabwe and beyond.

1.2 Statement of the Problem Statement

In Nyanga, Zimbabwe, secondary school students struggle passing mathematics at all levels due to limited resources and engagement issues (Chikoko and Mapolisa, 2019). Traditional teaching methods fail to address individual learning needs due to blotted classes and inadequate engagement times between learners and educators (Chigona et al., 2017). Integrating mobile learning applications offers a potential solution, yet its impact remains unexplored (Attewell and Savill-Smith, 2004). This research aims to investigate the impact of using mobile learning applications in enhancing mathematics education among secondary school students in Nyanga. The study seeks to provide insights into improving mathematics education in similar resource-constrained settings (Sharples et al., 2019).

1.3 Research questions

1. What is the impact of integrating mobile learning applications on the problem-solving abilities of secondary school students in Nyanga?
2. What are the perceptions of mathematics teachers in Nyanga regarding the effectiveness of mobile learning applications in supporting student learning?
3. How do the academic performance outcomes of students using mobile learning applications compare to those following traditional instruction methods?

4. What are the long-term challenges and barriers associated with incorporating mobile learning applications into mathematics education for student learning outcomes and educational practices in Nyanga, Zimbabwe?

1.4 Objectives of the study

1. To investigate the usage patterns of mobile learning applications by teachers and students in Nyanga.
2. To assess the impact of mobile learning applications on students' mathematics learning outcomes
3. To identify challenges and barriers to the effective integration of mobile learning applications in the classroom
4. To explore the support structures and training needed for teachers to effectively use mobile learning applications
5. To provide recommendations for improving the use of mobile learning applications in mathematics education

1.5 Scope of the study

The study investigated the integration of mobile learning applications among secondary school students in Nyanga. Participants included students and mathematics teachers drawn across secondary schools in Nyanga district. Data collection involved interviews on both teachers and learners and pre- and post tests administered on learners. Both qualitative and quantitative data were analysed as a mixed approach paradigm. The research was conducted over a predetermined timeframe, with limitations including sample size, access to technology and time constraints.

1.6.0 Significance of the Research

1.6.1 Educational Impact

This research has the potential to significantly impact on mathematics education in Nyanga, by providing insights into the effectiveness of integrating mobile learning applications to complement traditional teaching strategies among secondary school students. The findings could inform educational policies, curriculum development and instructional practices aimed at improving mathematics learning outcomes possibly by adopting recommendations the writer provided.

1.6.2 Technological Innovation

By exploring the use of mobile learning applications in a resource-constrained setting, this study contributes to the advancement of educational technology in Zimbabwe. It highlights the feasibility and benefits of leveraging mobile devices to supplement traditional classroom instruction, paving the way for future innovations in technology-enhanced learning.

1.6.3 Empowering Teachers and Students

The research empowers mathematics teachers and students in Nyanga by equipping them with new tools and strategies to enhance teaching and learning. By integrating mobile learning applications, teachers can personalize instruction, cater for diverse learning needs and engage students more effectively, ultimately fostering a positive learning environment.

1.6.4 Addressing Global Challenges

The study addresses broader challenges in education, such as improving access to quality education in rural areas and fostering digital literacy skills among students (UNESCO, 2017). By demonstrating the potential of mobile learning applications to bridge educational gaps and enhance learning outcomes, this research contributes to the global discourse on educational equity and innovation (Khan et al., 2015).

1.6.5 Sustainable Development

Enhancing mathematics education in Nyanga contributes to the long-term development of the district by equipping students with essential skills for future success (UNESCO, 2015). By improving problem-solving abilities and fostering a deeper understanding of mathematical concepts, this research supports sustainable development goals related to education, poverty reduction and economic empowerment (Chikoko andMapolisa, 2019).

1.7 Hypothesis:

The integration of mobile learning applications significantly enhances educational achievement among secondary school mathematics students.

1.8.0 Limitations

1.8.1 Sample Size and Generalizability

The study's findings may be limited by the size and representativeness of the sample. The research will focus on secondary schools in Nyanga, Zimbabwe, which may not fully represent the diversity of educational contexts and experiences within the province or the country as a whole (Chikoko and Mapolisa, 2019). Due to the specific geographic focus the findings may not be generalizable to other regions or educational settings outside of Nyanga, Zimbabwe. Factors such as socioeconomic status, infrastructure and cultural differences could impact the applicability of the results to other contexts (Chikoko et al., 2021).

1.8.2 Technology Access and Infrastructure

The effectiveness of mobile learning applications may be influenced by factors such as access to technology, internet connectivity and device compatibility. Limitations in technology access and infrastructure in Nyanga could affect the implementation and outcomes of the intervention.

1.8.3 Teacher and Student Readiness

The success of integrating mobile learning applications may depend on the readiness and familiarity of teachers and students with technology. Resistance to change, lack of training or discomfort with technology among educators and learners could hinder the effectiveness of the intervention.

1.8.4 Time Constraints

The research will be conducted over a predetermined timeframe, which may limit the depth and breadth of data collection and analysis. Time constraints could impact the researcher's ability to capture longitudinal data or explore additional variables that may influence the outcomes of the study.

1.8.5 External Factors

External factors such as changes in educational policies, curriculum revisions, or unforeseen events (e.g., natural disasters, socio-political unrest) could impact the research process and outcomes, potentially introducing bias or confounding variables.

1.8.6 Data Collection Challenges

The collection of data through interviews and pre and post tests may face challenges such as non-response bias, respondent fatigue or difficulties in accessing relevant information. Of much concern is these challenges could impact the reliability and validity of the findings.

1.9 Ethical Considerations

Ethical considerations related to informed consent, privacy and confidentiality were addressed throughout the research process. However, ethical constraints may limit the scope or methodology of the study, potentially affecting the comprehensiveness of the findings. For instance teachers of some schools declined to participate and this affects overall comprehensiveness and generalizability of the findings.

1.10 Definition of key terms

1.10.1 Mobile Learning Applications

Mobile learning applications refer to software applications designed to deliver educational content and facilitate learning experiences on mobile devices such as smart phones laptops and tablets (Kukulska-Hulme and Traxler, 2013). These are software tools designed for use on mobile devices that facilitates the teaching and learning of mathematical concepts. They provide interactive and engaging methods for students to enhance their problem-solving abilities, help in increasing access to instructional content, practice questions and receive feedback within a flexible digital environment. Examples include GeoGebra, Mathway, Photomath, Khan Academy among others.

1.10.2 Problem-Solving Skills

Problem-solving skills encompass the cognitive abilities and strategies used to identify, analyze and solve complex problems effectively (UNESCO, 2017). In the context of mathematics education, problem-solving skills involve the application of mathematical concepts, reasoning and critical thinking to solve mathematical problems or real-world problems that require mathematical reasoning (Chikoko and Mapolisa, 2019). Thus this term refer to the cognitive and analytical abilities that enable students to effectively identify, understand and resolve mathematical problems using logical reasoning and proper strategies.

1.10.3 Integration

Integration, in the context of this research, refers to the process of incorporating mobile learning applications into existing educational practices and curriculum in secondary schools, (Kukulska-Hulme andTraxler, 2013). It involves the seamless incorporation of technology-enhanced learning tools and resources to complement traditional instructional methods and support student learning and engagement in mathematics education.

1.11 Chapter summary

Chapter 1 provided an overview of the study on integrating mobile learning applications among secondary school students in mathematics education in Nyanga. It underscores the transformative impact of mobile learning technology on mathematics education, highlighting its potential to engage students and improve their understanding of mathematical concepts. The chapter reviews research objectives focusing on the benefits and challenges of using mobile learning applications in the classroom. It sets the foundation for the subsequent chapters, outlining the research methodology and framework that guided the investigation into this innovative educational approach.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter delves into the existing body of literature on mobile learning and its impact on secondary education, particularly in mathematics. It examines various studies and theories that highlight the benefits and challenges of integrating mobile learning applications into the classroom. The review provides a comprehensive understanding of the current state of mobile learning, focusing on its effectiveness in enhancing problem-solving skills. By synthesising past research, this chapter identifies gaps and sets the context for the study's investigation into the use of mobile learning applications in Nyanga.

2.1.0 Theoretical Framework: Socio-Constructivist Perspective

2.1.1 Constructivism

Constructivism posits that learning is an active, cognitive process in which learners construct their understanding of the world based on prior knowledge, experiences and interactions with their environment (Piaget, 1950; Vygotsky, 1978). In the context of mathematics education, constructivism emphasizes the importance of engaging students in meaningful, authentic learning experiences that promote the development of problem-solving skills through exploration, collaboration and reflection (Jonassen, 1999).

2.1.2 Socio-cultural Theory

Socio-cultural theory, as proposed by Vygotsky (1978), emphasizes the role of social interactions and cultural context in shaping learning and cognitive development. According to this perspective, learning occurs through social interaction and collaboration with more knowledgeable others, such as teachers, peers and technology-mediated environments (Wertsch, 1991). In the context of mobile learning, socio-cultural theory highlights the potential of collaborative, interactive learning environments to support the co-construction of knowledge and the development of problem-solving skills among students (Luckin et al., 2009).

2.2 Mobile learning in mathematics education

Research on mobile learning in mathematics education has highlighted its promising potential to positively impact on student engagement, motivation and overall learning outcomes (Sparshott, 2018). Specifically, mobile learning applications have been identified as effective tools for supporting the development of problem-solving skills among students (Looi et al., 2010). These applications offer unique opportunities for exploration, experimentation and reflection, all of which are essential components of effective problem-solving strategies.

For instance, interactive math applications enable students to interact with virtual objects, manipulate mathematical concepts and receive immediate feedback on their actions (Jong, Lee and Shang, 2017). This interactive feedback loop, according to Hohenwarter and Lavicza (2007), not only reinforces correct problem-solving approaches but also allows students to identify and rectify misconceptions in real-time. By providing a dynamic and immersive learning environment, mobile learning applications promote deeper understanding and retention of mathematical concepts, ultimately enhancing students' problem-solving abilities.

Moreover, mobile learning applications facilitate personalized learning experiences tailored to individual student needs and preferences. These applications can adapt content and instructional strategies based on students' performance data, allowing for differentiated instruction and targeted support (Sparshott, 2018). This personalized approach to learning helps address diverse learning styles and abilities, ensuring that all students have the opportunity to develop their problem-solving skills at their own pace.

Additionally, mobile learning applications offer flexibility and accessibility, allowing students to engage with mathematical content anytime, anywhere and on any device. This flexibility is particularly beneficial in the context of secondary school education in Nyanga, where access to traditional educational resources may be limited (Sparshott, 2018). By leveraging mobile technology, students can overcome geographical barriers and access high-quality educational materials that may not be readily available in their local schools.

In summary, research indicates that mobile learning applications have the potential to significantly enhance problem-solving skills among secondary school mathematics students. By providing interactive, personalized and accessible learning experiences, these applications empower students to become confident and competent problem solvers, capable of tackling mathematical challenges with creativity and resilience.

2.3 Collaborative learning

Mobile learning has emerged as a promising approach to mathematics education, offering unique opportunities to enhance student engagement, motivation and learning outcomes. Numerous studies have underscored the potential of mobile learning applications in supporting the development of problem-solving skills among students. These applications provide dynamic platforms for exploration, experimentation and reflection, allowing learners to interact with mathematical concepts in innovative ways. For instance, interactive math applications empower students to manipulate virtual objects, visualize abstract mathematical concepts and receive immediate feedback, thereby fostering deeper understanding and retention (Jong, Lee, and Shang, 2017).

Furthermore, mobile learning applications facilitate collaborative learning experiences by integrating features that promote peer-to-peer communication, shared workspaces and collaborative problem-solving activities. Through these functionalities, students can engage in meaningful interactions with their peers, teachers and external experts, leading to the co-construction of knowledge and the exchange of diverse perspectives and strategies. Collaborative problem-solving, in particular, allows students to pool their collective expertise and leverage each other's strengths to address mathematical challenges effectively (Sharples et al., 2019).

By harnessing the power of collaborative learning, mobile learning applications create inclusive and dynamic learning environments where students can actively engage with mathematical content and develop critical problem-solving skills. These applications not only facilitate knowledge sharing and peer support but also promote the development of essential 21st-century skills such as communication, collaboration and critical thinking. Moreover, collaborative learning experiences foster a sense of community and belonging among students, enhancing their motivation and confidence in tackling mathematical problems (Jones et al., 2017).

In summary, mobile learning applications offer valuable opportunities to promote collaborative learning in mathematics education, enabling students to work together to explore, analyze and solve mathematical problems. By leveraging the features and functionalities of these applications, educators can create immersive and interactive learning experiences that foster the development of problem-solving skills and promote deeper engagement with mathematical concepts. Collaborative learning through mobile applications holds significant promise for enhancing mathematics education and preparing students for success in an increasingly interconnected and collaborative world.

2.4 Scaffolding and Guided Discovery

Mobile learning applications play a crucial role in providing scaffolding and guided support to students as they navigate through problem-solving activities in mathematics education. Scaffolding, a concept rooted in socio-cultural theory, involves providing structured assistance and support to learners as they engage in challenging tasks (Wood et al., 1976). In the context of mobile learning, applications are designed to offer scaffolds such as prompts, hints and adaptive feedback mechanisms to guide students through the problem-solving process. These scaffolds are strategically integrated into the learning environment to bridge the gap between students' current knowledge levels and their desired learning outcomes (Savery and Duffy, 1996). For instance when using Khan Academy, in learning concepts like geometry or algebra, the application can provide virtual manipulatives that allow students to visually explore and manipulate geometric shapes or algebraic expressions, with in-built guidance on how to use them to solve problems.

By offering prompts and hints tailored to students' individual needs and learning trajectories, mobile learning applications provide targeted support to help learners overcome obstacles and navigate through complex problem-solving tasks. These prompts can range from simple hints to more detailed explanations, depending on the level of scaffolding required by the student. Adaptive feedback mechanisms embedded within the applications offer real-time feedback on students' progress and performance, helping to reinforce correct strategies and address misconceptions effectively (Hung and Zhang, 2008).

