EXPLORING SENIOR PHASE TEACHERS' USE OF KAHOOT! GAMIFICATION AS A FORMATIVE ASSESSMENT TOOL TO SCAFFOLD MATHEMATICAL UNDERSTANDING.

by

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Abstract

In South Africa, digital technology, particularly gamification, continues to become an important teaching and learning tool. Its importance lies in scaffolding mathematical understanding, improving the quality of assessment, and developing twenty-first-century technological skills for effective mathematics assessment. To explore this importance, senior phase mathematics teachers are encouraged to adopt gamification technology such as Kahoot! in assessment. The study adopted a case study research design with a interpretivist research paradigm, as this method allows detailed exploration and understanding of a specific context through a close connection with the participants. Data was collected using semi-structured questionnaires, focus group interviews, non-participant observations, and reflective journals. The research involved ten purposively selected senior-phase mathematics teachers from two schools in the Sarah Baartman District, Eastern Cape Province, South Africa. The study drew upon Vygoysky's Sociocultural Theory for its theoretical framework, while the Technological, Pedagogical, and Content Knowledge was used for analysis. The data analysis pursued an inductive approach. Adopting a thematic analysis included coding participant responses, organizing codes into concepts and categories, and developing a theoretical framework from the resultant categories.

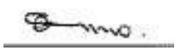
A four-phase process was involved: coding, conceptualizing, categorizing, and theorizing, was employed. This process and using NVivo software for data organization and management helped identify patterns, themes, and significant concerns surrounding the study's core subject. The findings from the study were as follows: Firstly, it was revealed that most teachers have a positive perception and attitude towards using Kahoot! for formative assessment, believing that it enhances teaching and learning quality. However, they showed scepticism due to insufficient Information and Communication Technologies knowledge and training. Second, teachers' pedagogical and technological experiences were predominantly enjoyable. Kahoot! was accepted as beneficial for promoting collaboration, interaction, and immediate feedback. Third, the study identified enabling and constraining factors in using Kahoot! for formative assessment. The enabling factors include Kahoot!, which was convenient and accessible, promoted immediate feedback and fostered collaboration and interaction. The constraining factors include Information and Communication Technologies and network interference, which posed limitations. The research concluded that Kahoot! as a platform for formative assessment indeed scaffold mathematical understanding. The study recommends increasing teachers' access to educational technology, incorporating continuous professional development programs, providing subject-specific training, and encouraging teachers to adapt to emerging technologies. The study also provided recommendations for future research to explore learner perceptions, employ a mixed methods approach to help quantify learner performance and investigate the pedagogical and technological experiences of senior phase mathematics teachers regarding formative assessment.

Keywords: Formative assessment, Gamification, Mathematical understanding, Mathematics Education, Scaffolding, Technology integration

Declaration

I, Silence (Learner Number: 13B7924), declare this thesis: Exploring senior phase teachers' use of Kahoot! Gamification as a formative assessment tool to scaffold mathematical understanding , is my own work and written in my own words. Where I have drawn upon the words or ideas of others, I have indicated and acknowledged the authors by means of complete references.

Silence Balele



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March 2023

Dedication

This thesis is dedicated to the loving memory of my late:

- father Luckson Langalibalele Dlomo, who never had the opportunity to study yet believed in education,
- son Sean,
- and my late brother Obedience, with whom I had planned and hoped to set new family academic heights.

Ndithi kuni (I say to you: reciting clan names);

Radebe. Bhungane kaNsele! Zikode! Bhungane wenza ngakuningi!
Makhulukhulu! Umkhulu Nkulunkulu kodwa awunganga Bhungane!
Unkulunkulu uziqu zintathu kodwa uBhungane uziqu zingamakhulukhulu, Mthimkhulu.

Mashiya amahle amade anjengawe nyamazane!
Sgoloza esimehlo abomvu esibheka muntu kubengathi siyamujamela!
Ndlubu ezamila ebubini bamadoda! Ndlubu ezamila emthondweni (KwaSothondose)! AbakaSothondose ngokuzimelela kwanda uBhungane, Yena owehla ezulwini ngesilulu! Inkunzi enezindlu ezamila emthondweni!

Bhungane ongumakhulukhulu!
Nina enindlebe zikhanya ilanga!
Nina enindlebe zinhle zombili!
Nina bosiba olude olungakhothami ndlwaneni kodwa kwezinde luyakhothama!
Nina omagawula imithi emncane emikhulu ivele iziwele!
MaHlubi amahle! Mangelengele amahle!
Nina maHlubi anzipho zimnyama ngokuqhwayana! Mashwabada owashwabadela inkoma kanye nezimpondo zayo yathi mayifika emphinjeni yadlamalala!

Bayede!!!

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In conclusion, I am truly blessed and humbled by the support and assistance I have received from all these individuals and organisations. Their contributions have been invaluable, and I am forever grateful for their presence in my research journey.

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List of Acronyms used in the study

CAPS: Curriculum and Assessment Policy Statement

CK: Content Knowledge

ICT: Information and Technological Knowledge

MKO: More Knowledgeable Others

PCK: Pedagogical Content Knowledge

PK: Pedagogical Knowledge

SAMR: Substitution, Augmentation, Modification, and Redefinition

SCT: Sociocultural Theory

TCK: Technological Content Knowledge

TIMSS: Trends in International Mathematics and Science Study

TK: Technological Knowledge

TPACK: Technological, Pedagogical and Content Knowledge

TPK: Technological Pedagogical Knowledge

AfL: Assessment for Learning

AaL: Assessment as Learning

CRL: Co-regulated learning

SRL: Self-regulated learning

PISA: Programme for International Learner Assessment

NCTM: National Council of Teachers of Mathematics

1 CHAPTER ONE

1.1 INTRODUCTION

1.1.1 Importance of Mathematics

Mathematics education plays a pivotal role in fostering the development of analytical skills and an analytical mindset. By engaging with mathematical concepts, learners are encouraged to carefully consider the underlying assumptions of a given problem or situation(Skousen, 2020). Consequently, they gain the ability to break down complex problems into more manageable steps, facilitating a deeper understanding of the subject matter.

One of the key benefits of learning mathematics lies in its potential to cultivate critical thinking skills (Jablonka, 2020; Cai & Hwang, 2023). Critical thinking is a crucial differentiator between individuals who can merely perform mathematical calculations and those who genuinely comprehend the subject (Jablonka, 2020; Willingham, 2019). Learners who have acquired mathematical knowledge through practice and memorisation can effectively apply formulas and explain concepts when assessed. However, it is essential to note that while they may be able to utilise these formulas, they may not always fully grasp the underlying principles behind them. Furthermore, mathematics education equips learners with the necessary abilities to solve problems and perform calculations and fosters critical thinking skills. By encouraging learners to delve into the assumptions and intricacies of mathematical problems, they are empowered to approach complex challenges with confidence and precision. While the ability to apply formulas and definitions is undoubtedly valuable, it is equally important to strive for a deeper understanding of the underlying concepts that drive mathematical reasoning.

1.1.2 Review of Mathematics Teaching and Learning in South Africa.

Learner performance in mathematics assessments continues to be a pressing concern(Skousen, 2020), as evidenced by the coverage in local media and reports on the state of mathematics education in South Africa. Several articles, such as “The shocking state of Mathematics and Science Education in South Africa” (businesstech.co.za, December 8, 2020), “South Africa’s poor mathematics and science skills hamper innovation” (sanews.gov.za, August 26, 2021), and “Sad state of the Matric Mathematics Pass Rate in SA” (2oceansvibe.com, February 24, 2021), shed light on this issue. Furthermore, the Trends in International Mathematics and Science Study (TIMSS, 2019) report raises additional concerns. Despite having a classroom advantage over learners in other countries, South African Grade 7 learners consistently rank among the lowest in various tests. The assessment results from TIMSS (2019) indicate that 41% of South African learners fail to acquire basic mathematics skills for their respective grades. It is crucial to note that higher performance on these assessments signifies learners' ability to apply their knowledge to simple and complex problem-solving scenarios and effectively communicate their understanding. Addressing South African learners' challenges in mathematics education requires a comprehensive and strategic approach. Learners may excel in mathematics and unlock their full potential by implementing targeted interventions, providing quality resources, and fostering a supportive learning environment(Skousen, 2020).

The report by Trends in International Mathematics and Scientific Study (TIMSS, 2019) is a comprehensive global examination assessing fourth- and eighth-grade learners' mathematical and scientific knowledge. The TIMSS summative assessment reports from 2015 and 2019 have revealed a significant gap in learners' fundamental mathematical understanding during the senior phase, particularly between grades 7 and 8 in South Africa. This deficiency in mathematical knowledge has been attributed to a lack of effective Assessment as Learning (AaL), which has severely impacted learners ' overall mathematical understanding. Assessment as learning aims to utilise assessment to assist and enhance learning rather than simply quantifying it (Skousen, 2020). When assessment is employed correctly, it can provide learners valuable feedback on their progress and highlight areas where improvement is needed. However, in many cases, assessment is primarily used for grading and ranking purposes, often focusing on memorisation and rote learning rather than fostering mathematical understanding.

According to the TIMSS results, in South Africa, learners in the senior phase struggle with fundamental mathematical concepts such as fractions, decimals, and percentages. These concepts are crucial for higher-level mathematics and science, and a lack of comprehension in these areas can significantly impact learners' future academic and employment opportunities. The statistics also indicate that learners in South Africa perform well below the international average in mathematics, highlighting the urgent need for intervention (Spaull, 2013; Soudien, Reddy, & Harvey, 2021; Naidoo & Sibanda, 2020). One potential intervention that could be targeted is formative assessment.

1.1.3 Motivation of Formative Assessment and Gamification

Formative assessment is closely linked to how learners improve their learning by making informed decisions based on feedback and actively engaging with classroom learning priorities, with the teacher serving as a facilitator (Dann, 2014). Internationally, formative assessment has gained recognition for its numerous benefits, including providing constructive feedback to learners (Gedye, 2010; Rakoczy et al., 2018).

Formative assessment is widely recognised as a crucial factor in enhancing intrinsic motivation (Hondrich et al., 2018), promoting learner participation (Minton & Bligh, 2021; Barana et al., 2019), and improving learner achievement in mathematics (Palm et al., 2017). Various formative assessment tasks can be employed at any lesson stage, including tests, assignments, games, group activities, projects, reports, presentations, progress checks, and simple question and-answer sessions. These assessments utilise diverse exercises, tools, and technologies to encourage active engagement from learners (Fisher & Frey, 2014; Irons & Elkington, 2021). Incorporating technology and game-based activities into formative assessments, as suggested by Wootton (2022), allows teachers to measure incremental progress towards individual lesson objectives and short-term learning goals.

On the one hand, game-based activities offer a unique approach, which has long been recognised as an exciting and enjoyable intervention in mathematics assessment (Gocheva, Somova, & Kasakilev, 2022; Alt, 2023). Educational games designed to teach and evaluate specific abilities or concepts fall under game-based activities. These games can be implemented in the classroom or through electronic devices such as computers or tablets. The primary aim of game-based activities is to enhance learner engagement and participation while providing teachers a valuable tool to assess their learners' understanding of the subject matter(Alt, 2023). Compared to traditional pen-and-paper assessments, using game-based activities in mathematics assessment offers several advantages, including fostering active learner engagement and participation. As Alt (2023) suggests, such game-based assessments can inspire learners and sustain their interest in the content. Moreover, game-based activities enable teachers to gain more detailed insights into their learners ' comprehension of the material. By monitoring learners ' progress and identifying areas of difficulty, teachers can tailor their instruction to address specific needs.

One of the key advantages of incorporating game-based activities into education is their ability to cater to individualised instruction. Teachers can utilise game-based exercises to adapt their assessments, teaching methods, and learning materials to meet their learners ' specific needs and abilities (Cheng et al., 2023). For instance, a teacher may employ a game-based exercise to offer additional practice to learners struggling with a particular subject while simultaneously challenging those who have already mastered the material.

Gamification, defined as integrating game elements into non-game environments, has been widely employed in education to enhance learner engagement and motivation (Fitria, 2022). In mathematics assessment, gamification can make the assessment process more enjoyable and effective as an innovative tool to inspire and engage learners in their learning journey (Mada & Anharudin, 2019; Prasetiyo, 2022; Simuja,2023). The initial application of gamification in mathematics assessment involves introducing game-like elements such as points, badges, and leader boards. These features can effectively incentivise learners to complete assessments and improve their scores.

Another approach to gamification in mathematics assessment is game-based assessments, which closely resemble games rather than traditional assessments. These assessments can be more exciting and enjoyable for learners, enhancing their performance (Mada & Anharudin, 2019). For example, a game-based assessment may involve solving mathematics exercises in a virtual world or applying mathematical skills to solve puzzles.

Simulations represent a third way gamification can be employed in mathematics assessment. Simulations provide virtual environments where learners can practice their arithmetic skills in a realistic setting (Mikeska & Howell, 2021). Using simulations, teachers can assess learners' understanding of arithmetic concepts and provide valuable performance feedback.

An exemplary example of game-based assessment technology is Kahoot! Gamification. Kahoot! offers learners an interactive and engaging experience, allowing them to participate in quizzes and challenges to reinforce their mathematical knowledge(Altawalbeh & Irwanto, 2023).

Kahoot! gamification is an interactive game that serves as a formative assessment tool, utilising points, badges, and leader boards to engage learners (Wang & Tahir, 2020). This game-based learning tool focuses on mathematics, allowing learners to participate in quizzes and activities reinforcing mathematical concepts. By providing rapid feedback and encouragement, Kahoot! assists learners in enhancing their understanding of mathematics (Licorish, George, Owen, & Daniel, 2017; Wang & Tahir, 2020; Altawalbeh & Irwanto, 2023).

Furthermore, Kahoot! offers quizzes and games that assess learners' knowledge and reinforce mathematical topics (Altawalbeh & Irwanto, 2023). These quizzes and activities can be customised to meet the specific needs of individual learners. For instance, a teacher can create a quiz on a particular mathematical concept.

1.1.4 ICT Integration Status in South African Schools

Given the proven benefits of Kahoot! Exploring its potential as a formative tool to scaffold mathematical understanding in South African senior phase mathematics is crucial. This tool reinforces mathematical concepts, provides instant feedback, fosters cooperation, and personalises learning experiences. On the other hand, the South African government actively promotes and advocates for the integration of information and communication technology (ICT) in teaching and learning (Sikhakhane, Govender & Maphalala, 2020; Spangenberg & Freitas, 2019; Maphala & Khumalo, 2023). Therefore, conducting a study on the implementation of Kahoot! in this context would be timely and relevant. The Department of Basic Education (DBE) continues to equip teachers with laptops and establish ICT centres in some schools, enabling teachers to integrate ICT skills into their teaching and learning practices.

Despite implementing various ICT education intervention methods by the DBE and Eastern Cape Department of Education (ECDoE), many mathematics teachers in South African schools still struggle to incorporate ICT into their teaching and learning. This issue highlights a disconnect between government aspirations and teacher practice, as noted by Padayachee (2017) and acknowledged in the DBE's 2019 Action Plan, which admits that ICT-enhanced learning in South Africa has not progressed as planned (DBE, 2015, p. 14). Shockingly, the DBE reports that only 26% of South African teachers possess basic technology skills, with a mere 7% having intermediate skills (DBE, 2018).

The challenges faced by teachers in integrating technology into the classroom are multifaceted. Some teachers feel overwhelmed by the sheer volume of material they need to teach, while others lack the necessary ICT expertise to successfully incorporate technology into their lessons(Mikeska & Howell, 2021).. Unfortunately, most ICT workshops have focused on providing a basic introduction to computer use rather than offering subject-specific training (Ngoungouo, 2017). Additionally, teachers express concerns about the potential consequences of losing government-provided ICT equipment, as they would be held responsible for the cost, potentially resulting in reduced salaries or pensions (Dodewar, 2020).

Consequently, these devices, such as computers, laptops, and tablets, often remain unused at home, becoming objects of curiosity, fear, and insecurity for teachers (Gamor, 2021).