Moreover, mobile learning applications facilitate guided discovery by encouraging students to explore and experiment with mathematical concepts in a supportive and structured environment. Instead of providing direct solutions to problems, these applications prompt students to engage in active inquiry and problem-solving, fostering a deeper understanding of mathematical concepts through discovery-based learning experiences. Guided discovery allows students to take ownership of their learning journey, develop problem-solving strategies and build confidence in their mathematical abilities (Vygotsky, 1978).

Through scaffolding and guided discovery, mobile learning applications empower students to take an active role in their learning process and develop the skills and strategies necessary for successful problem-solving in mathematics. By providing targeted support and guidance, these applications help students build a solid foundation of mathematical understanding and develop confidence in their ability to tackle complex problems independently. As a result, students are better equipped to apply their problem-solving skills in real-world contexts and succeed in academic and professional settings.

2.5 Reflection and Metacognition

Mobile learning applications play a pivotal role in fostering students' metacognitive development, which is essential for effective problem-solving in mathematics education. Metacognition refers to the awareness and regulation of one's own thinking processes, including planning, monitoring and evaluating one's learning strategies (Flavell, 1979). Through features that promote reflection, self-assessment and goal-setting, mobile learning applications provide students with opportunities to engage in metacognitive activities and develop a deeper understanding of their problem-solving approaches (Schraw andMoshman, 1995).

Reflection is a key component of metacognition, allowing students to critically evaluate their thinking processes and identify areas for improvement. Mobile learning applications encourage students to reflect on their problem-solving experiences by prompting them to review their strategies, assess their progress and consider alternative approaches. By engaging in reflective practices, students gain insight into their strengths and weaknesses as problem solvers, enabling them to make informed decisions about how to approach future challenges (Winne and Hadwin, 1998).

Self-assessment is another important aspect of metacognition that mobile learning applications support. By providing tools and prompts for self-assessment, these applications empower students to evaluate their own learning progress and performance objectively. Through self-assessment activities, students can identify their areas of proficiency and areas needing improvement, allowing them to set realistic learning goals and monitor their progress over time (Bransford et al., 2000). By taking an active role in assessing their own learning, students develop a sense of agency and responsibility for their academic success.

Goal-setting is a fundamental metacognitive skill that mobile learning applications facilitate through features that allow students to set, track and adjust their learning objectives. By encouraging students to set specific, measurable, achievable, relevant and time-bound (SMART) goals, mobile learning applications help students clarify their learning intentions and focus their efforts on areas of priority. Goal-setting activities promote self-regulation and motivation by providing students with a clear sense of purpose and direction in their learning journey (Zimmerman, 2002).

Thus, mobile learning applications serve as valuable tools for promoting metacognitive development and enhancing problem-solving skills among students in mathematics education. By providing opportunities for reflection, self-assessment and goal-setting, these applications empower students to take ownership of their learning process, develop effective problem-solving strategies and become self-directed learners. As students cultivate their metacognitive skills through engagement with mobile learning applications, they are better equipped to tackle complex mathematical problems and succeed in academic and real-world contexts (Bransford et al., 2000).

2.6 Implications for practice

Designing engaging and authentic learning tasks is paramount in mathematics education, especially when leveraging mobile learning applications to enhance student learning experiences. These tasks should be carefully crafted to resonate with students' interests, experiences and real-world contexts, fostering deeper engagement and motivation (Sharples, 2019). Unwin (2005) suggests that incorporating interactive features and multimedia capabilities offered by mobile learning applications, educators can create immersive learning experiences that captivate students' attention and stimulate their curiosity. For instance, interactive simulations, virtual manipulatives and gamified activities can make abstract mathematical concepts more tangible and accessible, encouraging students to explore, experiment and discover mathematical principles in meaningful ways.

Furthermore, authentic learning tasks should be relevant and connected to students' lives, interests and future aspirations. By contextualizing mathematical concepts within familiar and meaningful contexts, educators can enhance students' understanding and appreciation of the practical applications of mathematics in everyday life. For example, designing real-world problem-solving scenarios that mirror authentic challenges faced in various professions or industries can help students see the relevance and importance of mathematical problem-solving skills in their future careers.

Moreover, educators should ensure that learning tasks are aligned with curriculum standards and learning objectives, providing students with opportunities to develop essential mathematical competencies and skills. By setting clear goals and expectations, educators can guide students' learning experiences and monitor their progress towards achieving desired outcomes. Mobile learning applications offer flexible and customizable features that allow educators to adapt learning tasks to meet the diverse needs and preferences of their students, fostering a personalized and learner-centred approach to mathematics education.

In summary, designing engaging and authentic learning tasks is essential for maximizing the potential of mobile learning applications in mathematics education. By creating immersive, relevant and goal-oriented learning experiences, educators can cultivate students' interest, motivation and confidence in mathematics, while also promoting deep conceptual understanding and problem-solving skills (Sharples, 2019). Through thoughtful design and implementation of learning tasks, educators can harness the power of mobile learning applications to transform mathematics education and empower students to succeed in the digital age.

2.7 Fostering collaboration and peer interactions

Fostering collaboration and peer interaction is a fundamental aspect of effective mathematics education and mobile learning applications offer unique opportunities to facilitate such interactions both inside and outside the classroom (Roschelle et al., 2010). By leveraging the features of these applications, teachers can create a collaborative learning environment where students can actively engage with mathematical concepts and problem-solving tasks together. Through collaborative activities facilitated by mobile learning applications, students can share ideas, perspectives and strategies, enriching their learning experiences and deepening their understanding of mathematical concepts (Jones et al., 2017).

Research has shown that collaborative learning promotes higher levels of engagement, motivation and achievement in mathematics education (Slavin, 1995). By encouraging students to work together on mathematical tasks, teachers can foster a sense of community and cooperation among learners, creating a supportive learning environment where students feel empowered to take risks and explore new ideas (Dillenbourg, 1999). Mobile learning applications offer a range of collaborative features, such as shared workspaces, collaborative problem-solving tools and peer-to-peer communication channels that facilitate interaction and knowledge sharing among students (Sharples et al., 2019).

Moreover, collaborative learning experiences facilitated by mobile learning applications promote the development of essential 21st-century skills such as communication, collaboration and teamwork (Partnership for 21st Century Skills, 2009). By working together on mathematical tasks, students learn to communicate their ideas effectively, listen to and respect diverse perspectives and negotiate solutions collaboratively (Roschelle and Teasley, 1995). These skills are not only essential for success in mathematics but also for future academic and professional endeavours, where collaboration and teamwork are increasingly valued (Trilling and Fadel, 2009).

Additionally, mobile learning applications extend collaboration beyond the confines of the classroom, allowing students to collaborate and communicate with their peers anytime and anywhere. Through online discussion forums, virtual study groups and collaborative project spaces, students can engage in collaborative learning activities outside of traditional class hours, further enhancing their learning experiences and fostering a sense of community among learners (Sharples et al., 2019).

In summary, fostering collaboration and peer interaction through mobile learning applications is essential for creating a dynamic and inclusive learning environment in mathematics education. By leveraging the collaborative features of these applications, teachers can promote engagement, motivation and achievement among students, while also developing essential 21st-century skills that are crucial for success in an increasingly interconnected and collaborative world (Partnership for 21st Century Skills, 2009). Through collaborative learning experiences facilitated by mobile learning applications, students not only deepen their understanding of mathematical concepts but also develop the communication, collaboration and teamwork skills necessary for success in academia and beyond.

2.8 Providing scaffolding and feedback

Providing scaffolding and timely feedback to students as they engage with mobile learning applications is essential for facilitating their problem-solving skills development and overall learning progress. Scaffolding, as introduced by Wood, Bruner and Ross (1976), involves offering structured support to learners as they work on challenging tasks, gradually reducing this support as learners gain proficiency. In the context of mobile learning applications, scaffolding can take various forms, including prompts, hints, guided questions and examples, which are strategically integrated to guide students through problem-solving activities (Hung and Zhang, 2008).

By providing scaffolding, educators can help students navigate through complex mathematical problems, breaking them down into manageable steps and facilitating their understanding of underlying concepts. Scaffolds offered through mobile learning applications can adapt to students' individual needs and learning styles, providing personalized support tailored to each student's level of proficiency and prior knowledge (Savery and Duffy, 1996). For instance, students struggling with a particular problem may receive additional hints or examples to help them overcome obstacles and progress in their problem-solving process.

Furthermore, timely feedback plays a crucial role in supporting students' problem-solving skills development and learning progress. Feedback provided through mobile learning applications can be immediate, targeted and actionable, offering students' insights into their performance and guiding them towards improvement (Bangert-Drowns et al., 1991). By receiving feedback on their problem-solving strategies and approaches, students can reflect on their thinking processes, identify areas for improvement and adjust their strategies accordingly (Winne and Hadwin, 1998).

Moreover, feedback provided through mobile learning applications can be adaptive and responsive to students' responses and interactions, offering personalized guidance and support. For example, if a student demonstrates misconceptions or errors in their problem-solving approach, the application can provide targeted feedback to correct these misconceptions and steer the student towards the correct solution pathway (VanLehn et al., 2007). This adaptive feedback mechanism ensures that students receive tailored support and guidance that aligns with their individual learning needs and challenges.

In summary, providing scaffolding and timely feedback through mobile learning applications is crucial for supporting students' problem-solving skills development and overall learning progress. By offering structured support and guidance, educators can help students overcome challenges, develop effective problem-solving strategies and deepen their understanding of mathematical concepts (Wood, Bruner and Ross, 1976). Moreover, adaptive feedback mechanisms offered by mobile learning applications ensure that students receive personalized guidance tailored to their individual learning needs, fostering a supportive and engaging learning environment conducive to problem-solving skills development.

2.9 Promoting metacognitive awareness

Promoting metacognitive awareness is a critical aspect of mathematics education and mobile learning applications offer valuable tools for fostering students' metacognitive development. Metacognition, as defined by Flavell (1979), involves the ability to reflect on and regulate one's own cognitive processes, including problem-solving strategies, learning progress and comprehension monitoring. By explicitly teaching metacognitive strategies and encouraging metacognitive awareness among students, educators can empower them to become more effective and independent learners in mathematics.

Mobile learning applications provide opportunities for students to engage in metacognitive activities such as reflection, self-assessment and goal-setting (Schraw andMoshman, 1995). Through features such as self-assessment quizzes, progress trackers and reflective prompts, these applications encourage students to monitor their learning progress, evaluate their problem-solving processes and identify areas for improvement. By engaging in metacognitive activities, students gain insights into their own learning strengths and weaknesses, enabling them to make informed decisions about their learning strategies and approaches.

Furthermore, mobile learning applications can support metacognitive development by providing immediate and personalized feedback on students' problem-solving processes (Winne and Hadwin, 1998). By receiving feedback on their problem-solving strategies and approaches, students can reflect on their thinking processes, identify misconceptions or errors and adjust their strategies accordingly, (Miller, 2010). This feedback loop promotes metacognitive awareness by helping students understand how their cognitive processes impact their problem-solving performance, thus enabling them to become more strategic and effective problem solvers.

Moreover, educators can leverage mobile learning applications to scaffold metacognitive development by modelling and explicitly teaching metacognitive strategies (Efklides, 2008). By providing guided prompts, examples and instructional support, educators can help students develop metacognitive skills such as planning, monitoring and evaluating their problem-solving processes. For example, educators can encourage students to use think-aloud protocols while solving mathematical problems, prompting them to verbalize their thought processes and reflect on their problem-solving strategies (Hacker et al., 2008).

Promoting metacognitive awareness among students is essential for fostering their development as effective problem solvers and lifelong learners. By leveraging mobile learning applications, educators can create opportunities for students to engage in metacognitive activities, receive personalized feedback on their problem-solving processes and scaffold their metacognitive development through explicit instruction and modeling (Flavell, 1979). Through these efforts, educators can empower students to become more self-regulated and strategic learners, capable of monitoring their learning progress, adapting their strategies as needed and achieving success in mathematics and beyond.

By adopting a socio-constructivist perspective, educators can harness the potential of mobile learning applications to create rich, interactive learning environments that foster the development of problem-solving skills among secondary school mathematics students. By promoting authentic learning experiences, collaborative interactions, scaffolded support and metacognitive awareness, mobile learning applications can empower students to become confident and competent problem solvers capable of tackling complex mathematical challenges in academic and real-world contexts.

The reviewed literature highlights the potential of mobile learning applications to enhance problem solving skills among secondary school mathematics students. Drawing upon socio-constructivist principles, research suggests that mobile learning applications provide opportunities for authentic, collaborative and scaffolded learning experiences that promote engagement, motivation and deep conceptual understanding. By leveraging interactive features and multimedia capabilities, educators can design engaging and authentic learning tasks that resonate with students' interests and real-world contexts. Furthermore, fostering collaboration, providing scaffolding and timely feedback and promoting metacognitive awareness through mobile learning applications can empower students to become confident, competent problem solvers capable of tackling complex mathematical challenges.

2.10 Research gap

The existing literature highlights the potential benefits of mobile learning applications in enhancing problem-solving skills in mathematics education, yet it largely focuses on urban and well-resourced settings, leaving a significant gap regarding their efficacy in rural contexts like Nyanga. There is a notable lack of research addressing the challenges faced by rural students, such as limited access to technology and internet connectivity and the socio-economic and cultural factors that may influence the adoption and effectiveness of mobile learning tools. For instance Sharples, Arnedillo-Sánchez, Milrad and Vavoula (2009) studied about the broader implications of mobile learning in developed countries, highlighting the potential for flexible and personalized learning experiences facilitated by widespread access to mobile devices and high-speed internet. However, the study overlooks the barriers to mobile learning in rural or developing areas, such as limited access to technology and internet, which are crucial for the successful adoption of mobile learning applications. Furthermore, most studies, for instance those by Miller (2018) and Ertmer and Ottenbreit-Leftwich (2010), reflect Western educational paradigms, which may not align with the realities of students in rural Zimbabwe, highlighting the need for research that explores culturally relevant adaptations and equitable distribution of these educational benefits.

Additionally, there is limited understanding of the long-term impact and sustainability of mobile learning applications in rural education. The existing studies often emphasize short-term benefits without considering the prolonged effects on students' problem-solving skills and overall academic performance. Moreover, gaps exist in examining the preparedness and training of teachers in rural settings to effectively integrate mobile learning tools into their pedagogical practices. Addressing these gaps is essential for developing effective strategies for implementing mobile learning in rural areas, contributing to the global discourse on educational technology and promoting educational equity.

2.11 Chapter summary

This chapter reviews the existing literature on the impact of mobile learning applications on mathematics education, emphasizing their benefits and challenges. It explores the theoretical framework of socio-constructivism, which underpins the integration of these technologies in educational settings. The review highlights the potential of mobile learning to enhance problem-solving skills through interactive, personalized and collaborative experiences. However, it identifies significant gaps, particularly in the context of rural settings like Nyanga, where limited access to resources, cultural relevance and long-term impact are underexplored. By addressing these gaps, the study aims to provide a deeper understanding of effective strategies for integrating mobile learning in rural mathematics education, promoting educational equity and improving student outcomes.

CHAPTER 3

RESEARCH METHODOLOGY

3.0 Introduction

This chapter outlines the research methodology employed in this study to investigate the use of mobile learning applications in mathematics education among secondary school students in Nyanga. This chapter details the research design, including the qualitative and quantitative approaches used, data collection methods, sampling techniques and data analysis procedures. By employing a mixed-methods approach, this study aims to comprehensively explore the experiences and perceptions of students and teachers, providing valuable insights into the effectiveness and challenges of integrating mobile learning in a rural educational context.

3.1 Research design: Mixed methods approach

In the context of the current research topic a mixed-methods approach was employed. This approach integrates quantitative and qualitative data collection and analysis techniques to offer a comprehensive understanding of the research problem (Creswell and Creswell, 2017).

Quantitative methods were utilized to measure the effectiveness of mobile learning applications in enhancing academic achievement among secondary school mathematics students. A pre- and a post-test were administered to students to assess their performance. These quantitatively measured academic performance outcomes, providing objective data on the impact of mobile learning applications integration.

Complementing quantitative data, qualitative data was collected to explore the experiences, perceptions and challenges of students and teachers regarding the integration of mobile learning applications in mathematics education. Semi-structured interviews were conducted with students and teachers to delve deeper into their perspectives, attitudes and experiences with mobile learning applications (Denzin and Lincoln, 2018). These were also used to measure student engagement, interaction and learning outcomes during mobile learning applications activities, providing rich contextual insights into the implementation process (Merriam and Tisdell, 2016).

By employing a mixed-methods approach, this research aims to triangulate quantitative and qualitative data to gain a holistic understanding of the effectiveness and implications of integrating mobile learning applications in mathematics education in Nyanga. This comprehensive approach will allow for a nuanced analysis of the research problem, capturing both the quantitative impact on performance and the qualitative insights into the experiences and perceptions of students and teachers.

3.2 Participants

The sample selection process is crucial for ensuring the representativeness and validity of the findings. To achieve this, the researcher selected ten teachers using simple random sampling from the thirty four secondary schools in Nyanga district. In addition all of the twenty current form six students at Nyangani high school were also conveniently considered to represent the student side. The main purpose of this sampling technique is to allow the researcher to easily access participants who are readily available saving time and effort. However it must be noted that generalizability of findings tends to get limited with convenient sampling technique.

The sample consisted of secondary school mathematics students and teachers representing a diverse range of demographics and educational backgrounds. This diversity is essential for capturing a comprehensive perspective on the integration of mobile learning applications in mathematics education and its impact on problem-solving skills across different contexts. By including participants from various schools with varying levels of access to technology and prior experiences with mobile learning, the research can provide insights that are applicable and relevant to the broader educational landscape in Nyanga.

Additionally, the convenient sampling approach enables researchers to target specific groups of interest. The simple random sampling done on teachers enabled that teachers with varying levels of experience in using technology for teaching mathematics are included. This approach ensures that the sample is well-suited to address the research questions and objectives, allowing for a more nuanced analysis of the factors influencing the effectiveness of mobile learning app integration in mathematics education (Teddlie and Yu, 2007).

Moreover, efforts were made to obtain consent from participating schools, students and teachers, emphasizing the importance of ethical considerations and ensuring that all participants are informed about the research objectives, procedures and potential risks and benefits involved (Creswell and Creswell, 2017). Confidentiality and anonymity of participants was maintained throughout the research process to protect their privacy and foster trust and openness in data collection and analysis.

Overall, the simple random sampling and convenient sampling approaches enabled the research to capture a diverse range of perspectives and experiences related to the integration of mobile learning applications in mathematics education in Nyanga, contributing to a comprehensive understanding of the research topic and informing evidence-based recommendations for practice and policy.

3.3 Data collection

During the research period, standardized assessments or tests were utilized as part of the quantitative data collection process to measure academic performance outcomes. These assessments provided a standardized and reliable means of evaluating students' mathematical proficiency and problem-solving abilities (Sullivan and Artino, 2013). By administering pre- and post-tests, the researcher assessed the effectiveness of the mobile learning application intervention in improving students' problem-solving skills and academic achievement in mathematics.

It is essential to ensure that the methods used for quantitative data collection are valid, reliable, and culturally appropriate for the target population in Nyanga. Validity refers to the extent to which the instruments measure what they are intended to measure, while reliability reflects the consistency and stability of the measurements over time (Creswell and Creswell, 2017). Adapting existing validated instruments or conducting pilot studies to refine and validate the research instruments can help ensure the quality and rigor of the quantitative data collected in the study. In the current study the researcher used past examinations questions from Zimbabwe school examinations council for the sessions November 2023 paper 2 and November 2021 paper 2 for pre-test and post-test respectively

Moreover, researchers should consider ethical considerations related to the administration of assessments, such as obtaining informed consent from participants, protecting their privacy and confidentiality and addressing any potential risks or discomfort associated with the data collection process (Creswell and Creswell, 2017). The researcher sought consent from all the participants and they were informed that there were no consequences whatsoever if one decides not to be part of the participants. Further the participants were informed that they may withdraw at any time during the research period if they wish so. Creswell and Creswell (2017) emphasize that by adhering to ethical guidelines and best practices, researchers can maintain the integrity and trustworthiness of the quantitative data collected and minimize potential biases or confounding factors that may affect the validity and reliability of the findings.

Quantitative data collection methods such standardized assessments, provide valuable insights into the impact of mobile learning application integration on student outcomes in mathematics education. By systematically measuring and analyzing quantitative data, researchers can assess the effectiveness of the intervention, identify areas for improvement, and inform evidence-based recommendations for practice and policy in Nyanga.

One of the primary qualitative data collection methods utilized was semi-structured interviews conducted with students and teachers. These interviews allowed the researcher to delve into participants' perspectives, attitudes and experiences related to the use of mobile learning applications in mathematics education (Creswell and Creswell, 2017). Through open-ended questions and probes, the researcher explored a wide range of topics, including the effectiveness of the applications in enhancing problem-solving skills, students' engagement and motivation, challenges encountered and suggestions for improvement.

Qualitative data collection methods such as interviews offer rich, contextualized insights that cannot be captured through quantitative measures alone. By combining both qualitative and quantitative data collection techniques, the researcher gained a comprehensive understanding of the complexities and nuances surrounding the integration of mobile learning applications in mathematics education (Creswell and Creswell, 2017). The qualitative data collected through interviews provides depth and context to the quantitative findings, helping to illuminate the underlying factors influencing students' and teachers' experiences and perceptions.

Thus, interviews as qualitative data collection methods are invaluable for gaining insights into the complex dynamics of mobile learning applications integration in mathematics education. By systematically collecting and analyzing qualitative data, the researcher uncovered a rich and nuanced perspectives that inform evidence-based recommendations for practice and policy in Nyanga.

3.4 Intervention

In the context of the research topic on exploring the integration of mobile learning applications among secondary school mathematics students in Nyanga, the implementation of mobile learning applications is a critical component of the research methodology. Selecting appropriate mobile learning applications or software platforms for mathematics education is the first step in this process. It is essential to choose applications that align with the curriculum objectives, are user-friendly and offer interactive features and multimedia capabilities conducive to enhancing problem-solving skills (Crompton, 2013).

The researcher selected Khan Academy, Photomath, Geogebra, Desmos, Mathspace DragonBox, Prodigy Math Game, Kahoot! and Socratic by Google. Most of these applications offer comprehensive sets of video tutorials and practice exercises from basic arithmetic to advanced calculus. Photomath, in particular, allows students to take pictures of mathematics problems and provide step by step solutions and explanations. Socrates by Google uses artificial intelligence to help students understand mathematics by providing explanations and resources related to the problem at hand. Mathspace, for instance, provides step-by-step solutions to problems and interactive exercises, offering instant feedback and tailored learning experiences. In addition some of these applications allow students to visualise and understand mathematical functions and graphs on top of gamifying mathematics.

After the mobile learning applications were selected, the next step was to integrate them into the curriculum effectively. This involved designing learning activities and assignments that leverage the interactive features and multimedia capabilities of the applications to engage students in problem-solving tasks (Sharples et al., 2019). For example, Gegebra, Desmos and Mathway that offer virtual manipulatives, simulations, or gamified activities were used to create immersive learning experiences where students explored mathematical concepts, experiment with different strategies and solve real-world problems in a dynamic and interactive environment. Learners were introduced to the basics of how to manoeuvre through using the applications and were left to learn the rest on their own.

3.5 Data analysis

Quantitative data analysis plays a crucial role in evaluating the effectiveness of the intervention. The analysis involved several key steps to comprehensively assess the impact of mobile learning application integration on student outcomes.

Firstly, descriptive statistics were utilized to summarize and describe the responses and marks from pre-tests and post-tests. Measures such as means, frequencies and percentages were calculated to provide an overview of students' and teachers' bio data and preferences of mobile learning applications in teaching mathematics.

Additionally, inferential statistics were employed to compare pre and post intervention scores and assess the significance of any observed changes. Techniques such as matched pair t-tests were used to determine whether there were statistically significant differences in academic performance between the pre- and post- intervention results. By conducting inferential statistics tests, the researcher can ascertain whether any improvements observed in student outcomes are attributable to the intervention or occurred by chance, (Sullivan and Artino, 2013).

Qualitative data analysis is essential in this research for gaining deeper insights into students' and teachers' experiences with mobile learning applications. This analysis involves several key steps to systematically analyze interview transcripts and extract meaningful insights.

Firstly, thematic analysis was conducted to identify recurring themes, patterns and insights related to students' and teachers' experiences with mobile learning applications. This involved systematically coding the data to identify common topics and issues discussed by participants (Braun and Clarke, 2006). For example, themes such as students' perceptions of the usefulness of mobile learning applications for problem-solving, challenges encountered in using the applications and recommendations for improvement were identified.

Furthermore, the qualitative data analysis process involved iterative cycles of coding, reviewing, and refining codes to develop a comprehensive understanding of the data (Saldana, 2015). Researchers may engage in constant comparative analysis, comparing data across different participants and contexts to identify similarities and differences in experiences and perspectives (Charmaz, 2014). This iterative approach helped to ensure the reliability and validity of the findings and allows the researcher to capture the complexity and richness of participants' experiences with mobile learning applications.

Moreover, triangulation of data sources, such as interviews and pre- and post-tests, can enhance the credibility and trustworthiness of the findings. Creswell and Creswell (2017) vehemently stress that comparing and contrasting data from multiple sources allows researchers to corroborate findings and provide a more nuanced understanding of the research topic.

In summary, qualitative data analysis plays a critical role in exploring students' and teachers' experiences with mobile learning applications in mathematics education. By conducting thematic analysis of interview transcripts the researcher uncovered valuable insights into the factors influencing the integration of mobile learning applications among secondary school mathematics students in Nyanga.

3.6 Ethical considerations

Ensuring informed consent from all participants is a fundamental ethical consideration in research. The researcher obtaining informed consent by providing participants, including students and teachers with clear and comprehensive information about the research objectives, procedures, potential risks and benefits and their rights as participants (Creswell and Creswell, 2017).

Before data collection began, the researcher communicated with school authorities to obtain permission to conduct the research within the school premises. After permission was granted, researcher quested after informed consent from individual participants which was granted. It is always the case that for students under the age of 18, parental consent is also an important requirement in addition to the student's consent. However, in this study all the students were at least 18.

Informed consent forms were developed in accordance with ethical guidelines and regulations, outlining key information such as the purpose of the study, voluntary participation, confidentiality assurances and procedures for withdrawing consent (Creswell and Creswell, 2017). Participants were given sufficient time to review the consent form, ask questions and make an informed decision about their participation in the research.

Confidentiality and anonymity of participants' responses was strictly maintained throughout the research process. Personal identifiers were removed from data collected during interviews and pre- and post test to ensure that participants cannot be identified in any published reports or presentations. Confidentiality was upheld by the researcher and data was and will continue to be stored securely to prevent unauthorized access or disclosure.

Adhering to ethical guidelines for research involving human subjects is paramount to ensure the well-being and rights of participants. The researcher conducted the study with the utmost integrity, transparency and respect for the dignity and autonomy of all participants involved. Any concerns or issues raised by participants regarding their participation in the research were addressed promptly and appropriately.

By prioritizing informed consent and confidentiality, the researcher can uphold ethical standards and build trust and rapport with participants, thereby enhancing the credibility and validity of the research findings. Through ethical conduct and adherence to best practices, the researcher contributed to the advancement of knowledge and understanding in the field of mathematics education while safeguarding the rights and welfare of all participants involved.

3.7 Chapter summary

This chapter presents the research methodology for investigating the use of mobile learning applications in mathematics education among secondary school students in Nyanga. Utilizing a mixed-methods approach, the study integrates quantitative methods, including pre- and post-tests, and qualitative methods, such as semi-structured interviews, to comprehensively explore the experiences and perceptions of students and teachers. The chapter details the research design, sampling techniques, data collection methods and ethical considerations. By triangulating data, the study aims to provide a nuanced analysis of the effectiveness and challenges of mobile learning app integration in a rural educational context.