1.2 Statement of the problem

Mathematics knowledge is not only important in our daily lives but also essential for academic success and personal and professional development (Delaney & Devereux, 2019; Maas et al., 2019; Kufi, 2023). It serves as a mandatory foundation in subjects like science, engineering, and economics (Delaney & Devereux, 2019; Maas et al., 2019; Kufi, 2023). Without a strong mathematical foundation, learners may struggle to grasp complex concepts in these fields. Additionally, mathematics is a subject that builds upon itself, meaning that a weak foundation can lead to difficulties with more advanced content in higher grades. As Buchholtz (2023) emphasizes, understanding mathematics is crucial for applying mathematical principles to real-world situations.

Unfortunately, in South Africa, many learners in the senior phase grades lack mathematical understanding compared to their international counterparts (Spaull, 2013; Soudien, Reddy & Harvey, 2021; Naidoo & Sibanda, 2020;Simuja,2023). The significance of mathematical understanding lies in its role as the groundwork for more intricate mathematical concepts. Most learners struggle to comprehend complex ideas unless they grasp the basic principles. This lack of comprehension leads to frustration and disinterest in the subject, resulting in poor performance (Yonela & Thandiswa, 2023; Nasir et al., 2023). Furthermore, a solid mathematical foundation is often a prerequisite for many careers, and subpar mathematical performance can limit learners' career options. Therefore, to excel academically and professionally, learners must possess a strong understanding of mathematics. Although several factors contribute to poor learner performance, the lack of mathematical understanding is the most significant (Nasir et al., 2023).

Several challenges faced by South African schools contribute to the inadequate provision of resources for effective mathematics education. One of these challenges is the lack of funds to purchase teaching and learning materials (Chetty, 2019). Another longstanding concern is the massification of learners in these schools, which poses a significant issue (Moloi, 2019; Mokoena, 2021). The combination of large class sizes and limited resources makes it increasingly difficult for teachers to provide individual attention to each learner, ultimately impacting their learning. Massification restricts the amount of one-on-one time teachers can dedicate to each learner (Trust & Whalen, 2020). Consequently, learners who struggle to grasp mathematical concepts may not receive timely assistance, leading to falling behind their peers and struggling to keep up with the curriculum. Moreover, massification has the potential to diminish learner engagement.

These challenges, along with others, contribute to the inadequate assessment practices employed by most teachers (Kanjee & Sayed, 2013; Tzu, 2016; Musomi, 2022). As a result, learners often do not receive the necessary formative feedback during their learning process, leading to poor performance in summative assessments. Unfortunately, formative assessments are often conducted merely to meet the Department of Basic Education (DBE) requirements, rather than addressing learners' misconceptions and errors to inform the progression and integration of content. This approach fails to create opportunities for meaningful mathematical discussions that enhance understanding (Demosthenous, Christou, & Pitta-Pantazi, 2021; Nkuna, 2020; Suurtamm et al., 2016).

Furthermore, the lack of resources, massification of learners, and insufficient human resources pose significant challenges to mathematics education in South African schools (Musomi, 2022; Nkuna, 2020). These challenges hinder individualized attention, impede learner progress, and result in ineffective assessment practices. Addressing these issues is crucial to ensuring learners receive the support and opportunities to engage in mathematical discussions that enhance mathematical understanding (Suurtamm et al., 2016).

Mathematical understanding plays a crucial role in determining learners' performance in mathematics. Without a solid grasp of basic mathematical principles, learners will have difficulty comprehending and applying more advanced concepts in real-world scenarios. Enhancing mathematical understanding can significantly improve learner performance and create new opportunities for job prospects in the Eastern Cape. Consequently, this study aims to investigate the potential of utilizing Kahoot! Gamification as a platform for senior phase mathematics teachers to enhance mathematical understanding.

1.3 Research goal

This case study explores the use of Kahoot! Gamification as a formative assessment tool by senior phase mathematics teachers to enhance mathematical understanding. The main objective of this study is to thoroughly investigate and understand how teachers use Kahoot! as a formative assessment tool in mathematics education.

1.4 Research questions

Research questions are pivotal in every research project, serving as the cornerstone for its aim and objectives. They not only provide a concise and lucid statement of purpose but also steer the focus and direction of the study (Saliya, 2023). By formulating specific and measurable research questions, researchers can ensure the significance and rigour of their study(Creswell,2004). Moreover, research questions aid in defining the scope of the study and provide a framework for data collection and analysis. Consequently, researchers must dedicate ample time and effort to crafting well-defined research questions to guide their investigation effectively(Saliya, 2023).

The following research questions will be addressed.

1. What are the senior phase mathematics teachers' perceptions of using Kahoot! Gamification as a formative assessment tool prior to this study?
2. How do senior phase mathematics teachers use Kahoot! Gamification to scaffold mathematical understanding?
3. What are the enabling and constraining factors of using Kahoot! Gamification as a formative assessment tool to enhance mathematical understanding in senior phase classes?

1.5 Overview of the Thesis

This thesis comprises seven chapters.

Chapter One

Chapter One sets the stage for the entire thesis by thoroughly analysing the research's origins and goals. By exploring the topic's significance, the chapter aims to provide readers with a comprehensive understanding of the subject matter. Furthermore, it goes beyond the surface level by situating the study within both global and local contexts, allowing readers to grasp the broader implications of the research. The chapter also serves as a roadmap for the rest of the thesis, as it introduces the research questions that will guide the investigation and offers a tantalising glimpse into the content that awaits in the subsequent chapters.

Chapter two

The second chapter discusses the most recent and relevant literature related to the study. The research questions from chapter one guided the method for reviewing the literature. The research used electronic databases such as Google Scholar and the RU Library. Kahoot! Games, assessment, formative assessment, and mathematical understanding were the focus of the literature review. Additionally, several academic journals and research papers were reviewed to gather a comprehensive understanding of the topic. Including Google Scholar and the RU Library as sources ensured that the information presented in the literature review was reliable and backed by scholarly research. By focusing on Kahoot! games, assessment, formative assessment, and mathematical knowledge, the review aims to provide valuable insights into the effectiveness of Kahoot! as a tool for enhancing mathematical understanding and promoting active learning in the classroom.

Chapter Three

Chapter three introduces Vygotsky ' s Sociocultural and TPACK theories as theoretical and analytical frameworks. It provides an in-depth understanding of the reasons behind selecting these theories and their application in this study. Additionally, this chapter highlights the significance of understanding the theoretical underpinnings of the chosen frameworks and their relevance to the research topic. Furthermore, this chapter examines the RAT and SAMR models as potential frameworks that could have been utilised while elucidating the reasons for their exclusion. It explores the potential benefits and drawbacks of using the RAT and SAMR models, shedding light on why they were not deemed suitable for this study. The researcher also emphasises the importance of recognising the limitations of using TPACK as an analytical framework, which adds transparency and credibility to the research findings. Ultimately, the researcher concludes this chapter by acknowledging the limitations of implementing TPACK as an analytical framework. Overall, this chapter sets the stage for the subsequent analysis and interpretation of the data, ensuring a comprehensive and well-informed approach to the study.

Chapter Four

The fourth chapter of this research report examines the intricacies of the research design, situating it within the interpretive research paradigm through a case study approach. The rationale behind employing a qualitative design with a case study approach is thoroughly explored and justified. Furthermore, this chapter comprehensively explains and justifies the chosen sample size and sampling criteria. The advantages and disadvantages of the data generation methods are also carefully examined. The collection of data was accomplished through the utilisation of semi-structured questionnaires, reflection journals, observations, and focus groups. In addition to the data collection methods mentioned, the chapter also discusses the steps taken to ensure the validity and reliability of the gathered data. This includes establishing clear research objectives and carefully selecting participants who can provide valuable insights. Furthermore, the chapter explores the data coding and analysis process, highlighting the systematic approach employed to identify patterns and themes within the collected data. The study aims to comprehensively and accurately represent the research topic using rigorous data analysis techniques. Moreover, this chapter examines the processes of thematic data analysis, triangulation, and study evaluation, emphasising trustworthiness, credibility, transferability, and confirmability. The meticulous examination of these aspects ensures the robustness and reliability of the study's findings. Lastly, the chapter concludes by delving into the ethical implications of the study, highlighting the importance of conducting research in an ethically responsible manner.

Chapter Five

This chapter presents the study's outcomes, showcasing a comprehensive data analysis. Semi-structured questionnaires, focus group interviews, observations, and reflective journals were used to collect data

The findings presented in this chapter align seamlessly with the chosen methodology, ensuring accuracy and appropriateness. The findings are organised thematically based on the study questions to enhance clarity and coherence. This approach allows for a systematic data exploration, enabling a deeper understanding of the research objectives. Furthermore, the thematic organisation of the findings allows for a more holistic analysis of the research questions. By grouping related findings, patterns and trends can be identified, providing a more comprehensive understanding of the research topic. This approach also facilitates comparing and contrasting different perspectives and themes, contributing to a richer and more nuanced interpretation of the data. The systematic exploration of the data through thematic organisation enhances the overall rigour and validity of the study.

Recognising the importance of reliability, the utmost care has been taken to represent the teachers comments in their own words faithfully. By doing so, readers can be assured that the conclusions drawn from the data collected are credible and trustworthy. This chapter provides a comprehensive and reliable account of the study ' s findings. The meticulous analysis of various data sources and thematic organisation ensure a robust and compelling presentation of the research outcomes.

Chapter Six

The study ' s findings are thoroughly discussed in Chapter 6, compared to the previous research discussed in Chapter 2. This comparison highlights the consistency between the findings of this study and previous research while acknowledging any contradictory discoveries. The discussion of the findings in this chapter showcases a remarkable level of insight and originality as it identifies the potential ramifications. Moreover, this chapter effectively addresses the research questions, and the results of this study are justified in light of the methodology and relevant findings presented and discussed throughout this chapter. The chapter thoroughly analyses the research findings, thoroughly examining the data collected throughout the study. This chapter serves as a crucial component in understanding the implications and significance of the research conducted. By delving into the intricacies of the findings, this section aims to shed light on the key patterns, trends, and relationships that emerged from the data analysis. Moreover, it offers valuable insights into the implications of these findings for the field and provides a foundation for further research in the future. Furthermore, the effective addressing of the research questions in this chapter, along with the justification of the results based on the methodology and relevant findings, strengthens this study's overall credibility and validity.

Chapter Seven

This chapter concludes the thesis with a comprehensive overview of the entire study. Additionally, it summarises the significant findings derived from the study, from which conclusions are drawn, recommendations are made, and potential areas for future exploration are highlighted. Chapter Seven is a crucial component of this study, providing a comprehensive overview and examining the significant findings in detail. By presenting a summary of these findings, the chapter enables readers to grasp the key takeaways and understand their implications for the research. Moreover, the conclusions drawn from the study pave the way for valuable recommendations that can be implemented in practice while also identifying potential areas for further exploration, ensuring the study's impact extends beyond its current scope.

1.6 Summary

This chapter introduces the study and comprehensively explains its background and intricate concerns. It examines the assessment contexts and presents a compelling argument and need for senior phase teachers to integrate Kahoot! Technology to scaffold mathematical understanding. Furthermore, the methods employed to answer the research questions are thoroughly explained, along with a detailed discussion of the chosen method of data analysis. Additionally, a diagnostic reason for the limitations of this study is revealed.

Before delving into the subsequent chapters that make up this thesis, a concise explanation of the operational definitions utilised throughout the research process is provided. This ensures clarity and understanding for the reader. The chapter concludes with an overview of the upcoming study chapters, setting the stage for what lies ahead. Moving forward, the next chapter will focus on a comprehensive literature review. This review will address crucial arguments, predispositions, and gaps within the research field, providing a solid foundation for the subsequent chapters.

1.7 Definition of terms

Assessment: Assessment can be defined as the systematic process of collecting and analysing evidence to ascertain the level of achievement a learner has reached concerning the desired learning outcomes (Lam, 2019).

Classrooms: Classrooms are purposefully designed physical environments that foster learners' education and overall growth.

Errors: Errors are mistakes and lessons we learn along the way. Errors can be simple slips or logical. They can be caused by a lack of knowledge or a lapse in judgment (Liu, Oubibi, Zhou, & Fute, 2023).

Feedback: Feedback is a vital mechanism that provides individuals with valuable information regarding their performance or behaviour, enabling them to enhance their skills and attain their objectives (Plastow, 2023). It is a powerful tool for growth and development, allowing individuals to identify areas for improvement and make necessary adjustments.

Formative assessment: Formative assessment pertains to continuous evaluation of learners' progress and comprehension throughout a unit or course (Park & Ramirez, 2022). It is a valuable tool for gauging learners ' understanding and identifying areas requiring further attention or improvement.

Gamification: Gamification refers to applying game design principles and mechanics to non game contexts, intending to engage and motivate individuals(Yanuarto, Setyaningsih & Wahyuningsih, 2023).

Kahoot!: Kahoot! is an interactive learning platform that allows teachers to create engaging quizzes, surveys, and discussions for their learners. It was developed in 2013 by a Norwegian company to make learning more fun and interactive (Aljarrah, 2020).

Learning: Learning is a fundamental process that enables individuals to acquire knowledge, skills, and understanding through various means such as experience, study, or teaching (Drijvers, 2019). It serves as a cornerstone for personal growth and development, empowering individuals to expand their intellectual horizons and enhance their capabilities.

Mathematical Understanding: Mathematical understanding involves a profound comprehension of the fundamental concepts and the capacity to apply them across diverse contexts (Hwang, Wang, & Lai, 2021). This entails grasping the underlying principles and effectively utilising them in practical situations.

Mediation: Mediation is a crucial process in education where a skilled teacher or facilitator assists learners in bridging the gap between new information and their preexisting knowledge and experiences (Ye & Xu, 2023).

Misconceptions: Misconceptions refer to beliefs or ideas not grounded in accurate or comprehensive information. These erroneous notions often arise due to a lack of understanding or awareness regarding a particular subject matter. It is crucial to recognise that misconceptions can hinder our ability to make informed decisions or form accurate judgments (Sikurajapathi et al. (2021).

Scaffolding: Scaffolding refers to the assistance teachers provide learners as they strive to master a new concept or skill (Aljarrah, 2020). This support is gradually withdrawn as the learner becomes more proficient, enabling them to work autonomously (Coelho & Abreu, 2022).

Sociocultural-Theory (SCT): Sociocultural theory is a psychological and educational framework that places significant emphasis on the impact of social and cultural factors on human development (Nasution, 2022).

Teachers: Teachers are much more than just instructors; they are mentors, guides, and role models who possess the profound ability to shape the minds and futures of their learners (Miller, 2019).

Teaching: Teaching is the art of imparting knowledge, skills, and values to others to shape their minds and prepare them for life's challenges (Miller, 2019).

Technological Pedagogical And Technology Knowledge (TPACK): Technological Pedagogical and Technological Knowledge (TPACK) is a comprehensive framework that integrates three crucial components: technology knowledge, pedagogical knowledge, and content knowledge (Byrge, 2023) . This model is a valuable tool for teachers, enabling them to effectively leverage technology in the classroom to enhance the teaching and learning experience.

Technology: Technology is a broad term encompassing a diverse array of tools, techniques, and systems utilised to address challenges, enhance efficiency, and augment human capabilities. It plays a pivotal role in our modern society, revolutionising how we live, work, and interact with the world around us (Cadet, 2023)

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

According to Bazhair, Khatib, and Amosh (2022), literature is a compilation of published information found in books, educational journal articles, and other relevant sources on a specific area of research or topic. Conversely, a literature review entails a comprehensive analysis and evaluation of research and non-research literature pertinent to a chosen area of study or a particular topic (Ramdhani, Ramdhani & Amin, 2014). The primary objective of conducting a literature review is to enhance the researcher ' s understanding of existing research on the subject matter at hand. Additionally, it enables the researcher to identify gaps in the literature and be better equipped to address them, thereby contributing to advancing knowledge in the field of study. This aligns with the viewpoint of Paul and Criado (2020), who suggest that a literature review is conducted to comprehend previous research on the researcher's topic, examining what has already been accomplished, how it was executed, and the critical issues involved.