CHAPTER 4

DATA PRESENTATION AND ANALYSIS

4.0 Introduction

This chapter presents and analyzes the data collected in this study, focusing on the use of mobile learning applications in mathematics education among secondary school students in Nyanga. This chapter begins with an overview of the quantitative data, including pre- and post-test results, to assess the impact of mobile learning on students' academic performance. It also explores qualitative insights gathered from interviews with students and teachers, delving into their experiences, perceptions and challenges related to the integration of mobile learning applications. The chapter aims to address the key research questions: How effective are mobile learning applications in improving students' mathematics performance? What are the perceptions and experiences of students and teachers regarding the use of these applications? What challenges are encountered during the integration of mobile learning in a rural educational setting? The chapter will answer the central hypothesis: The integration of mobile learning applications significantly enhances students' mathematics performance. Through a detailed analysis, this chapter seeks to provide a comprehensive understanding of the impact and implications of mobile learning in the context of mathematics education in Nyanga.

4.1.0 General information on the respondents

The study involved a total of thirty participants, comprising twenty secondary school students and ten teachers from various secondary schools in Nyanga, Zimbabwe. The student participants were all current Form Six students at Nyangani high school, with an age range of 18-21 years. The gender distribution among the students was relatively balanced, with 12 males and 8 females. All students had prior exposure to using mobile devices for learning mathematics, though their experience with mobile learning applications varied.

The ten teacher participants were selected through simple random sampling from the thirty-four secondary schools in the Nyanga district. The researcher used an attendance register for a mathematics workshop where each school in the district was represented. The names were numbered and selected using the random number function of a calculator. These teachers had varying levels of experience in teaching mathematics, ranging from 3 to above 25 years. The gender distribution among the teachers was also balanced, with 5 males and 5 females. Their experience with integrating technology into their teaching practices differed, with some having used mobile learning applications extensively, while others were relatively new to the concept.

The diversity in the demographics and backgrounds of the participants provided a comprehensive perspective on the integration of mobile learning applications in mathematics education in the rural setting of Nyanga. This varied representation was crucial in capturing a broad range of experiences, perceptions and challenges associated with the use of mobile learning applications in this context.

Table 1 : Information about Teachers

Gender	Frequency	Percentages
Male	5	50%
Female	5	50%
Total	**10**	**100%**

Source: Primary Data 2024

Table 2 : Information about Learners

Gender	Frequency	Percentages
Male	12	60%
Female	8	40%
Total	**20**	**100%**

Source: Primary Data 2024

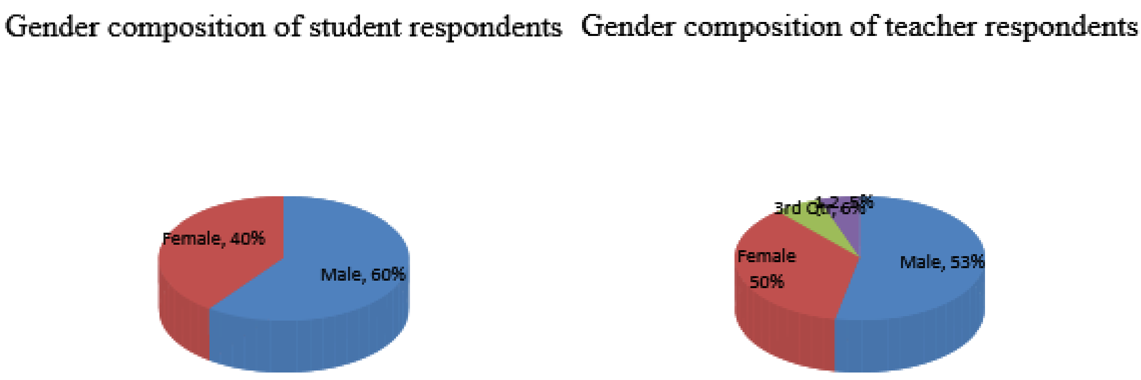

Figure 1 Gender composition of participants

Source: Primary Data 2024

From data collected about respondents as shown in figure 4.1 it is clear that there was gender equity and thus the findings were not biased towards a particular gender.

4.1.1 Information about the teaching experience of teachers

Table 3: Teaching experience of Teachers

Teaching experience in completed years	Number of teachers
1-5	1
6-10	3
11-15	3
16-20	2
20+	1

Source: Primary Data 2024

The table indicates a diverse range of teaching experiences among the teachers surveyed. The majority fall within the 6-15 years range, with three teachers each in the 6-10 years and 11-15 years categories, suggesting a balanced distribution of moderately experienced educators. There is one teacher each in the 1-5 years and 20+ years categories, indicating some representation of both relatively new and highly seasoned teachers. This variety in teaching experience contributes to a comprehensive perspective on the use and impact of mobile learning applications in mathematics education in Nyanga.

4.1.2 Information about highest qualifications of teachers

Table 4: Distribution of Teacher Qualifications

Highest Qualification	Number of teachers
Diploma in education	7
Barchelor's degree in education	2
Master's degree in education	1

Source: Primary Data 2024

The table reveals that the majority of teachers (seven out of ten) hold a diploma in education, indicating a foundational level of professional training. Two teachers possess a bachelor's degree in education, reflecting an advanced understanding of educational theories and practices. Only one teacher has achieved a master's degree in education, signifying specialized expertise and a higher level of academic and professional development. This distribution suggests that while most teachers have solid basic qualifications, there is a relatively small proportion with higher academic credentials, which may impact the depth and variety of pedagogical approaches used in integrating mobile learning applications.

4.2.0 Information of Applications Usage

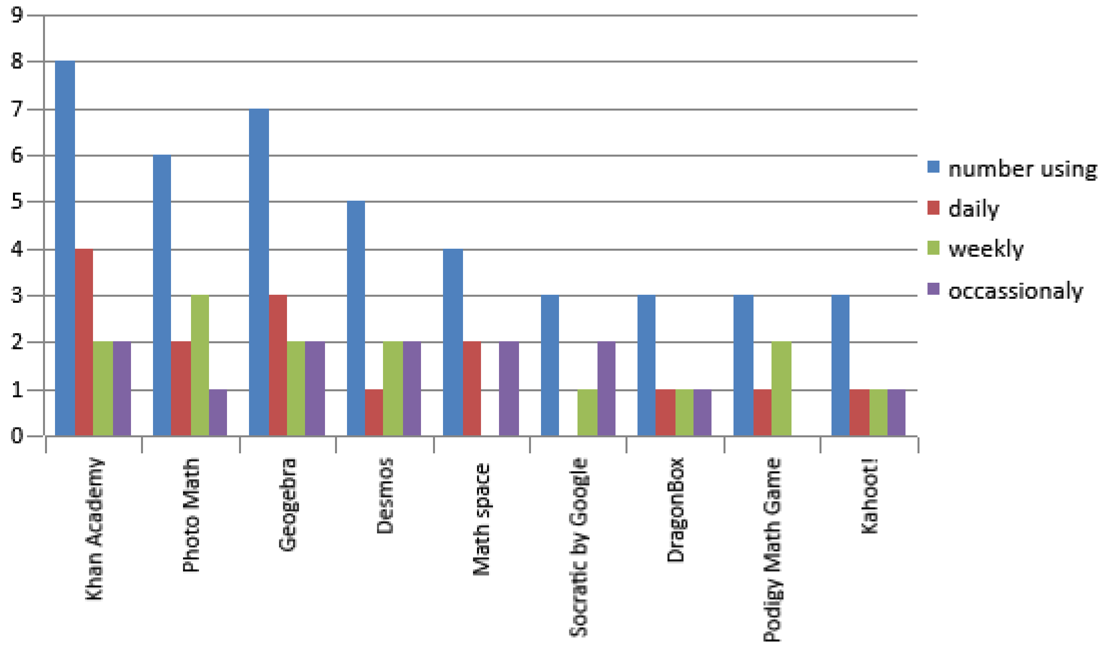

Figure 2: Bar graph showing how different applications are used by teachers.

Source: Primary Data 2024

The data indicate that Khan Academy is the most popular mobile learning application among teachers, with eight users, predominantly using it daily or weekly. Geogebra, which is used for creating and manipulating geometrical constructions on top of plotting and manipulating algebraic equations and functions and Photomath also see significant use, with seven and six users respectively. Desmos, which is predominantly used for graphing and Mathspace which gives step by step solutions to problems, are moderately used by five and four teachers respectively, primarily on a weekly or occasional basis. Socratic by Google, DragonBox, Prodigy Math Game and Kahoot have the least usage, with only three teachers using each of them. This distribution highlights the varying degrees of adoption and preference among teachers, reflecting their choices and possibly the suitability of each application for their teaching needs in Nyanga.

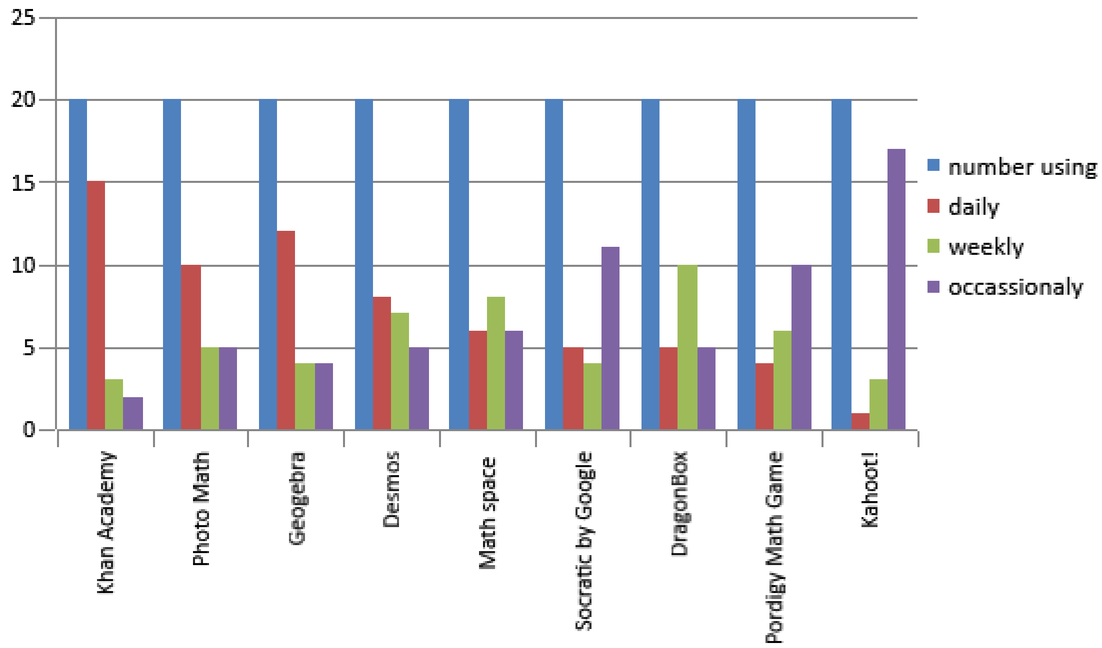

Figure 3: Bar graph showing how different applications are used by learners

Source: primary data (2024)

Khan Academy is the most frequently used app among learners, with 15 using it daily. Photomath follows, with 12 daily users. Geogebra and Desmos are used daily by 10 and 8 learners, respectively. DragonBox, Socratic by Google and Prodigy Math Game have 5, 5 and 4 daily usage respectively, while Kahoot! has the least daily usage of 1. The weekly and occasional usage patterns show that all applications are utilized to varying extents, reflecting diverse preferences and learning needs.

4.2.1 Overall Comment on General Usage

The data reveals that both learners and teachers actively use mobile learning applications, although usage patterns differ. Among learners, Khan Academy and Photomath are the most frequently used applications, with a significant number engaging with these applications daily. Geogebra, Desmos, Mathspace, and Socratic by Google also see substantial usage but at varying frequencies, indicating diverse preferences for different learning tools.

For teachers, Khan Academy and Geogebra are the most utilized applications, reflecting their preference for comprehensive and interactive educational tools. Photomath and Desmos are also commonly used, but Mathspace, Socratic by Google and Kahoot! see less frequent use.

This overall trend highlights the importance of versatile mobile learning applications in enhancing both teaching and learning experiences in mathematics education.

4.3.0 Pre-test and Post-test Scores (Research question 1& 3)

To complement the qualitative findings, quantitative data was collected through pre-test and post-test assessments administered to students. The following analysis provides a detailed examination of the pre-test and post-test scores, highlighting improvements in student performance following exposure to mobile learning applications.

4.3.1 Pre-test and Post-test Marks Analysis

Table 5 Pre-Test And Post-Test Marks For Students (Out Of 120)

Student	Pre-test	Post-test
A	56	59
B	42	96
C	61	67
D	30	28
E	44	73
F	50	42
G	32	110
H	66	80
I	17	51
J	108	114
K	16	91
L	67	93
M	63	77
N	32	26
O	14	59
P	77	62
Q	37	56
R	38	73
S	38	41

T	59	81

Source: primary data (2024)

Descriptive Statistics

Pre-test

Mean of pre-test scores: $\sum \frac{pretestmarks}{20} = \frac{1064}{20} = 53.2$

Median of pre-test scores: 50

Range of pre-test scores: $108 - 14 = 94$

Standard deviation of pre-test scores : $\sigma_{pre-test} = 24.64$

Post test

Mean of post-test scores: $\sum \frac{posttestmarks}{20} = \frac{1173}{20} = 58.65$

Median of post-test scores: 63

Range of post-test scores: $114 - 28 = 86$

Standard deviation of post-test scores : $\sigma_{post-test} = 22.38$

Figure 4: Back to Back Stem Plot comparing pre-test and post-test marks

Pre-test marks	Stem	Post- test marks
7 4 4	1	
	2	8
2 0	3	6
8 8 7 4 2 2	4	2 2
9 6 0	5	1 6 9 9
7 6 3 1	6	2 7
7	7	3 3 7
	8	0 1
	9	1 3 6
8	10	
	11	0 4

Key 1|6 means 61 Key 9|1 means 91

Source :Primary Data 2024

4.3.2 Comparison and Interpretation

The analysis reveals that the mean pre-test score was 53.2, with a standard deviation of approximately 24.64, indicating variability in initial student performance. Following exposure to mobile learning applications and subsequent post-test assessments, the mean post-test score increased to 58.65, with a slightly reduced standard deviation of approximately 22.38. This improvement suggests a positive impact of mobile learning applications on student learning outcomes in mathematics.

Further analysis of the data shows a range of improvements across individual students, with some demonstrating substantial increases in scores from pre-test to post-test. For instance, Student J exhibited a notable improvement, with a pre-test score of 108 increasing to 114 in the post-test, reflecting a gain of 6 marks. Conversely, Student K started with a pre-test scoreof 16 and significantly improved to 91 in the post-test, marking a substantial gain of 75 marks.

The median scores also illustrate improvement, with the post-test median of 63 exceeding the pre-test median of 50, indicating that a majority of students experienced enhancement in their understanding and application of mathematical concepts after engaging with mobile learning applications. From the stem and leaf diagram, it is shown clearly that overall the students performed better in the post-test than the pre test.

To supplement these findings, the researcher performed a matched sample t-test at 5% level of significance with null hypothesis H_1: ($\mu_d = 0$) there is no significant increase in performance of learners between the pre-test and post-test results against an alternative hypothesis H_1: ($\mu_d > 0$) there is significant increase in performance of learners between the pre-test and post-test results. The results of the one-tailed matched sample t-test conducted at a 5% level of significance reveal a test statistic of 3.943, which significantly exceeds the critical value of 1.729 from the t-distribution table with 19 degrees of freedom. Given that the test statistic falls well within the rejection region, we reject the null hypothesis, which posited no significant improvement in performance between the pre-test and post-test marks. Instead, the data provides sufficient evidence to support the alternative hypothesis, indicating a significant improvement in student performance as a result of the intervention with mobile learning applications. This finding underscores the effectiveness of the mobile learning tools in enhancing mathematics achievement among the students.

The literature, including studies by Hwang et al. (2015) and Crompton (2013), consistently highlights the positive impact of mobile learning on student achievement, particularly in mathematics. These studies suggest that mobile learning can enhance student engagement and provide personalized learning experiences, which contribute to better academic outcomes.

Both the research findings and the literature support the notion that mobile learning has a positive effect on student performance. The improvement observed in Nyanga aligns with broader research, reinforcing the idea that mobile learning applications can be powerful tools for enhancing learning outcomes in mathematics.

4.4.0 Thematic Analysis Overview

The thematic analysis involved a rigorous and systematic approach to identifying, analyzing, and reporting patterns (themes) within the qualitative data collected from interviews with teachers and students. The process began with an initial familiarization stage, where the transcripts of the interviews were read multiple times to gain a deep understanding of the content. This was followed by a coding phase, where significant statements and phrases were highlighted and initial codes were generated to capture key ideas across the dataset.

These initial codes were then grouped into broader categories based on their similarities and relevance to the research questions. During this phase, patterns began to emerge, leading to the identification of five main themes that encapsulate the core aspects of the participants' experiences and perceptions regarding the use of mobile learning applications in mathematics education in Nyanga.

Awareness and Familiarity with Mobile Learning Applications: This theme was established based on codes related to participants' knowledge of and exposure to various mobile learning tools. Statements reflecting the degree of familiarity, such as whether the participants had heard of or used specific applications, were central to this theme.

Integration into Teaching Practices: Codes that highlighted how teachers incorporated mobile learning applications into their lessons contributed to this theme. It included references to the frequency of use, specific teaching strategies employed and the challenges faced in integrating these technologies within the constraints of the existing curriculum and infrastructure.

Perceived Impact on Learning: This theme emerged from codes related to participants' observations and opinions on how mobile learning applications affected students' understanding, engagement and performance in mathematics. It included positive impacts, such as improved problem-solving skills, as well as any limitations or negative effects noted by the participants.

Challenges and Barriers: The identification of this theme was driven by codes that captured the obstacles encountered by both teachers and students in using mobile learning applications. Issues such as limited access to devices, internet connectivity problems, power outages and a lack of technical support were recurrent topics that formed the basis of this theme.

Recommendations for Improvement: Finally, this theme was developed from codes that focused on suggestions provided by the participants for enhancing the effectiveness of mobile learning applications in rural educational settings. These recommendations ranged from infrastructure improvements to the need for more tailored teacher training and support.

The establishment of these themes was not a linear process but rather an iterative one, involving continuous refinement as new insights were gained from the data. Each theme was carefully reviewed and refined to ensure that it accurately represented the underlying patterns in the data and provided a meaningful and comprehensive understanding of the participants' experiences with mobile learning applications. By organizing the qualitative data into these themes, the analysis aimed to provide a structured and insightful exploration of the complex dynamics at play in the integration of mobile learning technologies in a rural educational context.

4.4.1 Teacher responses (Research question 2)

Familiarity and Frequency of Use

This section delves into teachers' familiarity with various mobile learning applications and the frequency with which these tools are integrated into mathematics teaching practices at secondary schools in Nyanga. According to the data presented in **Figure 4.2**, teachers across the sample cohort referenced a variety of mobile learning applications, each with specific educational utilities. Applications such as GeoGebra, Desmos, and Photomath are noted for their capabilities in visualizing geometric concepts, algebraic graphing and step-by-step problem solving, respectively. Additionally, gamified applications like DragonBox and Prodigy Math Game were highlighted for their effectiveness in making learning enjoyable and engaging students in mathematical concepts through gameplay.

Teacher A, who has been teaching for over 15 years, commented, “I am somewhat familiar with mobile learning applications. We do not use them often due to limited access to smart phones and internet connectivity. However, I have used GeoGebra a few times to demonstrate geometric concepts like transformations and constructions. I usually project it in class when the electricity is available.” Similarly, Teacher C, with 12 years of experience, mentioned, “I have some experience with mobile learning applications, but the usage is limited. I have used Desmos for graphing functions during lessons when we have access to the computer lab.” Teacher B also noted, “I try to integrate mobile learning apps whenever possible, but it’s challenging because not all students have access to the necessary devices. I often use Kahoot! for quizzes when we have access to the school’s tablet.”

In contrast, Teacher E shared, “I have used DragonBox and Prodigy Math Game in my lessons, especially to engage students in learning basic concepts and problem-solving through games. These applications are particularly useful for making abstract concepts more concrete and fun.” Teacher D, however, indicated a more sporadic use, stating, “I use mobile learning apps like Photomath occasionally to help students understand complex problems. However, it's challenging to integrate them regularly due to device and internet limitations.”

Thus, familiarity and frequency of use of mobile learning applications among teachers reveal a mix of experiences. Some teachers have a basic understanding and occasional use of these applications, but their integration is limited by challenges such as unreliable internet and scarce access to devices. While a few educators actively use applications to enhance their teaching, their frequency of use is constrained by infrastructure issues. Overall, the use of mobile learning applications is inconsistent, with significant variation in how frequently and effectively these tools are incorporated into the classroom due to prevailing resource limitations.

Engagement and Motivation

This section delves into the impact of mobile learning applications on student engagement and motivation within the context of mathematics education in rural secondary schools in Nyanga. Teachers' observations and student feedback underscored significant improvements in student engagement when using applications such as Kahoot!, GeoGebra, Desmos, Photomath, DragonBox, and Prodigy Math Game. These applications were noted for their interactive and gamified features that captivated students' interest and participation during lessons.

Teacher B observed, “Students are more engaged and motivated when we use Kahoot! They enjoy the competitive element and the instant feedback on their answers.” This sentiment was echoed by Teacher H, who stated, “Students are very enthusiastic about using these applications. Kahoot! make learning fun and competitive, which motivates them to participate more actively." Teacher E also noted, "Students are highly engaged when using these gamified applications. They enjoy the game-like format, which makes learning more enjoyable and less intimidating."

In contrast, Teacher A noted, "I have seen that students are quite fascinated when I use GeoGebra. It helps them visualize the concepts better, especially those who struggle with abstract thinking." Teacher C highlighted a different aspect, saying, "When we use Desmos, students find it easier to understand graphing and algebraic functions. They can immediately see how changes in equations affect graphs, which helps solidify their understanding especially when teaching advanced level transformation of graphs."

Thus, the integration of mobile learning applications like Kahoot!, GeoGebra, Desmos, Photomath, DragonBox, and Prodigy Math Game has shown a remarkable impact on student engagement and motivation in mathematics education within the rural secondary schools of Nyanga. Teachers have consistently observed that these applications not only captivate students' interest through interactive and gamified features but also enhance their understanding of complex mathematical concepts. The feedback highlights how these tools make learning more enjoyable, competitive and accessible, thereby fostering a more positive and productive learning environment. This evidence underscores the potential of mobile learning applications to transform the traditional classroom experience, particularly in resource-limited rural settings.

Roschelle et al. (2010) and other scholars argue that mobile learning fosters a more interactive and engaging learning environment. The literature emphasizes that the use of multimedia and interactive features in mobile applications can transform traditional learning methods into more dynamic and student-centered approaches. The findings from the research in Nyanga align with the literature in terms of the benefits of interactive learning environments. Both sources give emphasis to the importance of engagement in enhancing student understanding and making learning more effective.

Overall, the integration of mobile learning applications in the mathematics classrooms of rural Nyanga has demonstrated a substantial positive impact on student engagement and motivation. Interactive tools such as Kahoot!, GeoGebra, and Desmos have proven effective in making lessons more engaging and helping students better understand complex concepts. The use of gamified and interactive features has notably increased students' enthusiasm and participation, aligning with scholarly research that supports the benefits of mobile learning in creating dynamic and student-centred educational experiences. While challenges such as limited access to devices and unreliable internet persist, the observed improvements suggest that with better infrastructure and support, mobile learning apps can play a crucial role in enhancing educational outcomes in these settings.

Learning Outcomes and Understanding

This section examines the impact of mobile learning applications on students' learning outcomes and understanding of mathematical concepts in rural secondary schools in Nyanga. Teachers' experiences as viewed from interview responses provide valuable insights into the effectiveness of various applications in enhancing learning outcomes.

Teacher C explained, “When we use Desmos, students find it easier to understand graphing and algebraic functions. They can immediately see how changes in equations affect graphs, which helps solidify their understanding.” Teacher B added, “Students are more enthusiastic about revising for quizzes and show a better understanding of the material when we use Kahoot!” Teacher E observed, “Students are highly engaged when using these gamified apps. They enjoy the game-like format, which makes learning more enjoyable and less intimidating. I have seen improvements in their enthusiasm towards mathematics and their ability to tackle problems more confidently.”

In contrast, Teacher D noted, “Students find Photomath helpful, especially for step-by-step problem solving. It’s a useful tool for showing them how to approach difficult questions. However, because we cannot use it regularly, the overall improvement in problem-solving skills is not as significant as it could be.” Similarly, Teacher F mentioned, “Students appreciate the detailed explanations provided by Mathway. It helps them understand the steps involved in solving difficult problems. Brilliant's interactive exercises are engaging and encourage students to think critically. Overall, these applications have made students more interested in mathematics.”

This, therefore, suggests that the use of mobile learning applications in rural secondary schools in Nyanga has proven to be a valuable asset in enhancing students' understanding and learning outcomes in mathematics. Teachers' insights reveal that these tools, such as Desmos, Kahoot!, Photomath, and Mathway, not only make abstract concepts more tangible but also foster greater student engagement and enthusiasm. Although some limitations exist in the consistent application of these technologies, the overall impact has been a more motivated, confident and critically thinking student body, demonstrating the potential of these apps to significantly improve mathematics education in resource-constrained environments.

In tandem with these observations, evidence from pre-tests and post-tests indicated measurable improvements in students' performance and comprehension following the integration of mobile learning applications. Statistical analysis, including paired t-tests, revealed significant differences in mean scores between pre-tests and post-tests, suggesting that app-based learning interventions contributed positively to students' academic progress in mathematics.

However, despite these positive outcomes, challenges such as limited access to devices, unreliable internet connectivity, and frequent power outages persisted. These infrastructural barriers often disrupted the continuity of learning and hindered students' ability to fully capitalize on the benefits of app-based educational tools.

4.4.2 Student responses

Usage and Engagement

This section explores the extent of student usage and their engagement with mobile learning applications in mathematics education at rural secondary schools in Nyanga. Data collected through interviews provide a nuanced understanding of how students interact with various educational applications, highlighting both usage patterns and the impact on their learning experiences.

Students reported diverse levels of engagement with mobile learning apps like Prodigy Math Game, DragonBox, Photomath, and Mathway. Applications such as Prodigy Math Game and DragonBox, designed with gamified features, were particularly popular. Over 90% of students noted that these applications made learning more enjoyable and less intimidating. For example, Student A shared, "Prodigy Math Game makes learning fun and interactive. It really captured my interest and made me look forward to math classes."

Photomath and Mathway were also well-received for their ability to provide instant feedback and step-by-step solutions. Student B stated, "Photomath helped me understand algebra problems better because it showed each step. It made solving complex problems much easier for me." Similarly, Student E commented, "Mathway's step-by-step explanations really helped me with differentiation and integration. It broke down problems into manageable steps, which made them less overwhelming."

Despite these positive experiences, students encountered several barriers that impacted their use of these applications. Challenges included limited access to smart phones or tablets, unreliable internet and frequent power outages. Student C highlighted, "Sometimes the power goes out, and I cannot access the applications. It is frustrating because it interrupts my study time." Student D added, "We do not always have access to a smartphone at home and the internet connection is poor. These issues make it hard to use the applications as much as I would like."

In conclusion, while mobile learning applications have shown significant potential in enhancing student engagement and motivation, addressing infrastructural challenges such as device access and reliable internet is crucial for maximizing their effectiveness in rural educational settings.

Perceived Impact on Learning

In this section, we explore the perceived impact of mobile learning applications on students' learning experiences and outcomes based on their perspectives. The data reveals varied insights into how these applications have influenced their understanding and engagement with mathematics education. Students generally expressed positive sentiments regarding the use of mobile learning applications, highlighting several key points:

1. **Enhanced Understanding:** Many students reported that mobile learning applications helped them understand complex mathematical concepts more effectively. Applications like GeoGebra and Desmos were particularly mentioned for their ability to visualize abstract concepts, making it easier for students to grasp and apply mathematical principles.
2. **Improved Engagement:** Students indicated that the interactive and gamified nature of some applications, such as DragonBox and Prodigy Math Game, significantly increased their engagement with mathematics. They found these applications

enjoyable and less intimidating than traditional methods, which often led to increased motivation and willingness to participate in class activities.