Furthermore, Elsbach and van Knippenberg (2020) argue that a literature review provides the necessary context and justification for the research, establishing a solid foundation for advancing knowledge. This study's literature has assisted the researcher in situating the study within the current scholarly discourse. A literature review critically analyses and evaluates the available literature on a specific topic, making it an indispensable component of any research endeavour. It aids in identifying gaps in knowledge, highlighting significant themes and concepts, and providing the necessary context for the research, all of which will be discussed in this chapter.

The literature in this study was sourced from a diverse range of academic journals, authoritative books, reputable conference proceedings, government reports, Newspaper and relevant research articles are carefully selected to provide a comprehensive and up-to-date foundation for the research topic. The literature review structure provides a comprehensive overview of the role of technology in teaching mathematics, the principles of mathematical understanding, formative assessment, and the benefits of using formative assessment in education. It discusses the importance of feedback, pedagogical practices, information gathering, collaborative learning, error correction, and misconceptions in enhancing learner learning outcomes.Furthermore, it explores the use of ICT in mathematics education and introduces gamification as a method to engage learners in assessment activities. The discussion culminates with an exploration of Kahoot! as a formative assessment tool and its potential to scaffold mathematical understanding among senior phase mathematics teachers.

In responding to the research questions posed in the study, the literature review sets the stage for analyzing senior phase mathematics teachers' perceptions of using Kahoot! gamification as a formative assessment tool (research question one). It also lays the groundwork for investigating how these teachers utilize Kahoot! to scaffold mathematical understanding(research question 2) and identifies enabling and constraining factors related to its implementation(research question 3).

The literature review in this study goes beyond examining the role of technology in teaching mathematics and delves into important theoretical frameworks such as Sociocultural Theory and Technological Pedagogical Content Knowledge (TPACK). These theories provide a strong foundation for understanding the complexities of integrating technology into mathematics education. By incorporating Sociocultural Theory, the review recognizes the significance of social interaction and scaffolding in the learning process. It acknowledges that collaborative social interaction plays a crucial role in addressing errors and misconceptions, thereby scaffolding mathematical understanding. This understanding is essential for the study's exploration of how gamification, specifically through the use of Kahoot!, can enhance learner learning outcomes. Furthermore, the review acknowledges the relevance of TPACK, which emphasizes the integration of technological knowledge, pedagogical knowledge, and content knowledge. This framework highlights the importance of senior phase mathematics teachers in effectively leveraging gamification as a formative assessment tool. By understanding the key tenets of TPACK, teachers can optimize the use of Kahoot! to foster mathematical understanding among their learners.

In summary, the literature review not only provides a comprehensive understanding of the benefits and challenges of integrating technology in mathematics education, but also incorporates important theories such as Sociocultural Theory and TPACK. This allows for a more nuanced analysis of how senior phase mathematics teachers can leverage gamification to enhance learner learning outcomes and foster mathematical understanding.

2.2 The role of technology in teaching Mathematics in South African primary schools

One of the most notable advantages of incorporating technology in mathematics education is improved visualisation. Graphing calculators, interactive whiteboards, and computer software enable learners to visualise mathematical concepts more interactively and engagingly. For instance, del Cerro Velazquez and Molares Mendez (2021) concluded in their study on the integration of ICT in the classroom that spatial intelligence is a crucial skill for comprehending and solving real-world problems, as it allows individuals to construct mental models of objects or graphical representations from algebraic expressions, two-dimensional designs, or oral descriptions. Spatial ability can be enhanced through innovative technologies such as augmented reality, which presents mathematical operations through images and graphics, enabling learners to perceive, grasp, and comprehend concepts related to mathematical functions. Moreover, teachers can use interactive whiteboards to visually and engagingly present mathematical topics, facilitating easier comprehension and retention for learners (Urbina, 2022; Simuja,2018). Increased engagement is another notable advantage of incorporating technology in mathematics education. Interactive platforms and applications encourage active participation and involvement from learners, fostering a more dynamic and stimulating learning environment.

Another critical advantage of technological advancements in assessment is the ability to track and analyse learners' progress over time (Thomas, 2014). Technology empowers teachers to gather and analyse vast data, providing valuable insights into learners' learning patterns and progress(Nepembe & Simuja, 2023). Information and Communication Technology (ICT) has emerged as a significant catalyst for daily life and economic activity in the twenty-first century. The ongoing technological revolution encompasses novel methods of capturing, processing, storing, and presenting information, thereby enhancing productivity and competitiveness by making information readily accessible (Anshari & Hamdan, 2022). In South African schools, technology has been introduced to enhance the teaching and learning of mathematics assessments (Mhlanga & Moloi, 2020). According to Oke and Fernandes (2020), technology revolutionises living, working, and learning. Over the years, technology has been integrated into education to improve mathematics teaching and comprehension. Incorporating technology has significantly enhanced learners ' understanding and grasp of mathematical concepts (Alabdulaziz, 2021; Cortez, 2020).

This data-driven approach enables teachers to identify trends, patterns, and areas for improvement, ultimately leading to more effective instructional strategies (Al-hadith & Ali, 2018). Moreover, technology facilitates the creation of personalised learning paths for individual learners, ensuring they receive the appropriate level of challenge and support. By harnessing technology for assessment, teachers can make informed decisions based on data and optimise the learning experience for each learner.

However, it is crucial to acknowledge the potential challenges and limitations of technological advancements in assessment. One such challenge is the need for reliable and valid assessment tools. As technology evolves, ensure the assessment tools are accurate, fair, and aligned with the intended learning outcomes (Al-hadith & Ali, 2018). Additionally, concerns may arise regarding the accessibility and equity of technology-based assessments, as not all learners may have equal access to technology resources (Thomas, 2014). Teachers must address these challenges and ensure technology is utilised to promote inclusivity and fairness in assessment (Al-hadith & Ali, 2018;Shambare and Simuja,2022). In addition, the impact of technological advancement on the assessment of learning in mathematics cannot be overstated. It has brought about a revolution in the way assessments are conducted, offering immediate feedback and facilitating data-driven decision-making. However, cautiously approaching technology integration in assessment is of utmost importance, ensuring that the tools employed are reliable, valid, and accessible to all learners. Furthermore, it is imperative to address the existing gaps, such as limited access to technology, inadequate teacher training, and the need for further research on the educational impact of technology.

To fully harness the potential benefits of technology in education, Simuja(2018) suggests that South African schools must proactively address these gaps by effectively leveraging technology. Teachers, including mathematics teachers, can elevate the assessment process and create a more personalised and impactful learning experience for learners. This enhances their academic growth and equips them with the necessary skills to thrive in an increasingly digital world.

In order to achieve this, schools need to invest in reliable and accessible technology resources, ensuring that every learner has equal opportunities to engage with digital assessments, according to Nieminen and Lahdenpera (2021). Additionally, comprehensive teacher training programs should be implemented to equip teachers with the necessary skills and knowledge to effectively integrate technology into their teaching practices (Nepembe and Simuja,2023). By doing so, teachers are empowered to utilise technology as a powerful tool for assessment(Sibanda & Rambuda, 2021), enabling them to provide timely and constructive feedback to learners, fostering their growth and development(Shambare et al., 2022).

2.3 Assessment of learning of mathematics in South African primary schools

Assessment practices in South African schools present challenges that impact education quality and learners' learning outcomes. These challenges include reliance on traditional assessments that prioritize rote memorization, lack of individualized feedback, meaningful engagement, and socio-cultural factors hindering learners' ability to demonstrate their potential.

Traditional mathematics assessments offer a standardised approach to assessing learners ’ understanding (Thambusamy & Singh, 2021; Nyirenda and Simuja,2023). The traditional assessment approach enables teachers to assess many learners within a limited timeframe. Moreover, traditional assessments are easy to administer and facilitate, comparing learners ’ performance across different schools, districts, and provinces (Govender & Hugo, 2020). However, it is essential to acknowledge that traditional assessment methods in mathematics have faced criticism for being outdated and ineffective (Thambusamy & Singh, 2021). These methods often prioritise memorisation and rote learning (Kundu, Bej, & Rice, 2021). According to Ahmad, Sultana, and Jamil (2020), traditional assessments frequently require learners to memorise formulas and procedures without genuinely grasping the underlying concepts, although easy to administer, often prioritize memorization over genuine understanding, hindering learners' ability to apply their knowledge in real-world situations.

This approach may potentially lead to an understanding of mathematics and hamper learners’ ability to apply their knowledge in real-world situations (Thambusamy & Singh, 2021). Furthermore, traditional assessment methods fail to consider individual learners ’ learning styles and preferences (Nieminen & Lahdenpera, 2021). According to the World Bank report of 2004 and scholars such as Thambusamy and Singh(2021), Govender and Hugo(2020), recent trends toward a constructivist approach to teacher-learner interaction suggest that integrating ICT supports cooperative learning, selfdirected learning, and metacognition and that visualisation can improve assessment. The interactive nature of most ICT devices lends itself well to a creative assessment technique that encourages experimentation and creative thinking in the mathematics classroom(Govender and Hugo,2020). One advantage of using ICT is that mathematics teachers can provide up-to-date Learning and Teaching Support

Materials (LTSM) online through one or more media. The teacher can customise these comprehensive resources to meet learning objectives.

Thambusamy and Singh (2021) believe that teachers who skillfully incorporate ICT into their assessments enhance their technological proficiency and pedagogical skills, ultimately improving learners ' mathematical understanding. Moreover, the COVID-19 pandemic profoundly impacted education systems worldwide, and South Africa is no exception. With the closure of schools and the transition to online learning, most teachers had to adapt their teaching and assessment practices to ensure that learners continued to receive high-quality instruction.

In the post-COVID-19 era, significant changes have occurred in the methodologies employed for assessing mathematics. Before the pandemic, traditional assessment methods such as written tests and exams were the primary means of assessing mathematical proficiency in South Africa. However, Jadhav and Takale (2020) argue that relying solely on tools like chalkboards, pencils, and paper to measure today ' s teaching and learning processes is no longer sufficient.

In order to adapt to the new educational landscape, teachers must embrace the potential of using ICT in assessment practices(Jadav & Takale, 2020). By doing so, they can enhance their own and provide learners with more engaging and interactive learning experiences. With the rapid advancement of technology, incorporating ICT tools such as interactive whiteboards, educational apps, and online assessments can offer a more comprehensive assessment of learners' knowledge and skills. These modern assessment methods enable teachers to gather real-time data on learners' progress, identify areas of improvement, and tailor their instruction accordingly. Additionally, ICT-based assessments can provide immediate feedback to learners, allowing them to self-assess and take ownership of their learning journey. Furthermore, using ICT in assessment practices promotes inclusivity by accommodating diverse learning styles and abilities. Learners who struggle with traditional pen-and-paper assessments can now demonstrate their understanding through multimedia presentations, online quizzes, or collaborative projects.

However, teachers need to strike a balance between traditional and ICT-based assessments. These new assessment strategies have allowed learners to engage with mathematics more dynamically and interactively, allowing for a deeper understanding of mathematical concepts (Attard & Holmes, 2022; Jadav & Takale, 2020).

While technology can enhance assessment practices, it should not wholly replace the valuable skills developed through traditional methods. Combining both approaches can provide a holistic view of learners' learning outcomes and ensure a well-rounded education(Nadeem & Falig, 2020). These new assessment strategies have allowed learners to engage with mathematics more dynamically and interactively, allowing for a deeper understanding of mathematical concepts(Attard & Holmes, 2022; Jadav & Takale, 2020).

One of the critical advantages of post-COVID-19 assessment strategies in mathematics is the ability to provide immediate feedback to learners (Nadeem & Falig, 2020). Teachers can now offer real-time feedback on learners' performance through online platforms, enabling timely intervention and support. This immediate feedback helps learners identify and correct their mistakes and fosters a growth mindset and a sense of ownership over their learning. In contrast, traditional pen and paper assessments often entail a significant amount of time for grading and feedback, which can impede learners' progress and hinder their learning (Perry, Katrina, Kane, & Mary, 2022).

In summary, the COVID-19 pandemic has necessitated a shift in assessment strategies in mathematics in South Africa. While traditional pen and paper assessments were the norm before the pandemic, the post-COVID-19 era has embraced more flexible and technology driven assessment methods. These innovative strategies have facilitated a more dynamic and interactive learning experience, providing learners immediate feedback and promoting a growth mindset(Nadeem & Falig, 2020). As teachers navigate the challenges of the postpandemic world, some teachers continue exploring and refining assessment strategies to ensure all learners access to quality mathematics education. Interestingly, the integration of ICT in mathematics assessment to enhance mathematical understanding as an alternative to traditional mathematics assessment in the senior phase seems to have escaped the attention of academic researchers. However, numerous studies have addressed the benefits and challenges of ICT integration in mathematics teaching and learning. This study aims to shed new light on how using Kahoot! as an assessment tool can enhance learners' mathematical understanding.

2.4 Teaching for Mathematical Understanding

Mathematical understanding encompasses the ability to comprehend, interpret, and grasp the meaning and implications of mathematical knowledge (Thambusamy & Singh, 2021). The acquisition of mathematical understanding is of utmost importance in learning mathematics. Skemp (1976) distinguished between two types of understanding: relational and instrumental.

Relational understanding involves comprehending both the “ what ” and the “ why” behind mathematical concepts and procedures (p. 2). On the one hand, relational understanding entails constructing a “conceptual framework to facilitate learning relational mathematics ”(p. 14). On the other hand, “ instrumental understanding refers to a superficial grasp of mathematical rules without a deeper understanding of their underlying reasons” (p. 2).

In a similar vein, Yu and Yang (2005) proposed a comprehensive five-level framework for understanding. The first level, the null level, signifies a complete absence of comprehension, indicating the initial cognitive process stage. At the null level, the learner lacks understanding or knowledge of the subject matter. They struggle to grasp the basic concepts or principles involved. However, as the learner progresses to the next level of the framework, known as the surface level, they acquire some basic understanding. For example, this could mean recognizing numbers and performing simple calculations. As learners advance in their learning journey, they move beyond the surface level and delve into a deeper level of understanding. At this stage, they grasp the basic concepts and develop a deeper comprehension of the underlying principles. For example, learners at this stage might understand the relationships between numbers, solve complex equations, and apply mathematical concepts to real-world problems, marking the conceptual level. As learner progress in their learning journey, they can think critically and analyze information more sophisticatedly. They become adept at recognizing patterns, making connections, and drawing conclusions based on their deep understanding. This comprehension level allows them to approach complex problems and find innovative solutions confidently.

Additionally, their critical thinking abilities enable them to identify logical fallacies and inconsistencies in arguments, allowing them to construct more persuasive viewpoints. Overall, this heightened level of critical thinking empowers learners to navigate the world's complexities with a discerning and analytical mindset. Finally, the endless level is characterised by the ability to acquire additional meanings or knowledge by reevaluating or applying previous understanding to new information (Yu & Yang, 2005; Simuja, Kraus and Conger,2016). Mathematical understanding encompasses the ability to perceive, comprehend, and access the meaning and connotation of mathematical knowledge. Skemp’s (1976) distinction between relational and instrumental understanding highlights the importance of comprehending the “what” and the “ why” behind mathematical concepts. Yu and Yang’s (2005) five-level framework further elucidates the progression of understanding from lacking comprehension to developing profound and limitless understanding. By fostering mathematical understanding, teachers can empower learners to engage with mathematics at a deeper level and cultivate their mathematical thinking skills.

Carpenter (1992, p. 68) states that a " mathematical idea, procedure, or fact is considered understood when it becomes part of an internal network " . This internal network refers to interconnected concepts that build upon each other, forming a cohesive understanding of a mathematical concept (Pambudi, Budayasa & Lukito, 2020). In order to construct this internal network, it is essential to identify the fundamental notions that serve as the foundation of a mathematical concept, as emphasised by Zhang, Lipton, and Smola (2021) and Kaiser (2020). For instance, concepts such as algebraic variables, equations, and functions are considered fundamental ideas. Once recognised, these concepts can be linked to a network of interconnected ideas, allowing for a broader understanding of mathematics.

The next step in building an internal network is identifying the relationship between concepts. For example, understanding the relationship between variables and equations is crucial for solving unknown variables in algebra. By comprehending these relationships, learners can better understand the mathematical idea and its application in various contexts. Representation is also recognised as a vital component of mathematical activity and a means of capturing mathematical thoughts (Boonen et al., 2014; Krauss , Simuja and Conger,2017). The National Council of Teachers of Mathematics (NCTM, 2000) defines representation as converting a problem or idea into a new form, such as a visual or physical model, using symbols, phrases, or sentences. However, it is worth noting that learner representation abilities are often insufficient, as most teachers do not consistently consider mathematical representation a crucial foundation for learning mathematics (Huda et al., 2019; Kaiser, 2020). Understanding mathematical concepts involves constructing an internal network of interconnected ideas. This network is built upon fundamental notions and their relationships, allowing for a comprehensive understanding of mathematics(Goldin, 2020). Additionally, representation plays a significant role in capturing mathematical thoughts. However, the ability to effectively communicate these ideas through various forms of representation enhances the learning experience and promotes mathematical understanding.

The South African Mathematics Curriculum promotes approaches that align with the constructivist paradigm, emphasising critical thinking, visualisation, strategic teacher intervention, and metacognition (DBE, 2011). Metacognition refers to the ability to reflect on one's mental processes. It is a higher-order thinking skill involving awareness of, monitoring, and controlling one's cognitive processes (Padmanabha, 2020). Learners utilise metacognitive techniques to regulate their thinking and learning, which can be applied to any activity or setting, ultimately enhancing their effectiveness as learners. Research has shown that employing metacognitive strategies leads to increased achievement, equivalent to an average of eight months of additional progress (Wall & Hall, 2016). Additionally, McMahon and Luca (2006, p. 563) argue that having "knowledge of one's cognitive processes and products and actively monitoring and regulating them in pursuit of a goal or objective constitutes metacognitive knowledge".

Metacognition plays a crucial role in mathematical understanding. According to Padmanabha (2020), learners with a strong sense of metacognition are better equipped to identify their strengths and weaknesses in mathematics. They can also determine their most effective strategies and adjust their approach accordingly. Moreover, metacognition is closely linked to mathematical problem-solving. When faced with complex problems, learners must think critically and reflect on their ideas. They can then draw upon problem-solving strategies that have proven successful and apply them accurately to solve the current problem. As Flavell (1976, p. 232) aptly states, " Understanding one ' s cognitive abilities and knowing how to utilise them effectively to comprehend new educational content, solve problems, and make informed decisions is a highly sought-after goal in education". Metacognition plays a crucial role in developing mathematical understanding. According to Padmanabha (2020), learners with solid metacognitive skills are better equipped to recognise their strengths and weaknesses in mathematics. Additionally, they can identify their most effective strategies and adapt their approach accordingly.

Metacognition is commonly regarded as a sophisticated framework that learners employ to assimilate and integrate knowledge to achieve their goals. As learners' understanding deepens, their mental representations of mathematical knowledge networks become more extensive and better organised(Wall & Hall, 2016). This occurs as they incorporate new representations or form new associations (Li & Wu, 2011; Conger, Krauss and Simuja,2015). According to Li, Li, and Risteki (2023), a firm grasp of mathematical concepts can alleviate the burden on memory, filter out irrelevant information, and enhance memory retention. Consequently, it can enhance learners' inductive and deductive reasoning abilities, enabling them to solve mathematical problems more fluidly (Pasnak et al., 2016). Metacognition is an indispensable component of mathematical understanding. It empowers learners to assess their abilities, identify effective strategies, and adapt their approach accordingly(Wall & Hall, 2016). By nurturing metacognitive skills, teachers can foster a more profound comprehension of mathematics and enhance problem-solving abilities, ultimately equipping learners with the tools they need to excel in the subject.

In order to enhance learners' mathematical understanding, it is crucial for teachers to engage with their learners actively(Martino & Maher, 1999). One effective way to achieve this is through the use of well-crafted questions. These questions serve multiple purposes, such as helping learners justify and expand upon their ideas, establish connections between different mathematical concepts, and develop general conjectures (Margot & Kettler, 2019; da Ponte, Mata-Pereira & Quaresma, 2023). However, it is important to note that acquiring these skills as a teacher does not happen overnight. It requires time and effort to develop the necessary expertise. Once these skills are honed, teachers can effectively facilitate and evaluate the growth of their learners' mathematical understanding (Martino & Maher, 1999).

To illustrate the significance of assessing mathematical understanding, Hiebert and Carpenter (1992, p. 68) proposed a set of criteria that can be used to evaluate an individual's grasp of mathematical concepts:

(i) learner errors and misconceptions,

(ii) the relationship between symbols and symbolic programs and corresponding references,

(iii) the relationship between symbolic procedures and informal problem-solving situations, and

(iv) the connection between different mathematical, symbolic systems

By carefully evaluating these criteria, teachers can gain valuable insights into their learners' level of comprehension and tailor their instructional approach accordingly. Fostering mathematical understanding among learners necessitates active interaction between teachers and learners (Margot & Kettler, 2019). Teachers can effectively support and evaluate the growth of their learners' mathematical understanding by employing thoughtful questioning techniques and continuously refining their skills. Furthermore, mathematics teachers maintain a delicate equilibrium among crucial factors to accurately evaluate a learner's mathematical understanding(ibid). These factors include the learner's mathematical knowledge and processes encompassing critical thinking, effective communication, visualization, feedback analysis, error identification, misconception rectification, and the ability to establish connections and representations(ibid). Additionally, the learner's mathematical disposition, which encompasses their attitude towards mathematics, perseverance, confidence, metacognitive abilities, and cooperative skills, should also be considered. To assess a learner's mathematical understanding effectively, the mathematics teacher must balance these essential attributes harmoniously. By doing so, the teacher can comprehensively understand the learner's mathematical proficiency, enabling them to provide tailored guidance and support.

It is also essential to note that considering the learner's mathematical knowledge, the teacher can evaluate the depth and breadth of their understanding (Margot & Kettler, 2019). This includes assessing their grasp of mathematical concepts, principles, and procedures. Furthermore, the teacher should also focus on the learner's mathematical processes involving various cognitive skills. These skills encompass critical thinking, allowing the learner to analyse problems, devise strategies, and make logical deductions (Hiebert & Carpenter,1992). Effective communication skills enable learners to articulate their mathematical reasoning and ideas clearly, according to Padmanabha (2020). Visualization skills aid in comprehending and representing mathematical concepts(ibid). Providing and receiving feedback is crucial for the learner's growth, as it allows them to identify and rectify errors and misconceptions(ibid). Moreover, the learner's capacity to establish connections between mathematical concepts and representations is vital for a holistic understanding of the subject matter. In addition to these attributes, the learner's mathematical disposition plays a significant role in their overall mathematical understanding(Kaiser, 2020). The teacher should consider the learner's attitude towards mathematics, as a positive mindset fosters engagement and motivation. Perseverance is another crucial aspect, as it enables the learner to persist in facing challenges and setbacks. Confidence in one's mathematical abilities is essential for taking risks and exploring new concepts.

2.5 Principles for Conducting Learning Assessment

The National Council of Teachers of Mathematics (NCTM, 2014) established six guiding principles for school mathematics education: teaching and learning, access and equity, curriculum, tools and technology, assessment, and professionalism. Assessment, in particular, plays a crucial role in an exceptional mathematics program. It encompasses a wide range of strategies and data sources, providing feedback to learners, making informed instructional decisions, and ultimately enhancing the program (NCTM, 2014, p. 5).

The first guiding principle, teaching and learning, emphasises engaging learners in meaningful mathematical tasks that foster understanding and problem-solving skills. Teachers are encouraged to create opportunities for learners to explore mathematical concepts and establish connections between them. Furthermore, learners should be actively encouraged to express their mathematical thinking and collaborate with their peers, as highlighted by Vygotsky's (1978) social interaction.

The second guiding principle, access and equity, ensures all learners have equal access to high quality mathematics instruction. Teachers should strive to provide diverse learning opportunities, catering to their learners' unique needs and backgrounds (Hunter & Stinson, 2019). Teachers need to be mindful of any barriers that may hinder learners from succeeding in mathematics and work towards eliminating them. Teachers can create a more engaging, inclusive, and effective mathematics learning environment by adhering to these guiding principles.

The third guiding principle focuses on the curriculum, emphasizing the significance of a well structured and targeted mathematics curriculum. It is crucial for teachers to ensure that the curriculum aligns with both state and national standards, providing learners with a profound understanding of mathematical concepts (Margot & Kettler, 2019). To support learner learning, teachers should employ diverse instructional strategies and resources.

The fourth guiding principle acknowledges the importance of utilizing appropriate tools and technology to enhance mathematics instruction (Drijvers, 2019). Furthermore, teachers should encourage learners to explore mathematical concepts by employing manipulatives, calculators, and other tools (Bouk, Park & Stenzel, 2020). Additionally, technology should be leveraged to support learner learning, allowing them to engage with virtual manipulatives and simulations.

The fifth principle revolves around assessment. Teachers need to implement effective assessment strategies to gauge learner progress accurately. By employing various assessment methods, teachers can gain valuable insights into learners' mathematical proficiency and identify areas that require further attention(Gibbs,1999). Assessment plays a vital role in learners daily lives as it provides with valuable information and validates the reasons behind decisions. Assessment is an essential component in education that influences crucial choices about teaching and learning, from individual learners to national education departments. As Broadfoot (2012) suggests, teachers and learners would be left in the dark about what is being learned without assessment. In essence, assessment serves as a means to determine if learning has occurred, requiring teachers to possess a deep understanding and skillset to ensure effective implementation.

Ramsden (1992, p. 182) defines assessment as enhancing teaching by precisely understanding what learners know and do not know. The assessment encompasses various aspects, including reporting learner performance and improving teaching by clarifying curriculum objectives. It is a central communication tool between teachers, learners, and the curriculum, conveying meaning and purpose. As Gibbs (1999) asserts, assessment empowers teachers to model how learners respond to courses and behave as learners. Black & William (1998, p.140) define assessments as all the activities teachers and learners engage in for self-assessment, providing valuable feedback to modify teaching and learning activities.

This study delves into formative assessments, focusing on their purposes and timing, particularly highlighting their role as a scaffold to mathematical understanding. In this study, formative assessment (see Section 2.5) is an ongoing information-gathering process on learner achievement and progress. It utilizes various forms of prompt feedback to support the learner's mathematical comprehension and subsequent instruction.

The guiding principles underscore the significance of a coherent and focused mathematics curriculum, the utilization of appropriate tools and technology, effective assessment strategies, and the importance of professionalism in mathematics instruction. By adhering to these principles, teachers can create an engaging and enriching learning environment that fosters learners' mathematical understanding and growth.

2.6 Formative Assessment

Formative assessments have emerged as a prominent instructional strategy, increasing recognition for enhancing learner learning and achievement across various subject areas (Brookhart, 2007; Magno & Lizada, 2015;). By allowing teachers to assess learners' current abilities in relation to learning objectives (Clark, 2012), formative assessments enable teachers to refine their instruction based on valuable feedback and observations (Cauley & McMillan, 2010). As Clark (2012) highlights, formative assessments empower teachers to identify areas where learners may struggle and adapt their teaching methods accordingly.

One of the primary advantages of formative assessments is their ability to provide instant feedback to teachers and learners(Yorke,2011). This feedback is a valuable tool for teachers to identify areas where learners may require additional support or instruction. For instance, if teachers notice that many learners are grappling with a specific concept, they can modify their lesson plans to provide more focused instruction. Moreover, formative assessments enable teachers to evaluate the effectiveness of their teaching approaches and gauge learner progress by observing how learners respond to different assessment methods(Clark, 2012).

Another significant benefit of formative assessment is its capacity to foster learner ownership of the learning process (Shraim, 2019; Canadas, 2021). When learners actively participate in the assessment process, they become more invested in their learning and are more likely to take responsibility for their academic growth. This increased sense of ownership and pride in their accomplishments can improve motivation, engagement, and overall learning outcomes (Canadas, 2021). Additionally, formative assessment provides learners with valuable feedback on their development, allowing them to identify areas for improvement and take proactive steps to address them. Regular and constructive feedback enhances learners' mathematical understanding and boosts their self-esteem, confidence, and sense of competence, confidence, and mastery (Kundu, Bej & Mondal, 2022). As such, formative assessment may be used to improve the quality of teaching and learning, provide feedback (both from the learner and the teacher), and improve mathematical understanding in preparation for summative assessment (Evans, 2013).

2.6.1 Formative assessment and providing feedback to inform further learning

According to Evans (2013, p. 71), assessment feedback encompasses all feedback that occurs during the design of assessments, within and outside the immediate teaching and learning context, and can be overt or covert, actively or passively solicited or received. Assessment feedback is a crucial process that bridges the gap between curriculum requirements, pedagogy, and content(Kundu, Bej & Mondal, 2022). Its purpose is to clarify what teachers expect learners to learn and how they should do it. Consequently, teachers' beliefs about learners' errors play a significant role in shaping their decisions regarding teaching and learning. Therefore, effectively addressing learners' errors and misconceptions during instruction is paramount.

Unlike summative assessment, formative assessment focuses on understanding learners' existing knowledge and identifying areas for improvement. It removes barriers to mathematical understanding and encourages learners to explore alternative problem-solving approaches. However, feedback is only considered formative if learners actively utilize the information to enhance their learning (Wiliam, 2007). This learning enhances their chances of success in summative assessments. Thus, formative assessment is often viewed as the outcome that presents an opportunity for learning and growth (Lam, 2019).

Feedback serves as an essential component of the learning process. It gives learners valuable insights into their performance and helps them enhance their skills and knowledge. However, not all feedback is created equal. McCallum, Hargreaves, and Gipps (2000) distinguish between constructive and descriptive feedback.

Constructive feedback encompasses teachers' positive and negative evaluations to assess learner performance(Park & Ramirez, 2022). It typically takes the form of grades and concise comments that convey praise or criticism. However, the impact of constructive feedback can vary among learners, as it has the potential to either motivate or demotivate them. Learners who receive negative feedback may feel discouraged and disengaged from the learning process (Mystkowska-Wiertelak, 2022). Conversely, learners who receive positive feedback may become complacent and fail to challenge themselves (Park & Ramirez, 2022). Therefore, it is crucial for teachers to offer descriptive feedback that provides specific instructions on the next steps, encouraging learners to take ownership of their learning.

Descriptive feedback emphasizes the learning process rather than solely focusing on the outcome (Park & Ramirez, 2022). Ainscow (2020) suggests that descriptive feedback should be precise, specific, and actionable. It helps learners understand their strengths and limitations while guiding them towards further development. This type of feedback can be delivered through various means, such as written comments, verbal feedback, and nonverbal cues. Another notable aspect of formative assessment is its continuous feedback loop with learners, particularly regarding their learning process(Park & Ramirez, 2022). Additionally, teachers can utilize information from formative assessments to enhance their teaching methods. When teachers utilize formative assessment data to determine the direction learners are heading, their current position, and the strategies employed to reach instructional goals, it becomes an assessment for learning (AfL) (Black and Wiliam, 2009; Garzon & Casinillo, 2021).

2.6.2 Assessment for Learning and Pedagogical Practice

Pedder and James (2012, p. 33) state that “assessment for learning refers to the instructional strategies teachers develop and utilize to support the learning process ” . This type of assessment, known as AfL, is particularly important as it addresses the teachers' Pedagogical

Content Knowledge (PCK). By gaining a deeper understanding of their learners' specific learning needs (Lam, 2019; Plastow, 2023), teachers can effectively implement AfL assessment to enhance the overall learning outcomes. Effective pedagogy is crucial in teaching and significantly impacts the learning process. As Westbrook and Noble (2013, p. 18) explain, " Effective pedagogy encompasses teaching and learning activities that result in observable changes in learners, leading to increased engagement, understanding, and measurable learning improvements". Teachers' pedagogical content knowledge is reflected in the diverse interactions that regularly take place within the classroom.