3. **Personalized Learning:** A notable aspect mentioned by students was the ability of mobile learning applications to provide personalized learning experiences. Applications like Mathway and Photomath were appreciated for offering step-by-step solutions tailored to individual problem-solving needs, thereby supporting self-paced learning and remediation.
4. **Convenience and Accessibility:** Despite challenges with internet access and device availability, students recognized the convenience of accessing learning materials anytime and anywhere through mobile applications. This accessibility was particularly beneficial for independent study and revision outside of regular classroom hours.
5. **Challenges Faced:** However, students also highlighted challenges such as limited access to smart phones, intermittent internet connectivity, and occasional power outages, which affected their ability to consistently use mobile learning applications for studying.

Overall, students' perspectives underscore the potential of mobile learning applications to positively impact learning outcomes in mathematics education. Their insights provide valuable feedback on the effectiveness and challenges associated with integrating these technologies into the curriculum, offering opportunities for further improvement and adaptation to better meet educational needs in the future.

4.4.3 Challenges and Barriers (Research question 4)

This section explores the challenges and barriers encountered by both teachers and students in the integration and use of mobile learning applications within the context of mathematics education in rural Nyanga. The data collected from both groups highlights several significant challenges that impact the effective implementation of mobile learning applications

A recurring issue reported by both teachers and students is the unreliable and often limited access to the internet. Many students, such as Student G, highlighted the challenge of having no internet at home: "I don't have internet at home, so I can only use the applications when I am at school." Similarly, Student H mentioned, "The internet at school is slow, and sometimes the applications take too long to load." This lack of connectivity not only makes it difficult for students to use mobile learning applications outside of school but also disrupts their usage within school settings. Student I noted, "Even when we have access to the applications at school, the slow internet speeds can be frustrating and make it hard to use them effectively."

Another major hurdle identified is the lack of access to suitable devices. Many students, such as Student K, noted that they do not own smart phones or tablets: "I do not have a smart phone, so I can only use the school’s tablets when they are available." Similarly, Student M mentioned, "I share a tablet with my siblings, so I do not always have it when I need it for studying." Teachers also observed this issue, with Teacher A commenting, “Many students struggle because they either don’t own a device or have to share one with their family, which limits their ability to use the applications consistently.” This limitation significantly impacts their engagement with mobile learning applications, especially those that are designed for individual device use.

Frequent power outages in Nyanga present a substantial barrier to the consistent use of technology in the classroom. Teachers and students alike have emphasized the disruptive impact of these interruptions on their learning experiences. For instance, Teacher A noted, “Power outages are a major issue. We often lose valuable teaching time because the equipment we rely on cannot function without electricity.” Students, too, have felt the effects, with Student N saying, “When the power goes out, I cannot access the applications we use for math, which means I miss out on important lessons.” These interruptions make it challenging to utilize mobile learning applications effectively, undermining both teaching and learning activities.

Teachers have voiced a strong need for more structured training and professional development opportunities focused on integrating mobile learning applications into their teaching practices. As Teacher B mentioned, “There is a significant gap in formal training for using these applications. Many of us have had to figure things out on our own or rely on informal sources.” Student J echoed this sentiment, noting, “Sometimes the teachers are unsure how to use the applications effectively, and it affects our learning experience.” This reliance on self-learning underscores the lack of comprehensive training programs that could bolster educators' confidence and effectiveness in employing these technologies in the classroom.

Both teachers and students have highlighted a significant lack of technical support, especially when it comes to troubleshooting issues with application functionality, internet connectivity, and device maintenance. Teacher D observed, "We often face technical problems with the applications and there is no dedicated support to help us fix these issues quickly." Student G similarly pointed out, "When the apps do not work properly or there is a problem with the internet, it is frustrating because there is no one to help us sort it out." This absence of dedicated support mechanisms not only causes frustration but also reduces the effectiveness and potential benefits of mobile learning applications in enhancing the educational experience.

Financial constraints at both individual and institutional levels significantly exacerbate the challenges of integrating mobile learning applications. Teacher B noted, "Our school struggles with funding for buying enough devices and maintaining a stable internet connection. This limits our ability to use the applications effectively." Similarly, Student J shared, "Many of us cannot afford smart phones and even when we do have access, it is often interrupted because of financial issues at home." These financial limitations impact the scalability and sustainability of using mobile learning technologies in rural settings, hindering their effectiveness and broader adoption.

Some teachers emphasized the need for mobile learning applications to better align with the national curriculum and be localized to reflect Nyanga's cultural and linguistic context. Teacher C remarked, "Many of the applications we use offer great content, but they do not always align with our national curriculum or reflect local teaching priorities." Student D added, "Some of the material on these applications does not fit with what we are learning in class or does not use terms we understand." This misalignment can limit the relevance and effectiveness of the educational content, making it less applicable to students' specific learning needs and objectives.

4.5.0 Integration of Quantitative and Qualitative Findings

The integration of quantitative and qualitative findings reveals a comprehensive view of the impact of mobile learning applications on mathematics education in Nyanga.

4.5.1 Comparison and Contrast

Quantitative data demonstrated significant improvements in student performance and engagement following the introduction of mobile learning applications. The analysis of pre- and post-test scores showed measurable gains in students' mathematical understanding. This aligns with qualitative findings, where teachers and students reported increased engagement and motivation when using applications like Kahoot!, GeoGebra, and Prodigy Math Game. Teachers observed that students were more enthusiastic and participative during lessons incorporating these applications. Both sets of data confirm that mobile learning applications positively affect student engagement and motivation. The quantitative improvements in test scores are corroborated by qualitative insights into classroom behavior and attitudes, indicating that these applications foster a more interactive and motivating learning environment.

However, a contrast arises in the frequency and consistency of applications usage. Quantitative data revealed varied levels of engagement, with some students showing consistent use while others struggled due to infrastructural constraints. Qualitative data further explained these inconsistencies, citing unreliable internet access and limited device availability as major barriers. This contrast highlights that while overall positive impacts are evident, they are not uniformly experienced by all students due to external factors.

Another point of contrast is the challenges faced by students and teachers, which were not fully captured by quantitative measures. Qualitative data revealed detailed barriers such as frequent power outages, lack of training and technical support issues. These insights suggest that despite positive quantitative outcomes, significant challenges remain that hinder the consistent application of mobile learning tools. Addressing these barriers is crucial for enhancing the effectiveness observed in the quantitative findings.

4.5.2 Triangulation

Triangulation of data from different sources strengthens the reliability and validity of the research findings. The alignment between quantitative improvements in test scores and qualitative reports of enhanced understanding and engagement reinforces the overall validity of the results. Quantitative measures provided a numerical basis for application effectiveness, while qualitative data offered contextual insights into how these improvements manifest in classroom behavior and student attitudes. The consistency between these data sources supports the robustness of the findings, confirming that the observed improvements are reflective of meaningful changes in student learning experiences.

4.5.3 Mixed Methods Insights

The mixed methods approach provides a comprehensive understanding of the impact of mobile learning applications. Quantitative data shows measurable benefits, such as improved academic performance and engagement, while qualitative data offers context, detailing how these applications affect student attitudes and behaviors. This synthesis not only highlights the effectiveness of the applications but also uncovers the conditions and factors influencing their implementation.

The combination of quantitative evidence and qualitative insights also identifies infrastructural needs that affect the implementation of mobile learning tools. While the quantitative data indicates overall effectiveness, qualitative findings reveal challenges such as internet connectivity and device access. This insight underscores the necessity for targeted interventions to address these barriers and maximize the potential benefits of mobile learning applications.

Finally, the integration of these findings provides guidance for future research and practice. The positive outcomes evidenced by quantitative measures and the contextual understanding from qualitative data inform practical recommendations for improving mobile learning applications. Future research can build on these insights by exploring strategies to overcome identified challenges and enhance the effectiveness of mobile learning in similar educational settings.

4.6 Chapter summary

This chapter dealt with the presentation an analysis of data for the current study. It encompassed both quantitative data and qualitative insights from teacher interviews. The research highlighted sporadic application usage due to infrastructural challenges like limited device availability and unreliable internet connectivity. Despite these obstacles, teachers demonstrated positive experiences when integrating applications like GeoGebra and Kahoot!, noting improvements in student engagement and comprehension. Students similarly reported enthusiasm, especially with gamified applications such as DragonBox and Prodigy Math Game. The chapter concluded with recommendations for enhancing infrastructure and providing targeted training to maximize app efficacy in the educational setting.

CHAPTER 5

SUMMARY, DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter provides a comprehensive synthesis of the research findings, offering a concise summary of the key insights from the study. It further presents the discussion and conclusions drawn from the data analysis, highlighting the implications for mathematics education in rural Nyanga, Zimbabwe. The chapter concludes with practical recommendations aimed at enhancing the integration and effectiveness of mobile learning applications in this educational context. Additionally, it suggests areas for further research to continue advancing the field and addressing the challenges identified.

5.1 Chapter summaries

Chapter 1 introduces the research focus on mobile learning applications in mathematics education within rural Nyanga, Zimbabwe. It outlines the background, objectives, and significance of the study, highlighting the context-specific challenges and opportunities.

Chapter 2 reviews existing literature on mobile learning applications and their impact on mathematics education globally. It explores various theoretical frameworks and empirical studies related to app usage, educational outcomes, and factors influencing adoption in similar rural and educational contexts.

Chapter 3 details the research methodology employed, including the research design, sampling strategy, data collection methods (interviews and pre-test and post test) and data analysis techniques (thematic analysis and quantitative analysis). It discusses ethical considerations and limitations encountered during the research process.

Chapter 4 presents the findings from both qualitative and quantitative data collected from teachers and students. It examines the usage patterns of mobile learning applications, impacts observed on learning outcomes, challenges faced in implementation and insights into the integration and support structures needed.

5.2 Discussion of Results

The findings of this study highlight both the potential and the challenges of integrating mobile learning applications into mathematics education in a rural setting like Nyanga. The discussion section delves into these findings, comparing them with existing literature, exploring their implications and considering the broader educational context.

5.2.1 To investigate the usage patterns of mobile learning applications by teachers and students in Nyanga, Zimbabwe

The study revealed that while teachers and students have some exposure to mobile learning applications, their usage is limited by factors such as lack of devices, unreliable internet connectivity, and frequent power outages. GeoGebra, Kahoot!, Desmos, DragonBox, and Mathway are among the applications used, with varying frequency and context.

5.2.2 To assess the impact of mobile learning applications on students' mathematics learning outcomes.

The analysis of both qualitative and quantitative data reveals a significant positive impact of mobile learning applications on students' mathematics learning outcomes. Teachers reported that applications like GeoGebra and Desmos enhanced students' understanding by visualizing abstract concepts, while gamified tools like DragonBox and Prodigy Math Game increased student engagement and confidence. This was corroborated by the quantitative data, which showed a notable improvement in post-test scores compared to pre-test scores, indicating that mobile learning applications effectively support problem-solving abilities. Additionally, student feedback highlighted that these applications not only facilitated a better grasp of mathematical ideas but also made learning more enjoyable and motivating.

5.2.3 To identify challenges and barriers to the effective integration of mobile learning applications in the classroom

The challenges identified in the study were primarily reported through interviews with teachers and students. Key issues included unreliable internet connectivity, which disrupted the use of mobile learning applications; insufficient access to devices, limiting students' ability to engage with the technology; and frequent power outages, which hindered the continuity of lessons. Additionally, a lack of formal training for teachers on how to integrate these applications effectively into their teaching and align them with the curriculum was noted as a significant barrier.

5.2.4 To explore the support structures and training needed for teachers to effectively use mobile learning applications

Teachers expressed the need for comprehensive training on mobile learning applications and ongoing technical support. Professional development opportunities and support from school administrations are crucial to enhance teachers' capabilities to integrate these tools effectively into their teaching practices.

5.3 Comments

5.3.1 Usage Patterns and Accessibility

The study revealed that, despite some exposure to mobile learning applications, the actual usage among teachers and students in Nyanga is limited by significant infrastructural barriers. This aligns with previous research indicating that rural areas often struggle with inadequate technological resources, as noted by Unwin (2005), who found similar challenges in other rural African contexts. The limited access to devices and unreliable internet connectivity reflect a broader digital divide that disproportionately affects rural students, limiting their educational opportunities compared to their urban counterparts.

5.3.2 Impact on Learning Outcomes

The positive impact of mobile learning applications on students' mathematics performance in Nyanga, particularly in terms of engagement and understanding of abstract concepts, is consistent with global studies on educational technology. For example, Hohenwarter & Lavicza (2007) demonstrated that visual and interactive tools like GeoGebra significantly enhance students' comprehension of complex mathematical ideas. The improvement in post-test scores in this study further supports the argument that technology, when effectively integrated, can lead to meaningful learning gains.

However, the reliance on external devices and internet connectivity suggests that these benefits might not be sustainable without addressing the infrastructural challenges. This echoes concerns raised by Miller (2018), who argued that without robust support systems, the positive effects of mobile learning could be short-lived.

5.3.3 Challenges in Integration

The challenges identified, such as insufficient training for teachers and lack of alignment with the local curriculum, are critical barriers to the effective use of mobile learning applications. This study's findings align with those of Ertmer and Ottenbreit-Leftwich (2010) who pointed out that teacher readiness is a key factor in the successful adoption of educational technology. In Nyanga, the lack of structured training not only limits teachers' ability to fully utilize these tools but also exacerbates existing educational inequalities.

Moreover, the study's participants highlighted the need for applications that are tailored to the local educational context. This suggests a gap in the current market offerings, which often prioritize global applicability over local relevance. The discussion by Gay (2010) on culturally relevant pedagogy point out the importance of localized content to ensure that technology resonates with students' lived experiences.

5.3.4 Implications for Educational Policy and Practice

The study's findings have significant implications for educational policy and practice in Zimbabwe, particularly in rural areas. The identified need for improved infrastructure, comprehensive teacher training and curriculum-aligned mobile learning applications suggests that a multi-faceted approach is necessary to fully realize the potential of mobile learning. This calls for coordinated efforts between government bodies, educational institutions and private sector stakeholders to create an enabling environment for technology integration.