Creating a positive learning environment is a fundamental aspect of effective instruction. Teachers who establish a classroom culture that fosters respect, collaboration, and inclusion are likelier to engage learners in the learning process (Ainscow, 2020). This can be achieved by setting clear goals, encouraging active learner engagement and preferences, and providing constructive feedback recognising learners' achievements. Additionally, employing differentiated instruction is another essential element of effective teaching. Teachers who tailor their instruction to meet the unique needs of their learners are more likely to enhance engagement and understanding (El-Sabagh, 2021). Differentiated instruction can be achieved by utilizing various teaching methods, offering multiple means of representation, and providing flexible learning opportunities (Singer, Montgomery & Schmoll, 2020).

Assessment for learning, effective pedagogy, and creating a positive learning environment are all vital components of professional instruction. By implementing these strategies, teachers can better support their learners' needs, enhance engagement and understanding, and ultimately foster a more successful learning experience.

2.6.3 Assessment and information gathering

Through the use of formative assessment, teachers can gather valuable information about the strengths and weaknesses of their learners. This information then guides their instructional decisions (Park & Ramirez, 2022). The data obtained from formative assessment plays a crucial role in enabling teachers to tailor their instruction to meet the unique needs of each learner, ultimately leading to improved learning outcomes. As Westbrook et al. (2013) state, effective pedagogy involves teaching and learning activities that result in observable learner changes, fostering greater engagement, understanding, and measurable impact on learning.

Using formative assessment to monitor learner progress, teachers can identify specific areas where learners may struggle to comprehend the content. Armed with this knowledge, teachers can then make necessary adjustments to their instruction to better cater to the needs of their learners, ultimately resulting in improved learning outcomes (Lam, 2019; Khoza & Biyela, 2020). Through implementing formative assessment, teachers can develop a more comprehensive understanding of how to design assessments that accurately measure learner learning. This newfound knowledge empowers teachers to create assessments that align with their instructional goals, ultimately leading to improved learning outcomes.

In the South African context, the Mathematics Curriculum, Assessment Policy Statement (CAPS) document serves as a guiding framework for mathematics teachers, providing valuable insights into the various types of assessments to be employed. Overall, formative assessment is a powerful tool for teachers to gather information about their learners' strengths and weaknesses. This information allows teachers to tailor their instruction to meet the unique needs of each learner, resulting in improved learning outcomes. By utilizing formative assessment, teachers can also better understand how to design assessments that accurately measure learner learning. In South Africa, the Mathematics Curriculum Assessment Policy Statement (CAPS) document is a valuable resource for mathematics teachers, guiding the types of assessments to be used.

The baseline assessment is an initial evaluation to determine whether learners possess the fundamental skills and knowledge to engage successfully with a particular mathematical topic. Conversely, the diagnostic assessment informs teachers of problem areas within learners' mathematical understanding that may hinder their overall performance (DBE, 2012).

However, formative assessment allows learners to reflect on and monitor their progress to determine their future learning goals. This form of formative assessment is called Assessment as Learning (AaL). According to Dann (2014), AaL considers how learners self-regulate their learning by making complex decisions about using feedback and engaging with classroom learning priorities. Cowie and Bell (1999) define assessment as the process teachers and learners use to identify and respond to learner learning to improve that learning. Thus, assessment is viewed as a social (Vygotsky, 1968) collaborative process in which teachers and learners construct knowledge and mathematical understanding. AaL strongly emphasizes feedback, self-directed learning, and metacognition. To implement William and Thompson's (2007) five critical methods of formative assessment:

- Clarifying, sharing, and understanding goals for learning and criteria for success with learners.

- Engineering practical classroom discussions, questions, activities, and tasks to elicit evidence of learner's learning.
- Providing feedback that moves to learn forward.
- Activating as owners of their learning.
- Activating as learning resources for one another.

In the South African education system, mathematics teachers are guided by the Mathematics Curriculum Assessment Policy Statement document (CAPS). This document provides valuable insights into the various types of assessments that should be employed. The baseline assessment is the initial step in evaluating learners' skills and knowledge and determining their readiness for a specific mathematical topic (DBE, 2012). Conversely, the diagnostic assessment aids teachers in identifying any specific problem areas in learners' mathematical understanding that may impede their overall performance Dann (2014).

Formative assessment is an invaluable tool for teachers to gather comprehensive information about their learner's strengths and weaknesses. Armed with this knowledge, teachers can personalize their instruction to cater to the unique needs of each learner, resulting in improved learning outcomes (ibid). By harnessing the power of formative assessment, teachers can also better understand how to design assessments that accurately measure learner learning.

In summary, formative assessment empowers teachers, learners, and their peers to make informed instructional decisions, enhancing knowledge acquisition. The Mathematics Curriculum Assessment Policy Statement document (CAPS) serves as a guiding light for mathematics teachers in South Africa, offering valuable insights into the diverse range of assessments to be utilized. Through baseline and diagnostic assessments, teachers can evaluate learners' readiness and identify areas of improvement. By leveraging formative assessment, teachers can tailor their instruction to meet individual needs, resulting in improved learning outcomes. Furthermore, formative assessment aids in the design of accurate assessments that effectively measure learner learning.

2.6.4 Co-regulated Learning (CRL) and Self-regulated Learning (SRL) in formative assessment

Co-regulated learning and self-regulated learning are two approaches that can be effectively utilized in the mathematics classroom to enhance learners' learning experience(McLeod, 2012). Co-regulation refers to the combined influence of a learner's self-regulation processes and the external sources of regulation within the learning environment. These external sources include the structure of “teaching and learning situations, the teacher's interventions and interactions with learners, the interactions among learners, and the instructional materials and tools used, particularly in the assessment context” (Allal, 2016, p. 263). Co-regulated learning is closely associated with Vygotsky's Zone of Proximal Development, involving learners working collaboratively to support each other's learning. Through social interactions, learners collaborate and assist one another in surpassing their current level of understanding and knowledge. The teacher or more knowledgeable peers are crucial in guiding learners within their Zone of Proximal Development, enabling them to successfully complete activities and develop self-regulation skills through social interaction (Siyephu, 2013; McLeod, 2012). Incorporating co-regulated learning within the formative assessment framework allows learners to share their ideas, ask questions, and receive peer feedback. This collaborative approach fosters a positive learning environment where learners feel supported and encouraged to take risks and learn from their mistakes (Peel, 2020).

On the other hand, self-regulated learning, as defined by Zimmerman (2000, p.14), encompasses “ self-initiated thoughts, emotions, and actions that are purposefully adjusted and adapted to achieve personal goals ” . Expanding on this, Panadero et al. (2018, p. 16) articulate “ self-regulated learning as a comprehensive framework that elucidates learners' conscious and unconscious cognitive, behavioural, motivational, and emotional processes”. These processes are experienced while engaging in mathematics tasks, ranging from explicit enactment of specific learning strategies like creating concept maps to emotional reactions triggered by negative feedback. In essence, self-regulated learning delves into learners' mental, emotional, and motivational journeys to pursue their goals.

In mathematics, metacognition and formative assessment hold significant relevance due to the discipline's emphasis on problem-solving and critical thinking (Peel, 2020). Engaging in metacognitive activities enables learners to gain a deeper understanding of their thinking processes, facilitating the identification of necessary actions to solve problems and address errors and misconceptions (Khoza & Biyela, 2020). Furthermore, formative assessment plays a crucial role by providing learners with valuable feedback on their progress, enabling them to evaluate their performance and pinpoint areas that require focused efforts. By actively participating in metacognitive activities, learners develop a heightened awareness of their learning processes, empowering them to identify areas for improvement and devise effective strategies to enhance their learning outcomes(Panadero et al., 2018).

Co-regulated and self-regulated learning are valuable strategies that can be employed in the mathematics classroom to enhance the learning process. By leveraging the power of collaboration and social interaction, learners can actively engage with their peers and develop their self-regulation skills. This approach promotes a positive learning environment and empowers learners to take ownership of their learning journey(Peel, 2020). Integrating selfregulated learning, metacognition, and formative assessment in mathematics teaching and learning fosters a more comprehensive and effective learning experience(Siyephu, 2013). By understanding and actively managing their cognitive, emotional, and motivational processes, learners can optimize their learning potential and succeed tremendously in their mathematical endeavours.

2.6.5 Errors and Misconceptions in formative assessment

Learner errors and misconceptions play a crucial role in formative assessment as they directly contribute to the processes of Assessment for Learning (AfL) and Assessment as Learning (AaL). On the one hand, these errors and misconceptions provide valuable insights to teachers regarding their learners' mathematical understanding, enabling them to plan targeted interventions. Learners can better prepare themselves for summative assessments by discussing and addressing these errors.

According to Sikurajapathi et al. (2021, p. 41), "correcting errors and engaging in discussions about them is essential for learners to benefit from the assessment process truly". Mistakes offer a unique learning opportunity, as teachers are likely to adjust their instructional strategies to meet the specific learning needs of their learners. This adaptation in the teaching approach is a direct result of the errors made by learners. The significance of learner errors and misconceptions lies in their potential to serve as alternative answers to the questions posed. As Glendon and Clarke (2006) suggest, these errors and misconceptions aid in acquiring knowledge and scaffold the development of mathematical understanding.

It is also important to note that learner errors and misconceptions are invaluable tools in formative assessment. They provide teachers valuable insights into their learners' mathematical comprehension, allowing targeted interventions. Furthermore, learners can enhance their preparedness for summative assessments by addressing and discussing these errors. Correcting errors and engaging in discussions about them is crucial for effective learning from assessments. Ultimately, these errors and misconceptions serve as alternative answers and contribute to acquiring knowledge and scaffolding mathematical understanding.

2.6.6 Use of ICT in Mathematics Assessment

According to the existing literature, numerous researchers have utilized data from significant international comparative studies, such as the TIMSS and the Programme for International Learner Assessment (PISA), to examine the correlation between the use of ICTs and learner achievement in mathematics(Bulut & Cutumisu, 2017; Demir & Kiliç, 2009; Falck, Mang, & Woessmann, 2018). These studies have yielded mixed results, with some indicating positive associations and others revealing negative relationships. Let us first delve into the findings that highlight the benefits.

Several studies have demonstrated a positive correlation between the use of ICTs and learner achievement in mathematics (Hwang, Wang, & Lai, 2021). Notably, using ICTs in mathematics assessment has significantly enhanced learner achievement. For instance, Bulut and Cutumisu (2017) examined the PISA 2012 data to evaluate the impact of ICTs on learners' mathematics achievement. Their research revealed that learners with access to computers at home and school performed better in mathematics. Similarly, Skryabin, Zhang, Liu, and Zhang (2015) and Petko, Cantieni, and Prasse (2017) discovered a significant positive relationship between the use of home computers and mathematical achievement.

Furthermore, interactive whiteboards have been linked to improved learner performance, particularly in English and mathematics. Skryabin et al. (2015) found that Grade 8 learners who frequently utilized computers at home, primarily for educational purposes, achieved better results in mathematics. Computers at home may have provided learners a more dynamic approach to studying mathematical concepts in a virtual context, leading to higher mathematics scores (Kul, Celik, & Aksu, 2018). In addition, technology-based assessment serves as a bridge between the school and home environments, allowing learners to engage in real-time practice, enhance their knowledge, and work at their own pace, both inside and outside the classroom (Kukulska-Hulme et al., 2022). Moreover, these assessments incorporate multimedia features that aid learners in visualizing complex concepts (Wang & Tahir, 2020). Simuja (2018) and Nasution (2022) assert that memory retention is enhanced through visual support and wellstructured activities, enabling learners to recall the necessary knowledge better. Additionally, Wang and Tahir (2020) suggest that multimedia elements, such as visual and auditory textbased materials, effectively enhance learners' mathematical language skills compared to traditional paper-based materials.

Ayieko, Gokbel, and Nelson (2017) conducted a study investigating the relationship between computer usage and mathematics achievement in Taiwan, Singapore, and Finland, utilizing data from TIMSS (2011). The researchers found that learners in Taiwan who utilized computers both at home and school exhibited poorer mathematical reasoning skills.

In contrast, Kruger (2018) explored the connection between investment in ICTs for learning and teaching and mathematical achievement in a South African context, utilizing TIMSS (2011) and TIMSS (2015) data. The findings revealed that South African learners who regularly used computers to search for mathematical principles, concepts, and practice skills and procedures performed worse than their counterparts who did not rely heavily on computer usage. Moreover, these learners also exhibited lower mathematical performance when frequently using computers for information retrieval and data analysis. Kruger (2018) further discovered that the more frequently learners utilized computers at home, the more their mathematical results suffered.

Integrating ICT into assessment has become a necessary component of effective teaching that enhances learning, particularly in the 21st century(DBE, 2019). In this digital age, learners are driven by their passion for technology and digital tools, making it crucial to motivate and encourage them to learn through the integration of ICT (Wood et al., 2013; Erduran, 2019). While some South African schools have a technological infrastructure supporting technologybased assessment, most still rely on traditional paper-based assessments. This creates a knowledge gap regarding integrated or alternative assessment methods (DBE, 2019).

Technology-based assessments offer numerous advantages over traditional paper-based forms. By utilizing ICT, learners can personalize their learning experience. Adaptive learning software enables learners to receive individualized education and practice tailored to their needs and abilities(Kapp,2012). This ensures that each learner is appropriately challenged and can progress at their own pace. The use of ICT in mathematics assessment brings several benefits for both teachers and learners. It enhances grading accuracy and efficiency, simplifying the assessment process (Baguio et al., 2021). Additionally, it fosters a more engaging and interactive learning environment, capturing learners' attention and interest(Ke & Clark, 2020). Furthermore, ICT allows for personalized education, catering to the unique needs of individual learners (Alam, 2021). As technology advances, we can anticipate even more innovative applications of ICT in education. These advancements will further enhance teaching practices and promote compelling learners' learning experiences.

2.6.7 Use of Gamification in Assessment of Mathematics

The National Council of Teachers of Mathematics (NCTM) (2014) has emphasized incorporating formative assessment and technology into the mathematics classroom to facilitate meaningful learning. Consequently, many teachers have been integrating various technologies, including game-based or gamification approaches, to assess learners formatively. In his work, Kapp (2012, p. 23) defines a game as " a system in which players engage in an abstract challenge, guided by rules, interactivity, and feedback, ultimately resulting in a measurable outcome that often elicits an emotional response " . Technology-based games, also known as gamification, have proven to be effective tools for enhancing learning and motivation by integrating the principles of game thinking into the educational process(Aljarrah, 2020).

Mathematics is crucial in fostering inventiveness and creative capacity within the teachinglearning process. This creative aptitude extends to learners who actively construct meaningful learning experiences and solve problems (Ye & Xu, 2023; Aljarrah, 2020). Moreover, mathematics is essential for individuals to actively contribute to an equitable society (Kearns & Roth, 2019; Wood et al., 2013; Baguio et al., 2021). Specific rule systems characterize games and involve competition or conflict among players to pursue specific goals or outcomes (Coelho & Abreu, 2022). Umay (2002, p. 280) further asserts that "most games are predominantly mathematics, and mathematics itself is akin to a game " . The underlying structure of mathematics reveals the presence of creative thinking, deductive reasoning, and interconnectedness, mirroring the structure of games. Integrating formative assessment and technology, mainly through gamification, may significantly enhance learning outcomes and motivation.