Furthermore, the discussion extends to the broader impact on educational equity. Ensuring that rural students have the same access to high-quality educational tools as their urban peers is crucial for bridging the educational divide. This study contributes to the growing body of evidence that targeted interventions in infrastructure and teacher support can lead to substantial improvements in educational outcomes.

5.4 Conclusion

Research Question 1: What is the impact of integrating mobile learning applications on the problem-solving abilities of secondary school students in Nyanga?

The study demonstrates that integrating mobile learning applications, such as GeoGebra and Desmos, significantly improves students' mathematical problem-solving abilities. Quantitative analysis of pre-test and post-test scores reveals a marked increase in mean scores, indicating that these applications enhance students' conceptual understanding and problem-solving skills. This finding is supported by qualitative feedback from both teachers and students, who report that the visualization features of these tools help in grasping complex mathematical concepts, leading to better problem-solving outcomes.

Research Question 2: What are the perceptions of mathematics teachers in Nyanga regarding the effectiveness of mobile learning applications in supporting student learning?

Mathematics teachers in Nyanga perceive mobile learning applications as effective tools for enhancing student learning. Teachers noted that applications like GeoGebra and Desmos facilitate the visualization of abstract concepts, making it easier for students to understand and apply mathematical principles. Additionally, gamified tools such as DragonBox and Prodigy Math Game have been credited with increasing student motivation and confidence. However, teachers also expressed concerns about the lack of structured training and technical support, which hampers their ability to fully integrate these technologies into their teaching practices.

Research Question 3: How does the academic performance outcomes of students using mobile learning applications compare to those following traditional instruction methods?

The study finds that students using mobile learning applications perform better academically compared to those following traditional instruction methods. The improvement in pre-test and post-test scores suggests that mobile learning tools contribute to a deeper understanding of mathematical concepts and more effective problem-solving strategies. This aligns with teacher and student feedback, which highlights the enhanced engagement and comprehension facilitated by these applications. The data suggest that mobile learning applications provide a more interactive and engaging learning experience than traditional methods.

Research Question 4: What are the long-term challenges and barriers associated with incorporating mobile learning applications into mathematics education for student learning outcomes and educational practices in Nyanga, Zimbabwe?

Despite the positive impact on student performance, the study identifies several persistent challenges that hinder the full integration of mobile learning applications. Key barriers include inconsistent access to digital devices, unreliable internet connectivity, and frequent power outages, which disrupt the learning process and limit the effectiveness of these tools. Teachers also pointed out the need for ongoing professional development and technical support, as the lack of structured training limits their ability to utilize mobile learning applications effectively. These challenges highlight the need for targeted interventions, including investments in technological infrastructure and the development of supportive educational policies, to ensure the sustainable and effective use of mobile learning applications in rural contexts like Nyanga

5.5 Limitations

While this study provides valuable insights into the integration of mobile learning applications in mathematics education within rural Nyanga, Zimbabwe, several limitations should be acknowledged:

Sample Size and Generalizability: The study's sample size was limited to a specific number of schools and students in Nyanga. As a result, the findings may not be generalizable to other rural or urban settings in Zimbabwe or similar contexts. A larger and more diverse sample could provide a more comprehensive understanding of the impact and challenges of mobile learning applications as suggested by Creswell (2014).

Infrastructural Constraints: The study was conducted in an environment with significant infrastructural barriers, including unreliable internet connectivity, frequent power outages, and limited access to devices. These constraints may have influenced the effectiveness of mobile learning applications and the participants' experiences. This is in tandem with Unwin, Kleessen, Hollow, Williams, Oloo, Alwala, Mutimucuio, Eduardo, and Muianga, (2010) who highlights the infrastructural challenges faced in African contexts, such as unreliable internet connectivity and power outages, which can significantly affect the implementation and outcomes of technology-enhanced learning initiatives. Future research could benefit from exploring settings with more stable infrastructure to compare findings.

Data Collection Methods: The study relied on a combination of qualitative and quantitative data, including surveys and interviews. While this approach provides a broad view of the research problem, it may not fully capture the nuanced experiences of all participants. For example, self-reported data from teachers and students might be subject to bias or inaccuracies. Complementing these methods with observational data or longitudinal studies could enhance the depth of understanding.

Technological Variability: The research focused on specific mobile learning applications, such as GeoGebra, Kahoot!, and DragonBox. The effectiveness and usability of other applications or newer technologies were not assessed. Future studies could examine a broader range of tools to provide a more holistic view of the technological landscape.

Training and Support: The study identified a lack of structured training and technical support as significant barriers. However, the research did not assess the effectiveness of various training programs or support models. Investigating different approaches to teacher training and support could offer insights into how to overcome these barriers more effectively.

Curriculum Alignment: The research highlighted the need for mobile learning applications to be better aligned with the local curriculum. Thus was highlighted by Pachler, Bachmair and Cook (2010). However, the current study did not explore how different levels of curriculum alignment might impact learning outcomes. Future research could investigate the specific ways in which curriculum alignment influences the effectiveness of mobile learning applications.

Contextual Factors: The study was conducted in a specific rural context, which may have unique characteristics influencing the results. Factors such as local educational policies, community attitudes toward technology, and socioeconomic conditions could affect the findings. Exploring similar studies in diverse contexts could provide a more comprehensive understanding of the challenges and benefits of mobile learning applications.

Acknowledging these limitations provides a foundation for future research to build upon and address the gaps identified in this study. By considering these factors, researchers can develop more robust strategies and interventions to support the effective integration of mobile learning applications in diverse educational settings.

5.6.0 Recommendations

The study recommends as follows:

5.6.1 Improve Infrastructure

To enhance the effectiveness of mobile learning applications in schools, it is crucial to ensure reliable electricity and internet access, provide sufficient devices like tablets and smart phones for student use and develop offline versions of these applications to address connectivity issues.

5.6.2 Enhance Teacher Training

To support the effective integration of mobile learning applications in mathematics education, it is essential to conduct comprehensive training sessions for teachers, provide ongoing professional development and technical support and foster peer collaboration and knowledge sharing on effective application usage.

5.6.3 Support from Educational Authorities

The findings from the study underscore the need for supportive policies and resource allocation to address the challenges faced in integrating mobile learning applications in Nyanga's schools. The study highlights inadequate infrastructure, including unreliable electricity and internet access and insufficient devices as major barriers. To overcome these issues, implementing policies that endorse the use of mobile learning tools, allocating specific funds for technology integration and fostering partnerships with NGOs and the private sector can provide the necessary resources and support. This strategic approach aligns with the study's findings by directly addressing the identified challenges, thus facilitating more effective integration of digital tools and improving overall educational outcomes.

5.6.4 Application Development and Adaptation

The findings of the study emphasize the need for mobile learning applications to be better aligned with the local curriculum and educational standards in Zimbabwe. Developing or adapting these applications to meet specific curricular requirements and ensuring they are user-friendly for both teachers and students can address current challenges. Moreover, incorporating features that cater to diverse learning styles and levels of understanding will enhance the accessibility and effectiveness of these tools, directly addressing the concerns raised by participants about the relevance and usability of existing applications.

5.6.5 Parental and Community Involvement

The research underscores the importance of involving both parents and the community in the effective deployment of mobile learning applications. By educating parents and local stakeholders about the advantages of these tools and encouraging them to support their children's access to technology, schools can address barriers like limited resources. Raising awareness about the critical role of technology in contemporary education will also contribute to more successful integration and utilization of mobile learning applications in Nyanga.

5.6.6 Monitor and Evaluate

To ensure the continued success of mobile learning applications, it is crucial to regularly evaluate their impact on student performance and engagement. Gathering consistent feedback from both teachers and students will help pinpoint areas needing improvement. This ongoing assessment process will enable the refinement and enhancement of integration strategies, leading to more effective use of these applications in educational settings.

5.6.7 Localized Content

Developing content in local languages and incorporating culturally relevant examples into mobile learning applications is crucial for enhancing their effectiveness, as evidenced by the findings in the study. The research highlighted that, students in Nyanga benefit from educational tools that resonate with their cultural context and language. Tailoring applications to reflect local educational standards and incorporating examples familiar to the students significantly improves engagement and understanding, addressing the challenge of limited relatability and making the learning experience more effective.

5.6.8 Resource Allocation

Providing schools with necessary funds for purchasing and maintaining technological resources, and ensuring equitable distribution, especially in underserved rural areas, directly addresses the challenges identified in the findings. The study noted that inadequate access to devices and unreliable infrastructure hindered the effective use of mobile learning applications in Nyanga. Allocating targeted financial resources and ensuring that these resources are equitably distributed can help overcome these barriers, thereby enhancing the accessibility and effectiveness of technology in rural education settings.

5.7 Suggestion for further studies

Future studies could explore the long-term impact of mobile learning applications on students' mathematical proficiency and overall academic performance in rural settings. Research could examine the effectiveness of specific application features, such as gamification and interactive simulations, in enhancing problem-solving skills and engagement. Comparative studies between rural and urban schools could identify unique challenges and advantages in different contexts. Investigating the role of teacher training and support in the successful integration of technology in classrooms would provide valuable insights. Additionally, exploring the potential of localized content and applications designed for offline use could address infrastructure limitations. Longitudinal studies could track progress over several years to assess the sustainability and evolution of mobile learning integration in mathematics education.

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Appendix A : APPROVAL LETTER

SAMED

P Bag 1020
BINDURA
ZIMBABWE

Tel: 0271 - 7531 ext 1038
Fax: 263 - 71 - 7616

BINDURA UNIVERSITY OF SCIENCE EDUCATION

Date: 01/08/24

TO WHOM IT MAY CONCERN

NAME: BININGU BORNWELL REGISTRATION NUMBER: B1234287

PROGRAMME: MScEd Mathematics PART: 2.1

This memo serves to confirm that the above is a bona fide student at Bindura University of Science Education in the Faculty of Science Education.

The student has to undertake research and thereafter present a Research Project in partial fulfillment of the Master of Science Education programme. The research topic is: Exploring the integration of mobile learning applications among secondary level mathematics students

In this regard, the department kindly requests your permission to allow the student to carry out his/her research in your institutions.

Your co-operation and assistance is greatly appreciated.

Thank you

BINDURA UNIVERSITY OF SCIENCE EDUCATION
DEPARTMENT OF EDUCATIONAL FOUNDATIONS
9 APR 2024
P. BAG 1020
BINDURA

Z Ndemo (Dr.)
CHAIRPERSON - SAMED

APPENDIX B: INTERVIEW GUIDE FOR LEARNERS

Introduction

1. Introduce yourself and explain the purpose of the interview.

2. Ensure the student understands that their participation is voluntary and that their responses will be kept confidential.

Background Information

3. Can you tell me about your experience with using mobile learning apps for learning mathematics?

4. How do you feel about using mobile learning applications, Photomath, Desmos, Mathway etc, to learn mathematics?

Use and Impact of Mobile Learning Applications

5. How often do you use mobile learning apps to study mathematics?

6. Can you describe a specific instance where you used a mobile learning app to solve a mathematics problem?

7. How do you think mobile learning apps have helped you improve your problem-solving skills in mathematics?

Engagement and Motivation

8. Do you feel more engaged or motivated to learn mathematics when using mobile learning apps? Why or why not?

9. Have you noticed any changes in your attitude towards mathematics since using mobile learning apps?

Challenges and Preferences

10. What challenges, if any, have you encountered when using mobile learning apps to learn mathematics?

11. Are there any specific types of mobile learning apps or features that you find most helpful for learning mathematics?

Future Recommendations

12. Based on your experience, what improvements or enhancements would you suggest for mobile learning apps to better support your learning of mathematics?

13. How do you think mobile learning apps could be used more effectively in mathematics education?

Conclusion

14. Is there anything else you would like to share about your experience with using mobile learning apps for learning mathematics?

Closing

15. Thank the student for their time and participation in the interview.

16. Clarify any follow-up steps or information that may be needed.

APPENDIX C: INTERVIEW GUIDE FOR TEACHERS

Introduction

- Greet the participant and introduce yourself.
- Explain the purpose of the interview and the research study.
- Assure confidentiality and seek consent to record the interview.

Section 1: Background Information

1. Can you please tell me about your teaching experience and your background in mathematics education?

   - Number of years teaching
   - Educational qualifications
   - Current teaching position and school

2. How familiar are you with mobile learning apps?

   - Types of apps used
   - Frequency of use

Section 2: Integration of Mobile Learning Apps

3. Can you describe how you integrate mobile learning apps into your mathematics lessons?

   - Specific apps used
   - Types of activities (virtual manipulatives, simulations, gamified activities)
   - Frequency of integration

4. What are the main objectives when you use mobile learning apps in your teaching?

   - Enhancing problem-solving skills
   - Engaging students
   - Supplementing traditional methods

5. How do you select the mobile learning apps that you use in your classroom?

   - Criteria for selection (alignment with curriculum, ease of use, student engagement)

Section 3: Impact on Students

6. What impact have you observed on students' problem-solving skills since you started using mobile learning apps?

   - Specific improvements
   - Examples or anecdotes

7. How do students generally respond to using mobile learning apps in their mathematics lessons?

- Engagement and motivation
- Feedback from students

8. Are there particular groups of students who benefit more from using mobile learning apps?
   - Differences based on skill level, interest, or other factors

Section 4: Challenges and Barriers

9. What challenges have you faced in integrating mobile learning apps into your teaching?
   - Technical issues (device availability, internet connectivity)
   - Pedagogical challenges
   - Student-related issues (access, familiarity with technology)

10. How do you overcome these challenges?
    - Strategies and solutions implemented

Section 5: Support and Training

11. What kind of support or training have you received for using mobile learning apps?
    - Professional development opportunities
    - Support from school administration

12. What additional support or resources would help you better integrate mobile learning apps into your teaching?
    - Training needs
    - Technological resources

Section 6: Recommendations and Future Directions

13. What recommendations do you have for improving the use of mobile learning apps in mathematics education?
    - For teachers
    - For school administrators
    - For app developers

14. What future developments or features would you like to see in mobile learning apps to better support mathematics education?