Incorporating games into mathematics instruction has become essential to enhance the learning experience (Hacsaliholu-Karadeniz, 2017; Ke & Clark, 2020). Effective gamification inspires and engages players for an extended period, allowing learners to participate in the mathematics classroom, leading to a fruitful exploration of ideas, concepts, preconceptions, and experiences (Ye & Xu, 2023). Numerous studies have demonstrated the significant contribution of gamification to mathematics instruction (Kim & Castelli, 2021; Klock et al., 2020; Lister, 2015;). For instance, Landers and Callan (2011) developed an online learning course incorporating optional multiple-choice quizzes, allowing learners to earn badges upon completion. Feedback from learners indicated that these gamified assessments were entertaining and rewarding at the end of the semester. Similarly, Alsawaier (2019), Acevedo (2021), and Walsh (2014) agreed that gamification helps foster critical thinking abilities, promote cooperation, and enhance user engagement while positively influencing behaviour. Furthermore, Berger, Lahmer, Reuther, and Schoch (2023) reported that gamification aids learners in understanding the numbering system and improving their skills with multidigit numbers. Landers (2019) conducted a study comparing gamified and non-gamified courses and found that any form of gamification in learning, regardless of the specific game components used, produced beneficial effects for learners. However, Mader and Bry (2019) cautioned that gamification could lead to an overreliance on incentives, and removing the reward system may result in demotivation. Additionally, leader boards may create unhealthy competitiveness and discourage less competitive learners from participating in gamified courses, thereby undermining their learning and motivation.

Game thinking, as defined by Kim and Ke (2017), refers to a specific game design that effectively engages players and motivates them to persist until they master the given task. This design technique, resembling elements of gaming, enhances performance and fosters a desire to succeed (Kim, 2017). In mathematics education, this characteristic proves highly effective as it stimulates critical thinking and instils a problem-solving mindset, ultimately leading to a deeper understanding of mathematical concepts (Nasution, 2022). According to Angesleva (2014), gamification offers individuals a multi-sensory experience, encouraging active engagement and continuous cognitive processing. Unlike traditional learning methods that rely on rote memorization, gamification stimulates the brain and promotes flexibility, resulting in improved learning outcomes (Featherstone, 2022). This impact on brain structure and learning ability is particularly pronounced in learners naturally inclined to adapt to new ideas and embrace change more readily than adults (Angesleva, 2014).

Wang (2015) highlights three compelling reasons for incorporating gamification into teaching practices. Firstly, it allows teachers to monitor learners' progress in real-time, enabling timely interventions and providing immediate feedback (Sindre, Nattvig & Jahre, 2009; Spodark, 2010). Secondly, gamification facilitates the development of skills that may not be easily cultivated through traditional teaching methods (Owston, Wideman, Ronda & Brown, 2009). Lastly, it enhances learner motivation, engagement, and overall learning experience.

Acknowledging the perspective presented by Zhang and Yu (2021), who argue that gamification may not be universally beneficial for all learners, is essential. Some individuals may become overly engrossed in the entertainment aspect of games, leading to distractions from the subject matter and hindering the development of critical thinking skills (Alhammadi, 2021). Katmada, Mavridis, and Tsiatsos (2014) argue that while gamification can motivate learners, further investigation is necessary to establish its impact on academic performance in mathematics. Geelan et al. (2015) also emphasize the need for additional research to validate the effectiveness of gamification in meeting learner needs and enhancing learning outcomes.

In comparing traditional education and instructional approaches incorporating gamification, Putnam (2020) concludes that traditional instruction prioritises objectives over actual learning outcomes. Traditional methods often rely on prescribed lists of activities, lack interactivity, and rely on summative assessments rather than ongoing formative assessments and feedback (Levent & Ertok, 2020). Conversely, Dauda (2021) argues that traditional instruction methods are unproductive, while gamification offers a more personalized and learner-centred approach. Liu, Oubibi, Zhou, and Fute (2023) assert that interactivity, continuous corrective feedback, and challenging tasks are crucial for achieving the goals of gamification and positively impacting learning outcomes. Furthermore, gamification bridges traditional classroom teaching and the digital world (Yanuarto, Setyaningsih & Wahyuningsih, 2023).

Miller (2019) believes mathematics is vital in developing intellect and fostering coherence in thoughts and ideas. As Dauda (2021) highlighted, these abilities provide learners with the necessary skills to engage with and make sense of the world around them. Tolentino and Roleda (2019) outline three essential rules for the appropriate application of gamification. Firstly, a thorough understanding of the target audience is crucial. Secondly, clear objectives for the activity or system should be defined to ensure that players understand their expected roles. Lastly, appropriate game components are suggested to motivate individuals to participate actively. Understanding learners and their perceptions is crucial from an educational standpoint, as they are the key players in the system. This is essential for enhancing learners' motivation and engagement, thereby promoting the effectiveness of gamified classrooms.

However, a study by Yanuarto, Setyaningsih, and Wahyuningsih (2023) suggests that further mathematical gamification research is needed. This is because most mathematical games fail to engage learners in addressing real-world problems and utilizing their mathematical skills. According to Miller (2019), every learner has the potential to solve mathematical problems and apply their knowledge and skills to establish a connection with the world. Byrge (2023) also agrees that gamification should be designed to allow learners to transition into an authentic, real-world setting. Learners who can create links with real-life situations will better appreciate mathematics's value, extent, and boundaries in influencing their everyday decisions (Putman, 2020). These behaviours can contribute to promoting lifelong learning.

Moreover, Byrge (2023) argues that game thinking requires in-depth study and understanding of motivation and design methods rather than relying on a badge and leaderboard system. This shift in perception necessitates changes in instruction and the establishment of specific instructional connections with mathematics. The need for pedagogical change calls for developing new procedures to enhance mathematics instruction, making it crucial to experiment with new strategies. The exploration of this study, the use of gamification in instruction, and the recommendations highlighted by the scholars mentioned above were prompted by the achievement gap in mathematics. It is imperative to recognize the significance of understanding learners, their perceptions, and the potential of gamification in mathematics instruction. This understanding can lead to improved engagement, motivation, and real-world application of mathematical skills, ultimately bridging the achievement gap and promoting lifelong learning.

2.7 Use of Kahoot! as gamification technology

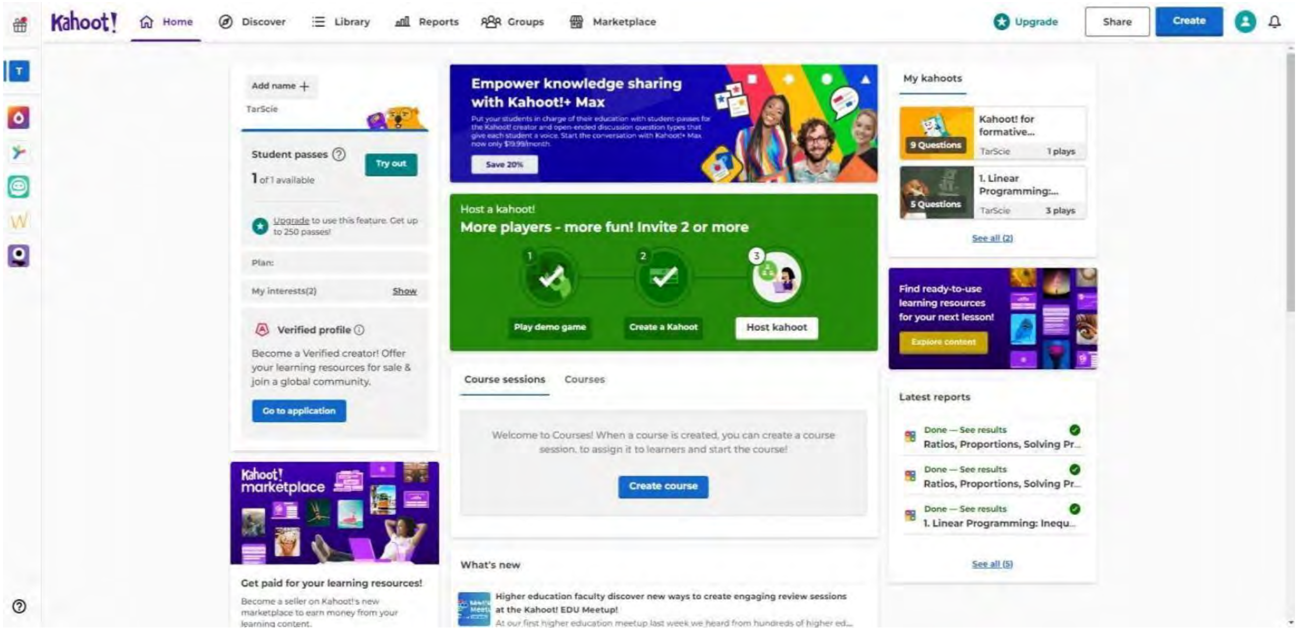
In recent years, gamification technology has gained significant popularity, with many teachers embracing it to engage learners. One such tool that has emerged is Kahoot!, a game-based learning platform that enables users to create and participate in quizzes, polls, and debates. This platform offers a range of question formats, including multiple-choice, true/false, and openended questions, allowing learners to test their knowledge and receive immediate feedback on their responses (Ilmudinulloh, 2023; Zhiwei, 2019).

The feedback provided by Kahoot! is invaluable in scaffolding learners' mathematics education, as it helps identify areas where additional support is needed. For instance, if a learner answers a question incorrectly, Kahoot! not only reveals the correct answer but also explains its accuracy. These comments enhance learners' understanding of the concept and improve their performance in subsequent quizzes and games. Moreover, Kahoot! Facilitate learner collaboration (Zhang, 2022; Cadet, 2023). Learners can benefit from each other's knowledge and perspectives through group quizzes and exercises. For example, if a learner struggles to comprehend a particular topic, they can work alongside their classmates to gain a better understanding. This collaborative approach fosters a deeper mathematical understanding by offering additional support and diverse insights (Lee, 2016; Moloi,2024).

It is worth noting that Kahoot! is a dynamic platform that is constantly evolving. To access this tool, individuals can easily sign up for a free Kahoot! account on the website https://create.Kahoot!.it. For a visual representation, please refer to Figure 1 below.

Figure 1

Kahoot! homepage



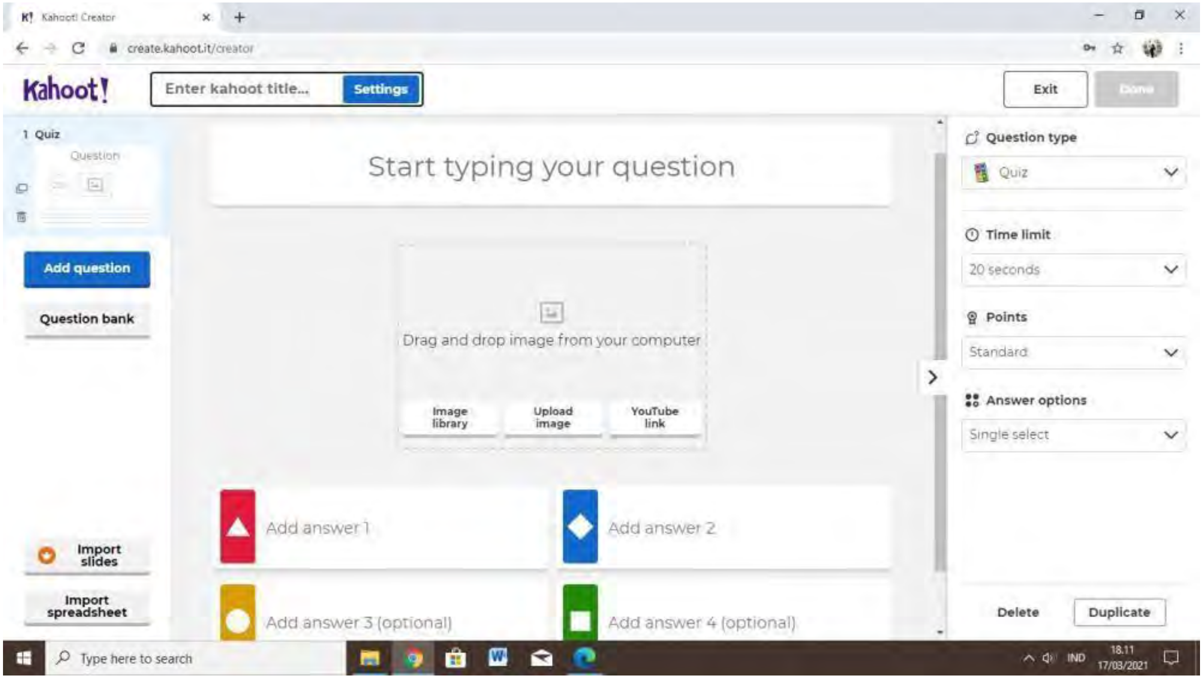
Using Kahoot!, teachers can leverage gamification technology to create an engaging and interactive learning environment. This platform provides immediate feedback to learners and promotes collaboration and a deeper understanding of mathematical concepts.

The teacher can create their quizzes by clicking on the blue button labelled "Create" in the top right corner of the screen. Each question within the quiz can be assigned a specific time limit, ranging from 5 to 20 seconds, depending on the difficulty level. The types of questions available include True or False questions, which are accompanied by four options. These options are visually designed with unique symbols and colours to enhance the learning experience. Additionally, teachers can incorporate images or videos into their quizzes, effectively capturing the learners' attention.

Kahoot! allows teachers to upload pictures or link to YouTube videos to enhance their quizzes further. Furthermore, teachers can choose whether to keep the game private or share it with a broader audience. The platform also offers a wide range of pre-made Kahoot! projects that can be published and modified using the discovery option. To add an element of competition, teachers can set a specific time limit for learners to answer each question, ranging from 5 to 120 seconds (refer to Figure 2). Moreover, the platform allows teachers to assess learners' performance and award bonus points to those who answer questions correctly at a faster pace compared to their classmates.

Figure 2

Kahoot! Question screen



The teacher begins by creating a free account on Kahoot! Website, specifically at https://create.Kahoot!.it. Once the account is set up, the teacher can choose to play the game in either team mode or classic mode, which is player vs player. This allows for a more interactive and engaging experience in the classroom, as it encourages teamwork and healthy competition. It is important to display the image on a large screen to ensure everyone can see the game. This way, all learners can easily follow along and participate in the game. The next step is for the learners to connect to Kahoot! using their mobile devices. They need to enter the unique PIN code displayed on the screen. This pin code is key to accessing the game and joining in the fun.

Once connected, learners are presented with four options, each represented by a different shape: a triangle, a diamond, a circle, and a square. They must tap the correct symbol within the given time limit. This not only tests their knowledge and understanding but also adds an element of excitement and challenge to the game. After each question, answers are distributed on the subsequent screen(s). This allows learners to see which options received one or more check marks, indicating the correct answers. This feedback helps them gauge their performance and learn from their mistakes.

2.8. Benefits of using Kahoot! Gamification for formative assessment

Gamification has emerged as a popular and influential trend in education with Kahoot! standing out as one of the most widely utilized gamification tools for formative assessment. Kahoot! is a dynamic game-based learning platform that empowers teachers to create interactive quizzes, surveys, and discussions, all of which learners can actively participate in using their mobile devices. Adopting Kahoot! for formative assessment offers numerous advantages, particularly fostering learner engagement and motivation (Thomas, 2014). By infusing an element of fun and excitement into the learning process, Kahoot! provides an engaging avenue for learners to participate actively. The platform's competitive nature fuels a sense of enthusiasm and determination among learners, ultimately leading to enhanced learning outcomes and academic success (Dunn & Kennedy, 2019; Rambe, 2021).

Another notable advantage of incorporating Kahoot! into formative assessment practices in providing rapid feedback to learners (Nadeem & Falig, 2020). Following each question, learners receive immediate feedback on the accuracy of their responses, enabling them to learn from their mistakes and make swift improvements. Simultaneously, this feature empowers teachers to identify areas where learners may struggle, allowing them to adapt their teaching methods accordingly. The efficiency of the Kahoot! Gamification platform in facilitating formative assessment, also known as evaluation for learning, has been widely acknowledged (Budiati, 2017; Mada & Anharudin, 2019). By enabling teachers to design real-time quizzes and surveys, Kahoot! equips teachers with the means to gauge learner progress and identify areas that require additional attention. This invaluable insight empowers teachers to tailor their instruction to meet the specific needs of their learners.