Conclusion:

- Thank the participant for their time and insights.
- Ask if they have any additional comments or questions.

- Reiterate the confidentiality of their responses and explain the next steps in the research.

APPENDIC D: COMPLETED INTERVIEW FOR LEARNER

Student 'J'

Dt: / /
Page No.:

Background information

I have been using mobile learning apps since last year but not so often. After they were introduced to the whole class last month I started to use them more often.

Use and impact to mobile learning apps

I use these apps whenever I do my homework or don't understand something in class. Wolfram Alpha helps me with complex problems and Edmodo let me do assignments online. These apps have improved my problem solving skills alot.

Engagement and motivation

I'm more engaged because the apps are easy to use and help me learn at my pace. Edmodo's quizzes are fun and Wolfram Alpha's solutions are really detailed.

Challenges and preferences

The main challenge is not having internet at home & mobile data is expensive. I have to use the school's computers when I can. However the internet is very slow due to congestion. I like Edmodo because it lets me see my grades and do home work online.

Future recommendation

Edmodo will be extensively helpful if it can work without internet so I can do do assignments at home. Schools should provide more devices and teach us how to use these apps better.

APPENDIX E: COMPLETED INTERVIEW FOR TEACHER

Teacher 'B'

Dt: / /

Page No:

Background information.

I have been teaching mathematics for 10 years currently stationed at a rural secondary school in Nyanga. I have a diploma in education currently pursuing a Degree in Mathematics education. I teach Form 1 & 3.

Integration of mobile learning apps

I try to integrate mobile learning apps where possible, but its challenging, because not all students have access to the necessary devices. I often use Kahoot! for quizzes when we have access to the school's tablet. Its a great tool for reviewing topics and making learning more engaging.

Impact on students

- Students are more engaged and motivated when we use Kahoot. They enjoy the competitive element and the instant feedback on their answers. I have noticed they are more enthusiastic about revising for quizzes and show a better understanding of the material

Challenges & Barriers

Lack of reliable internet devices is a ~~disaster~~ significant barrier. Many students come from low-income families and cant afford smart phones or tablets. Additionally we experience perential power outages which disrupt the our use of technology in the classroom.

Support and training

We haven't recieved much formal training on how to use mobile learning apps. Most of what I know comes from my own exploration and occassional workshops offered by the ministry of education. More comprehensive training and technical support would be very helpful

Recommendations & Future directions

I think mobile learning apps have great potential but for them to be effective in Nyanga we need better infrastructure & more support from government. Schools should be provided with necessary devices, reliable internet and backup power. It would be also be beneficial if the apps were available in local languages to make them more accessible to all students and enhance their understanding.

APPENDIX F: PRE-TEST ITEMS

Section A (40 marks).

Answer **all** questions in this section.

1 **(a)** Simplify $\frac{3^{2x-3}.81^{x+\frac{1}{2}}}{27^x}$. [3]

(b) Hence or otherwise solve the equation

$$\frac{3^{2x-3}.81^{x+\frac{1}{2}}}{27^x} = \frac{1}{5^{x-1}}$$

giving the answer in exact form. [4]

2 **(a)** Show that 1 is a root of the polynomial $Q(x) = 2x^3 + 3x^2 - 4x - 1$. [2]

(b) Hence find the polynomial $P(x)$ such that $Q(x) = (x-1)P(x)$ [3]

(c) **(i)** Express $P(x)$ in the form $A(x+B)^2 + C$. [3]

(ii) Hence state the minimum value of $P(x)$. [1]

3 The curved surface area, A of a cylindrical drum varies jointly as its circular base diameter d, and its height l. Given that the curved surface area of the drum is $2.64m^2$ when its base radius is 0,35m and its height is 1.2m,

(a) find the relationship between A, d and l, [5]

(b) calculate the radius of a cylinder whose surface area is $14{,}52m^2$ and height is 3m to 2 decimal places. [4]

4 Given that $f(x) = kx^2 + 3x + 3$ and $g(x) = kx + 7$, find the range of values of k for which $f(x) = g(x)$ has two distinct solutions. [5]

5 **(a)** Given that $2x^3 + ax^2 + x - 3 \equiv (bx^2 + c)(x-3)$, find the constants a, b and c. [4]

(b) Hence express $\frac{1+6x}{2x^3+ax^2+x-3}$ in partial fractions. [6]

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Section B (80 marks)

Answer any **five** questions from this section. Each question carries **16** marks.

6 Functions $f(x)$, $t(x)$ and $h(x)$ are defined by

$f(x) = 12x + 20$
$t(x) = e^x$
$h(x) = 2x + 3.$

(a) **(i)** Find $th(x)$. [1]

(ii) On the same axes, sketch the graphs of $y = f(x)$ and $y = th(x)$. [5]

(b) Calculate by integration the area between the graph of $y = f(x)$, $y = th(x)$ and the lines $x = -1.5$ and $x = 0$. [3]

(c) **(i)** Estimate the area in **(b)** using the trapezium rule with 4 ordinates. [4]

(ii) Calculate the relative error made in estimating the area in **(b)** using the trapezium rule. [3]

7 **(a)** Prove the Identity $\frac{2\,Cot\,2\theta}{1-Tan^2\theta} \equiv Cot\,\theta$. [4]

(b) Hence or otherwise solve the equation $\frac{2\,Cot\,2\theta}{1-Tan^2\theta} = 2\,Cosec^2\theta - 1$, for θ in the range $0° \le \theta \le 360°$. [12]

8 Matrices A and B^{-1} are given by

$$A = \begin{pmatrix} 1 & 2 & 1 \\ x & 1 & x+1 \\ 2 & x-2 & 0 \end{pmatrix}, x > 0$$

$$B^{-1} = \frac{1}{8}\begin{pmatrix} 1 & -1 & 1 \\ 2 & 1 & 0 \\ 1 & 0 & 3 \end{pmatrix}$$

(a) Calculate the value of x given that the determinant of A is equal to 13 [5]

(b) Hence find

(i) A^{-1}. [7]

(ii) $(AB)^{-1}$. [4]

9 The sum of n terms of a sequence, S_n is given by

$$S_n = \frac{n}{4}(5 - n), \text{ for } n = 1; 2; 3 \ldots.$$

(a) Find the second and third terms of the sequence. [4]

(b) Hence or otherwise, find the general term of the sequence in term of n. [3]

(c) Calculate the number of terms needed for the Sum, S_n, to be equal to -9. [5]

(d) Find the range of value of n for which $S_n > 0$. [4]

10 A quadrilateral ABCD has vertices at points A(-1;1); B(3;7); C(4;2) and D(2; −1), respectively.

(a) Find the equation of line AB. [4]

(b) Show that line AB is perpendicular to line AD. [4]

(c) Find the equation of a circle with center at point D and radius CD in the form $x^2 + y^2 + ax + by = c$ where a, b and c are constants. [5]

(d) Show that the circle in (c) passes through point A. [2]

(e) Explain why line AB is a tangent to the circle in (c). [1]

11 Triangle ABC has vertices with position vectors $\boldsymbol{i} + 2\boldsymbol{j} + 2\boldsymbol{k}$, $2\boldsymbol{i} + 5\boldsymbol{j} - 2\boldsymbol{k}$ and $5\boldsymbol{i} + 4\boldsymbol{j} + \boldsymbol{k}$ respectively.

Find

(a) $\overrightarrow{AC}$, [2]

(b) the cartesian equation of line AC, [4]

(c) (i) the perpendicular distance of point B from line AC, [8]

(ii) the area of triangle ABC. [2]

12 (a) Express $g(x) = \frac{4x+5}{2(x+1)}$ in the form $A + \frac{B}{2(x+1)}$, where A and B are constants. [2]

(b) With the aid of diagrams, in each case, illustrate the transformations which maps the graph of $y = \frac{1}{x}$ on to the graph of $y = g(x)$. [10]

(c) Find the inverse of $g(x)$ and state its domain. [4]

APPENDIX G: POST –TEST ITEMS

2

Section A (40 marks).

Answer **all** questions in this section.

1 Solve the inequality

$|2x - 3| < x - 5.$ [4]

2 **(a)** Prove the identity
$cosec\ 2\theta + cot\ 2\theta \equiv cot\ \theta.$ [3]

(b) Hence or otherwise solve the equation
$cosec\ 2\theta + cot\ 2\theta = 0,5$, for $0 \leq \theta \leq 2\pi$, giving the answer to 2d. p [4]

3 **(a)** Find the value of x given that $3^{x+2} = \frac{1}{81}$. [3]

(b) Solve the equation.
$3(2^{2x}) - 7(2^x) + 2 = 0$ [5]

4 Given that $-m, n$ and 1 are any consecutive terms of a geometric progression and 1, n and m are the first three terms of an arithmetic progression,

(a) show that $n^2 + 2n = 1$, [5]

(b) hence or otherwise find the exact value of m if n is positive. [4]

5 **(a)** Show that the set $\{0,1,2,3\}$, forms a group under addition modulo 4. [7]

(b) Show that group is abelian. [2]

(c) Write down the subgroups of the group. [2]

(d) State the order of the group. [1]

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Section B (80 marks)

Answer any **five** questions from this section. Each question carries **16** marks.

6 Functions h and g are defined by

$h: x \longmapsto \frac{1}{2}x - 4, \qquad x \in \mathbb{R}$

$g: x \longmapsto \frac{32}{4-x^2} \qquad x \in \mathbb{R}\ x \neq k.$

(a) Find

(i) the possible values of k, [3]

(ii) the values of x for which $hg(x) = 0$, [3]

(iii) $h^{-1}(x)$. [3]

(b) On the same axes sketch the graphs of $y = h(x)$ and $y = h^{-1}(x)$ showing clearly the relationship between the graphs. [3]

(c) Describe completely the sequence of transformation which map the graph $y = \frac{1}{x^2}$ onto $y = \frac{32}{4-x^2}$. [4]

7 A curve has the equation $y = x^2 - xy$ and passes through the point $P\left(1; \frac{1}{2}\right)$

(a) Find the equation of the tangent to the curve at P. [6]

(b) Hence or otherwise show that the equation of the normal to the curve at P intersects the curve again at $\left(-\frac{11}{14}\,;\,\frac{121}{42}\right)$. [8]

(c) Find the distance between the two points $\left(1\,;\,\frac{1}{2}\right)$ and $\left(-\frac{11}{14}\,;\,\frac{121}{42}\right)$. [2]

8 The vector equations of the lines n and m, and the plane π_1, are

$$\boldsymbol{r} = \begin{pmatrix} 4 \\ -3 \\ 7 \end{pmatrix} + \mu \begin{pmatrix} -1 \\ 2 \\ 1 \end{pmatrix},$$

$$\boldsymbol{r} = \begin{pmatrix} 0 \\ 10 \\ 7 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ 3 \\ 2 \end{pmatrix} \text{ and}$$

$$\boldsymbol{r} \cdot \begin{pmatrix} 3 \\ 2 \\ -1 \end{pmatrix} = -1$$ respectively where μ and λ are parameters.

[Turn over

The line m intersects the plane π_1, at a point P.

(a) Show that the line n lies in the plane π_1, [2]

(b) **(i)** Find the coordinates of point P. [4]

(ii) Hence or otherwise find the vector equation of the plane π_2 passing through point P and perpendicular to the line n. [3]

(c) **(i)** Find the point of intersection of the line n and the plane π_2 [4]

(ii) Hence or otherwise show that the vector equation of the line through point P which lies in plane π_1 and is perpendicular to line n is; $\boldsymbol{r} = \begin{pmatrix} -2 \\ 4 \\ 3 \end{pmatrix} + t\begin{pmatrix} 2 \\ -1 \\ 4 \end{pmatrix}$ [3]

9 **(a)** **(i)** Find the first 3 terms of the Maclaurin series in the expansion of $ln\,(5 + x)$. [3]

(ii) Write down the first 3 terms of the Maclaurin series in the expansion of $ln\,(5 - x)$. [1]

(iii) Hence or otherwise show that when x is small $ln\left(\frac{5+x}{5-x}\right) \approx \frac{2x}{5}$. [2]

(b) **(i)** Prove by mathematical induction that

$$\frac{d^n}{dx^n}(x^m) = \frac{m!}{(m-n)!}.x^{m-n}$$

for all $n \in Z^+$ [8]

(ii) Hence find $\frac{d^4}{dx^4}(x^5)$. [2]

10 Given the complex numbers
$z_1 = 2$ and $z_2 = 2 + 2i$,

(a) **(i)** express z_2 in the form $r(Cos\theta + isin\theta)$, [3]

(ii) hence or otherwise, express the complex number $\frac{z_1}{z_2}$ in polar form. [3]

(b) Describe fully the locus represented by Re $\frac{z+3}{z-3} = 0$ given that z is a complex number $x + iy$. [4]

(c) By using de Moivres theorem or otherwise, find the roots of the equation, $z^4 + 4 = 0$ [6]

11 It is given that $\mathbf{A} = \begin{pmatrix} 3 & -1 & 2 \\ 1 & -1 & 0 \\ -2 & 4 & -3 \end{pmatrix}$ and $\mathbf{B} = \begin{pmatrix} 3 & -1 \\ 2 & 2 \end{pmatrix}$.

(a) A line with the equation $y = 2x - 3$ is transformed under the transformation matrix B. Show that the equation of its image is $y - 6x + 24 = 0$. [5]

(b) Evaluate A^{-1}. [7]

(c) Hence or otherwise solve the following simultaneous equations. [4]

$$3x - y + 2z = 1$$
$$x - y = 2$$
$$-2x + 4y - 3z = 3$$

12 **(a)** A learner used the value of π as $\frac{22}{7}$ to calculate the volume of a sphere of radius 8 cm.

Find correct to 3 decimal places the

(i) absolute error involved,

(ii) percentage error involved. [5]

(b) **(i)** Sketch on the same axes the graphs of $y = ln\ 2x$ and $y = x - 1$ and state the number of real roots for the equation $ln\ 2x = x - 1$.

(ii) Show that a root of the equation $ln\ 2x = x - 1$ lies between 0.2 and 0.3.

(iii) Using 0.2 as the first approximation, use the Newton Raphson method twice to obtain an approximation to the root correct to 3 decimal places. [11]