Furthermore, Kahoot! Gamification actively promotes collaboration and communication among learners (Zhang & Yu, 2021). The platform's team-based approach allows learners to work together, pooling their knowledge. Collaboration and communication are crucial for success in the 21st century (Dunn & Kennedy, 2019; Rambe, 2021; Zhand & Yun, 2021). Utilizing Kahoot! Gamification as a tool for formative assessment can enhance these skills. This game-based learning platform is accessible and adaptable, making it suitable for various educational settings such as traditional classrooms, online classrooms, and remote learning environments. Furthermore, Kahoot! is inclusive, catering to learners with disabilities, and can be personalized to meet individual needs.

According to Thomas (2014), teachers can benefit from using Kahoot! when presenting new material or reviewing previous concepts. Teachers can assess learners' understanding of a topic by collecting and analyzing data in an Excel spreadsheet. As an assessment tool, Kahoot! effectively evaluates learner progress and fosters a learner-centred environment (Licorish, Owen, Daniel & George, 2018). Teachers can create or utilize existing online games, enhancing learner engagement, motivation, and interest in the subject matter (Mart, 2019; Budiati, 2017; Mada & Anharudin, 2019). Moreover, Kahoot! encourages learners to apply their knowledge and test their critical thinking skills. The game also provides a constructive competitive environment that promotes learner interaction (Mubaslat, 2012; Rambe, 2021). In comparison to paper-based assessments, game-based assessments offer several advantages.

Figure 3

Kahoot! Gamification's Strengths and Weaknesses (SWOT analysis), adapted from Kumari and Alex (2022).

Strength	Weakness
• Attractive, colourful interface • answer questions without embarrassment • with colour vision impairment. • Encourages active participation. • Completely free. • Multiple question styles. • Allows the shy learner to answer questions without embarrassment. • Shapes are used to accommodate any learner with colour vision impairment. • Immediate feedback	• Aware of an expectation for a quick response, learners may guess or answer questions without thorough consideration. • Noise generated when large groups of learners become excited. • learners without a device are not monitored. • Being ranked on performance does not appeal to all learners
Opportunities	**Threats**
• Can be used on most browsers; app available but not essential • Enables social interaction and discussions between class members • Tagging *Kahoot!* quizzes can further discussion and sharing via social media sites • A bank of quizzes is available for adaptation	• Limits on characters allowed per question: ninety per question; sixty per answer • If connection is lost, user will lose track of progress • Cannot be embedded within slides without use of third-party provider

Furthermore Kahoot! Gamification proves to be an effective tool for formative assessment, offering a wide range of benefits. These include heightened engagement and motivation, immediate feedback, assessment for learning, enhanced collaboration and communication, and improved accessibility and flexibility. By incorporating Kahoot! into the classroom, teachers can create a dynamic and interactive learning environment that fosters learner success and achievement. However, it is crucial to acknowledge that Kahoot! should not be regarded as a substitute for traditional teaching methods. While gamification technology can yield positive results, it should be employed with other teaching strategies. Moreover, exercising moderation when utilizing Kahoot! is essential, as excessive use can lead to diminished engagement and burnout. By striking a balance between traditional teaching methods and the integration of Kahoot!, teachers can harness the full potential of this gamification tool. This approach ensures that learners remain actively engaged and motivated while benefiting from the immediate feedback and collaborative opportunities that Kahoot! offers. Ultimately, the judicious use of Kahoot! contributes to a well-rounded and effective educational experience.

2.9 Summary

This chapter discussed the significance of assessment in primary schools and provided comprehensive assessment guidelines. Additionally, it identified the gaps in assessment practices within South African primary schools, explored the integration of ICT in assessment, and emphasized the importance of formative assessment in mathematics. To illustrate the integration of ICT in mathematics assessment, the chapter introduced Kahoot! Gamification as a prime example. By drawing upon relevant literature, the chapter substantiates the relevance and advantages of this platform, making it particularly suitable for implementation in South Africa. Furthermore, the chapter thoroughly examines macro and micro assessment contexts, employing a literature review to address key arguments, biases, and research gaps on Kahoot! Gamification as a formative assessment tool to scaffold mathematical understanding. In conclusion, Kahoot! emerges as a valuable gamification technology that has the potential to enhance engagement, foster collaboration, and facilitate effective learning. Its versatility and customization options render it an invaluable tool for teachers. However, it is crucial to exercise moderation and supplement its usage with other teaching strategies. By effectively harnessing the power of Kahoot!, teachers can create a more captivating and impactful learning environment. The subsequent chapter will delve into the theoretical framework underpinning this study.

3 CHAPTER THREE: THEORETICAL AND ANALYTICAL FRAMEWORK

3.1 Introduction

A theory is a "set of interrelated constructs [concepts], definitions, and propositions that present a systematic view of phenomena by specifying relations among variables to explain and predict the phenomena" (Cohen et al. 2007, p. 12). A theoretical framework grounds the study and directs or guides the questions, research design, and methodology (Hartmann, Wieland & Vargo, 2018). Regoniel (2015, p. 2) states that a conceptual framework establishes the actions required during the study and considers prior knowledge of other researchers' "views and observations of the research subject." An analytical framework, on the other hand, provides a method for collecting and interpreting data to derive meaningful results and make sense of them (Goos, 2003). It is created by using existing theories as a framework or guide for the research (Magher, 2018). A conceptual framework explains, either graphically or in narrative form, the main things to be studied - the key factors, constructs or variables - and the presumed relationships among them.

Frameworks can be " simple or complex, theoretical or common-sensical, descriptive or causal" (Miles & Huberman, 1999, p.18). The theoretical frameworks in this study are informed by Vygotsky's (1978) Sociocultural theory and Thompson and Mishra's (2006) Technological, Pedagogical, and Content Knowledge (TPACK) framework. This chapter begins with a broad discussion of the Sociocultural theory. It discusses the five main factors crucial in this study: social interaction, zone of proximal development, social interaction, scaffolding and mediation. It further discusses the TPACK framework, which was the preferred framework for this study and further alluded to why the Replacement, Amplification, and Transformation (RAT) model and the Substitution, Augmentation, Modification, and Redefinition (SAMR) Framework, which are also frameworks for ICT adoption were not considered. The chapter concludes with a discussion of the limitations of the TPACK framework.

3.2 Sociocultural theory (SCT)

Sociocultural theory, proposed by Lev Vygotsky, is a psychological and sociological theory that highlights the influence of social and cultural factors on human development (Vygotsky, 1978). Vygotsky believed that social interaction and cultural context play a crucial role in shaping human cognition and behavior. This theory emerged as a response to the limitations of behaviorist and cognitive theories, which failed to consider the impact of social and cultural variables on development (Vygotsky, 1978). Vygotsky argued that individual factors such as genetics and cognitive processes alone are insufficient to explain human cognition and behavior. Instead, he emphasized the significance of social norms, language, and cultural practices in shaping human development.

Central to sociocultural theory is the concept of the zone of proximal development (ZPD). The ZPD refers to the gap between what a learner can accomplish independently and what they can achieve with the guidance of a more knowledgeable person (Correia & Harrison, 2020). According to Vygotsky (1978), learning occurs when a learner operates within their ZPD with the assistance of a more knowledgeable individual. This concept has been widely employed in educational research to help teachers understand how to scaffold learning for their students (Erbil, 2020).

Moreover, sociocultural theory offers valuable insights into the role of culture in human development. Cultural practices and beliefs have a profound impact on individuals' thinking and behavior (Erbil, 2020). For example, storytelling as a cultural practice has been shown to enhance language development and socialization in young children. Sociocultural theory explores how cultural practices and ideas influence human development across different cultures. The social constructivist paradigm underpins sociocultural theory, positing that knowledge is socially constructed through interaction and shared among individuals (Bryman, 2001; Correia & Harrison, 2020). According to Vygotsky (1978), learning and development are embedded in social events, occurring as learners interact with others, tools, objects, and events in their community environment.

This study draws upon four key ideas from Vygotsky's sociocultural theory: social interaction, the zone of proximal development (ZPD), mediation, and scaffolding. These concepts provide a framework for understanding how formative assessment can be utilized to scaffold mathematical understanding and promote effective learning experiences for learners.

3.1.2 Social Interaction (SI)

According to Vygotsky's (1978) theory, social interaction (SI) is pivotal in learning and teaching. Vygotsky posited that learning is inherently social, occurring through meaningful interactions. Social interaction emphasizes that learning is most effective when individuals engage in collaborative activities with others with more excellent knowledge and expertise

(Erbil, 2020). This concept is called the zone of proximal development (ZPD), which represents the disparity between a learner's independent capabilities and potential with appropriate guidance and support (Vygotsky, 1978). Vygotsky's theory underscores the significance of social engagement in the educational journey. By recognizing the value of interactions, teachers can foster an environment that promotes active learning and knowledge acquisition. Encouraging learners to collaborate with peers with advanced skills and understanding can enhance their learning experiences. This collaborative approach allows learners to bridge the gap between their current abilities and untapped potential, ultimately facilitating their growth and development(Teo, 2019).

The zone of proximal development serves as a guiding principle for teachers, highlighting the importance of providing appropriate scaffolding and support to learners. By identifying a learner's ZPD, teachers can tailor their instruction to meet individual needs, ensuring that learners are neither overwhelmed nor unchallenged. This personalized approach empowers learners to progress at their own pace while fostering autonomy and self-efficacy. SI in learning and teaching is important because it allows learners to engage in meaningful interactions with others. Through these interactions, learners can acquire new knowledge, skills, and perceptions that they may not have been able to acquire on their own. Additionally, SI helps learners develop social skills such as communication, collaboration, and empathy, which are essential for success in academic and non-academic settings (Erbil, 2020; Teo, 2019).

This study adopted SI because formative assessment involves lucrative activities, including discussions, debates, group projects, and peer feedback. These activities promote learning by allowing learners to share ideas, receive feedback, and engage in critical thinking. Formative assessment can be practical when teachers create engaging opportunities for learners to plan or organize their group work and make group decisions by compromising and resolving conflicts to be effective (Dilova, 2021). Damon (1983) and Azmitia (1988) see sustained conversation as a critical feature of effective peer interaction in the classroom. Moreover, building on other learners' ideas and providing explanations that stimulate the explainer to justify, reorganize, and clarify their thinking is a form of learning (Webb, 1995). Learning is not complete when learners have given up.

Black and Wiliam (2009) also found that social interaction is a vital process in assessment because it systematically reveals learners' hidden beliefs, opinions, and ideas (i.e., tacit knowledge). Activities that promote spontaneous interaction are highly engaging and a fundamental reason for the popularity of computer games (Malone & Leper, 1987). This social and cultural interaction is mediated through culturally constructed tools such as language, materials, signs, and symbols that create uniquely human forms of higher-level thinking. Black and Wiliam (2009) also acknowledge this complexity and refer to the inherent spontaneity of constructive dialogue as "a daunting problem for teachers" (p. 13). It is difficult because it confronts teachers with how learners reason, evaluate and synthesize information to solve problems. It often requires a radical change in their approach to teaching (Black & Wiliam, 2006; 2009). Social interactions in formative assessment can be in the form of teacher(parent) -learner (in this study, researcher-teacher), peer (learner/ teacher – teacher), cooperative learning groups, and communities of practice since the study is working with mathematics professionals.

Interaction is crucial in this study as it catalyzes learning acquisition and assimilation (Danilov, 2020). During workshop discussions, teachers engaged in meaningful interactions with each other and the researcher, fostering the exchange and acquisition of knowledge. Schoen (1987) aptly describes reciprocal interaction as a dynamic and unpredictable process encompassing a range of activities such as questioning, responding, adjusting, listening, demonstrating, observing, imitating, and critiquing. These interconnected actions create a chain reaction, where one intervention or response can trigger or build upon another (p. 114). Kyriakides, Anthimou, and Panayiotou (2020) argue that learners can only develop meaningful knowledge and acquire metacognitive skills when they establish connections between concepts and procedures. In line with this, Veenman and van Cleef (2019) advocate for instructional approaches that explicitly demonstrate the interplay between concepts and procedures, ultimately leading to a deeper understanding of mathematical principles.

However, despite its many benefits, the social interaction I observed during the research activities shortfalls that can impact individuals and learning. Firstly, social interaction, in some cases, leads to misunderstandings and conflicts. When people were interacting with one another, there were instances of miscommunication or misinterpretation of intentions. This results in misunderstandings that strain relationships and lead to conflicts. For example, a simple comment by one participant in a conversation could be taken out of context and offend the other person. These misunderstandings and conflicts create tension and hostility, making it difficult for individuals to maintain healthy and positive relationships.

Secondly, social interaction can also subject individuals to peer pressure and conformity (Villeval, 2020). When people interact with others, they often find themselves influenced by the opinions and behaviours of those around them. This can lead to a strong desire to fit in and conform to societal norms, even if doing so contradicts their beliefs or values. The impact of peer pressure can be particularly pronounced among young people, who may feel compelled to conform to their peers' expectations to gain acceptance (Kaur & Gupta, 2023). Consequently, individuals may compromise their identity and make choices they disagree with.

Social interaction can contribute to disseminating misinformation and rumours (Kaur & Gupta,2023). Information can spread rapidly through social media platforms and online communities in today's digital age. While this can be advantageous for sharing knowledge and connecting with others, it also means that false information and rumours can quickly gain traction. This can result in confusion, fear, and even harm if individuals act based on inaccurate information. Therefore, it is crucial for individuals to critically evaluate the information they receive and verify its accuracy before accepting it as truth.

While social interaction offers numerous benefits, it is essential to acknowledge and address the potential drawbacks it can bring. By being aware of the potential for misunderstandings and conflicts, resisting the pressures of conformity, and critically evaluating the information we encounter, we can navigate social interactions more effectively and ensure that they contribute positively to teaching and learning.

3.1.2 The Zone of Proximal Development ZPD

The Zone of Proximal Development (ZPD) (Vygotsky, 1978) concept is central to formative assessment in the classroom, which entails a significant shift in classroom culture from a teacher-centred culture to one that promotes equality and reciprocity among learners. Vygotsky (1978: p. 85) defines the ZPD as "the distance between the actual developmental level determined by independent problem solving and the level of potential development determined through problem-solving under adult guidance or in collaboration with more capable peers." As can be seen from this definition, knowledge development is enabled by the collaboration between an individual whose cognitive mindset shows potential for change and another individual (or a collective) who intentionally works together to accomplish a task and pursue a common goal. Using terms such as "equality, reciprocity, and collaboration" in the above definitions is consistent with this study, which views the researcher and teachers as participants in a reciprocal dance of acquiring ideas and actions (Brown et al., 1993).

Common teaching applies in workshops where the researcher and teachers explore mathematics problems and then share their problem-solving strategies in an open dialogue (Hausfather, 1996; Andri, 2020). This two-way communication becomes an instructional strategy by encouraging teachers to go beyond answering questions and engage in the discourse (Watling and Ginsburg, 2019; Thomas and Brown, 2021). The researcher acknowledges that teachers, as trained professionals, can achieve as individuals but believes that teachers can achieve more when collaborating within a community of practice. This view is shared by Andri (2020), who contends that one way to view teacher-learner interactions in formative assessment is to view their activities as ongoing participatory appropriation of each other's ideas and activities in a co-constructed ZPD. At the first level, mathematics teachers will learn to use Kahoot! Gamification is a formative assessment to improve mathematical understanding during social interactions and workshops under the guidance of the more knowledgeable other (MKO) (first, the researcher and second, the technology). The researcher will explain and demonstrate the use of Kahoot! as an assessment tool and discuss assessment and mathematical understanding with teachers.

This study is based on the view that technology can potentially act as an MKO because specific ways of using technology can guide individuals in their learning, as technology can act as self direction. Through this collaboration, individual teachers can achieve higher levels of technological proficiency (Vygotsky, 1978). argue that instruction needs to be directed toward the upper limits of a learner's ZPD and that by doing so, "the teacher is guided to a level of success that neither the teacher nor the teacher him/herself had previously contemplated" Brown and Ferrara (1985, p. 302). Understanding how collaboration and support from teachers, peers, or technology can influence learning allows us to explore how technology can best enhance individuals' ZPD and leverage MKOs. Understanding Vygotsky's theory of technology as a mediation tool will allow this study to explore different ways to integrate technology in the classroom.

Through formative interactions and dialogue with teachers, the researcher can gain a more profound, practical understanding of assessment at the second level. In this study, the researcher gained knowledge of the cultural tools and learners' errors and misconceptions that constitute the mediation tools for various topics and reciprocated the knowledge by sharing it with teachers by explaining how they can be used in formative assessment with Kahoot! Gamification. As Kao (2010, p. 117) notes, "Interaction with people, usually parents, teachers, or peers, who have different skills or knowledge often leads to effective learning that encourages individuals to reach the next level of learning or understanding." Therefore, mediated learning relies on the guidance of an advanced learner, such as a teacher whose role is to help interpret the complex world of input from the environment so that the learner can focus, classify, and consider relationships (Brower, 2019; Friedman, 2003). Later, what is learned through collaboration is then assimilated and internalized at the individual level, i.e., the individual transforms what is known through interaction and is enabled to use that knowledge independently.

3.1.3 Mediation of Learning

According to Vygotsky (1978), all human psychological processes are mediated by psychological tools such as language, signs, and symbols. Teachers teach learners these tools during the mediation process during their joint activity. Learners internalize them, which then act as mediators of learners' broader psychological processes (Pavlenkovich, 2022; Tzuriel, 2021). Pavlenkovich (2022) asserts that one of the essential concepts of Sociocultural Theory is that the mind is mediated. This means the individual does not establish a direct relationship with the world but is mediated through tools (Vygotsky, 1978). Collaborating with others, the individual uses tools to navigate the world according to their needs and goals. In this sense, tools become mediators between the subject and the object. In the 21st century, "symbolic tools" have proven to be very effective in translating a mostly abstract mathematical concept into the real world, such as using Geogebra software to teach functions and trigonometry, arithmetic systems, music, and language (Tzuriel, 2021).

Using tangible objects or artefacts as tools is a form of mediation. Hegel's theory that tools help people achieve their ends is the basis for the broader tool concept developed by Vygotsky. This emphasizes the function of tools to build activities (Vygotsky, 1978). Initially, physical tools were used to extend human talents. For example, a fishing rod was once considered an extension of the hand that facilitated fishing. However, the theory about using tools and their connection to human activities has since evolved beyond the idea of body extension. Material, symbolic, conceptual, or behavioural tools and their use have evolved in a culture and have become an integral part of human activities, acting as "carriers" of Sociocultural patterns and knowledge. They structure practical human training and activate various mental processes that regulate and qualitatively change this functional activity by acting as mediators. Researchers have developed the idea of artefact mediation by extending the original connections between real instruments and ideas (Cole, 1996).

According to recent studies, technological tools have emerged as powerful instruments to transform our understanding of technology (Geertsema, 2014; Jaakkola, 2020). For instance, research on artefact mediation suggests that while experts can effectively express and communicate their knowledge, novices often struggle (Wozney, Venkatesh & Abrami, 2006; Shepherd & Suddaby, 2017). However, novices can bridge this gap and develop interaction patterns similar to those of experts when provided with a learning environment that encourages the use of tangible tools (Flick, 2011; Goeker, 2016). Kahoot gamification is good for mediation because it promotes active engagement and participation among learners. By incorporating game elements such as quizzes, challenges, and rewards, Kahoot gamification motivates novices to interact with the learning content actively. This interactive approach allows novices to bridge the gap between their current knowledge and the expertise of experienced individuals. Additionally, Kahoot! Gamification provides an enjoyable learning experience, further enhancing the development of similar interaction patterns among experts.

3.1.4 Scaffolding

Scaffolding and formative assessment are strategies teachers use to promote learning in the zone of proximal development. Scaffolding refers to the support teachers provide to learners during problem-solving through reminders, cues, and encouragement to ensure the successful completion of a task. An essential feature of scaffolding, especially in authentic classroom contexts, is the retention of the task as a whole," the control of those elements that are beyond the learner's ability" (Wood, Bruner, & Ross, 1976, p. 90). According to Larkin, scaffolding is the systematic sequence of guided content, materials, tasks, and support from teachers and other Learners to optimize learning. Scaffolding supports learners until they can apply new skills and strategies independently. Morrissey and Brown (2009, p. 107) explain that "the goal of scaffolding is to ultimately transfer responsibility for the task to the learner as adult support decreases and the learner's skills increase." This can be accomplished by withdrawing support once the learner shows competence. For effective scaffolding, instruction should focus on skills that are "not too easy and not too hard, but just right" (Morrissey & Brown, 2009, p. 4). Based on the above definitions, scaffolding is a process in which a teacher or MKO supports the learner in their ZPD when needed and withdraws that support when it is no longer necessary. If the learner is struggling, the MKO or teacher stays in the area and increases their purposefulness just enough to support him, but not so much that he takes over the task. It decreases the purposefulness when the learner begins to succeed.

In his study, Anghileri (2006) categorizes scaffolding procedures into three main categories: environmental arrangements, review and restructuring, and the development of conceptual thinking. The first level of scaffolding, as proposed by Angileri(2006), focuses on creating a conducive learning environment. This can be achieved through various means, such as displaying puzzles, providing necessary tools, arranging seating and groupings, utilizing computers, offering encouragement, and organizing structured work. Another form of scaffolding involves the use of questioning. In this approach, the teacher or More Knowledgeable Other (MKO) guides the learners' understanding through purposeful questioning and positive interaction. Scaffolding is a crucial pedagogical technique that supports learners' learning process. Teachers can enhance learners' conceptual thinking and overall academic development by implementing adequate environmental arrangements and employing strategic questioning (Sutiarso et al., 2017).

Learners require a variety of alternative concepts based on their experiences, observations, perceptions, previous teacher explanations, and instructional materials (Wood, 2023). ICT gamification provides a rich resource for scaffolding learning. ICT can play a complementary and central role in learning by providing digital cognitive or adaptive tools or systems to support constructivist learning (Finali, Rulyansah, & Hutama, 2023). Implementing technology as a scaffolding, such as media scaffolding, during geometry teaching and learning processes can help learners complete a geometrical problem, shorten learning time, and provide a solid impetus for understanding geometry concepts (Sutiarso et al., 2017). Other researchers, including Wood (2023), have referred to McLeod's (1976) support as scaffolding. As Bandura (2011) stated, "Effective efficacy builders do more than convey positive appraisals; they structure situations for others in ways that bring success and avoid prematurely placing them in situations where they are likely to fail" (p. 32).

This study emphasizes scaffolding as a teaching method because it allows the researcher to act as a mentor and facilitator rather than an expert, which increases the opportunity for shared learning between the researcher and participants. It also encourages learners to take a more active role in their education and take responsibility for their learning (Berk & Winsler, 2002). Learners need a set of alternative conceptions based on the teacher's explanations, observations, perceptions, and instructional materials (Wandersee et al., 1994). As such, in this study, Kahoot! Gamification might provide a wealth of resources for learning scaffolds. Kahoot! Offer digital cognitive or adaptive tools or systems to promote constructivist learning and function as both a complementary and a central component of the educational process

(Sirkemaa, 2001). Scaffolding can be used successfully with a class and individual learners (Rulyansah & Hutama, 2023). Overall, scaffolding encompasses all the support teachers can provide learners to promote learning.

However, it is essential to remember that while scaffolding is better than other teaching methods, it is not the most effective. Abrieu (2000) claims that Vygotsky's theory overemphasized social effects on cognitive development at the expense of biological influences. However, this theory cannot explain why cross-cultural studies show that the developmental stages (apart from the formal operational stage) suggest that cognitive growth results from a biological maturation process similar across cultures. Teachers are prepared to guide learners based on the premise that scaffolding is an effective teaching strategy (Chen & Law, 2016; Segal & Stupel, 2023).

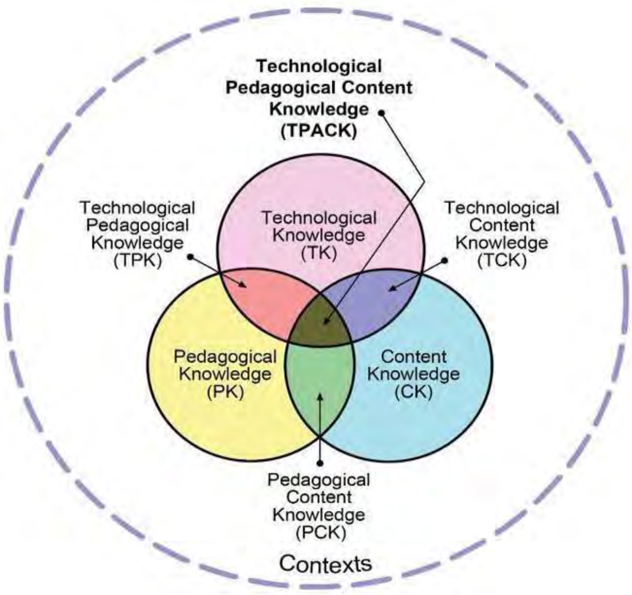
3.2 Technological Pedagogical Content Knowledge (TPACK)

Mishra and Koehler (2007) developed the Technological Pedagogical Content Knowledge (TPACK) Framework as a foundational theoretical structure that explores the relationship between pedagogy, content knowledge, and technology. This framework was built upon Shulman's (1986) Pedagogical Content Knowledge (PCK) descriptions. Mishra and Koehler (2006) enhanced the PCK by incorporating teachers' understanding of educational technologies to facilitate effective technology-enhanced instruction. TPACK serves as the basis for effective teaching with technology, requiring an understanding of how concepts are represented using technology, pedagogical techniques that utilize technology to teach content constructively, knowledge of the challenges and facilitators of learning, and how technology can address these issues. It also involves understanding learners' prior knowledge, theories of epistemology, and how technology can be used to build on existing knowledge and develop new ways of knowing (Koehler, Mishra, & Cain 2013, p. 16).

In a learning setting, TPACK is a comprehensive system that integrates Technological Knowledge, Pedagogical Knowledge, and Content Knowledge. TPACK aims to merge these three domains to create meaningful and competitive learning experiences. Mishra and Koehler (2006) initially developed TPCK with the intention of incorporating technology into teaching (see Figure 4). However, Thompson and Mishra (2007) later changed the name from Technological Pedagogical Content Knowledge (TPCK) to TPACK, emphasizing the concept of a total package of technologies that can support teaching and learning. The TPACK framework consists of seven knowledge domains: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), Pedagogical Content Knowledge (PCK), and Technological Pedagogical Content Knowledge (TPCK) (TPACK).

Figure 4

The TPACK model - Mishra & Koehler (2006)



This study mainly draws from two knowledge constructs of TPACK: Technological Pedagogical knowledge (TPK) and Technological Content Knowledge (TCK). However, other constructs are relevant in some contexts, and a description of each knowledge domain follows:

3.2.1 Content Knowledge (CK)

Content Knowledge (CK) is the teacher's knowledge of the subject matter, including concepts, theories, evidence, and practices that emerged during the development of that content. According to Shulman (1986), CK deals with images, philosophies, ideas, frameworks, evidential knowledge and procedures, and strategies for knowledge creation. It entails;

- the teacher's understanding of learning concepts, methods, and theories and the application of subject matter.
- the ability to create learning materials.
- provides pertinent information to the subject.

- formative assessment

In this study, the four characteristics of CK are improved through social interaction during workshops.

3.2.2 Pedagogical Knowledge (PK)

Pedagogical Knowledge (PK) refers to teachers' comprehensive understanding of various teaching methods and strategies rooted in educational theories. PK encompasses the expertise of teachers in employing diverse teaching styles and procedures, all guided by pedagogical principles. This knowledge encompasses a deep understanding of how learners acquire knowledge, effective instructional strategies, familiarity with different educational theories, meticulous lesson planning, efficient classroom management, and the implementation of appropriate assessment techniques (Chai et al., 2011; Schmidt et al., 2009).

Pedagogical Knowledge (PK) is essential to a teacher's professional repertoire. It encompasses various teaching methods and strategies, all grounded in educational theories. PK empowers teachers to employ various teaching styles and procedures, ensuring their instructional approaches align with pedagogical principles. This comprehensive knowledge encompasses a deep understanding of how learners acquire knowledge, the effective use of instructional strategies, familiarity with different educational theories, meticulous lesson planning, efficient classroom management, and the implementation of appropriate assessment techniques (Nepembe and Simuja 2023). Teachers with robust Pedagogical Knowledge (PK) are equipped with the necessary tools to create engaging and effective learning experiences for their learners. This knowledge encompasses diverse teaching methods and strategies, all rooted in educational theories. With PK, teachers can seamlessly adapt their instructional approaches to cater to their learners' unique needs and learning styles. This expertise includes a profound understanding of how learners acquire knowledge, the skilful use of instructional strategies, familiarity with various educational theories, meticulous lesson planning, effective classroom management techniques, and the implementation of reliable assessment methods (Schmidt et al., 2009). Pedagogical Knowledge (PK) is a vital asset for teachers, enabling them to employ various teaching methods and strategies based on educational theories. This comprehensive knowledge encompasses an understanding of learner learning.

3.2.3 Technological Knowledge (TK)

Technological Knowledge (TK) refers to the knowledge required to utilize and apply technology effectively. In today's world, technology has become an indispensable tool in education, particularly in light of its significant role in supporting the education system and various departments during the COVID-19 pandemic. Teachers need to be proficient in utilizing essential programs such as word processors, spreadsheets, browsers, and other relevant software to ensure seamless technology integration into their teaching practices(Jardin, 2023). Additionally, they should possess a fundamental understanding of hardware components and operating systems.

Teachers with the requisite technological skills can use technology's potential to enhance learning. This skill enables teachers to effectively engage learners, provide interactive and dynamic classes, and cultivate a digitally literate generation (Shambare and Simuja,2022). Teachers must constantly improve their technological knowledge and skills, given the everchanging technological landscape. This continuing professional development keeps teachers at the forefront of educational innovation, allowing them to adapt to new technologies and successfully educate learners for the demands of the digital age.

3.2.4 Pedagogical Content Knowledge (PCK)

Pedagogical Content Knowledge (PCK) refers to teachers' specialised knowledge, encompassing teaching methods tailored to a specific subject matter. PCK is the foundation for teachers to effectively transform their content knowledge and facilitate the development of a profound understanding among their learners (Shulman, 1986). PCK encompasses various aspects, such as pedagogical techniques, understanding the challenges and facilitators of concept acquisition, familiarity with learners' prior knowledge, and applying theories in specific contexts (Koehler & Mishra, 2009). Moreover, teachers with PCK comprehensively understand their learners' cultural capital, including factors such as age group, cognitive abilities, and how learners acquire skills and construct knowledge. In essence, PCK empowers teachers beyond mere subject expertise and equips them with the necessary tools to convey knowledge to their learners effectively. By leveraging pedagogical techniques and understanding the nuances of concept acquisition, teachers with PCK can create an engaging and enriching learning environment. They possess the ability to identify potential challenges that learners may face and employ strategies to overcome them. Furthermore, their knowledge of learners' prior knowledge and cultural capital allows them to tailor their teaching approaches to meet the unique needs of each learner. Teachers can promote a more comprehensive understanding of the subject matter in learners by incorporating PCK into their instructional methods. This broad knowledge enriches the learning experience by encouraging critical thinking, problem-solving, and application of knowledge in real-world scenarios.

3.2.5 Technological Content Knowledge (TCK)

Technological Content Knowledge (TCK) is the knowledge of selecting relevant technology for teaching a particular content. TCK is the knowledge about using technology to represent the content differently (Chai et al., 2011), such as using internet games to show the operations of fractions. Teachers need to know the technologies that best match particular subject content and how technology can alter the subject matter or vice versa (Koehler & Mishra 2008). Hence, in this study, TCK refers to the knowledge and skills teachers need to integrate technology into their formative assessment practice effectively. In the case of Kahoot!, teachers with strong TCK can create quizzes that align with their learning objectives and provide meaningful feedback to+ learners. They can also use Kahoot! as a tool for formative assessment, which involves gathering data on learners ’ learning to adjust instruction and improve outcomes.

However, teachers may struggle to use Kahoot! effectively with weak TCK. They may create quizzes that do not align with their learning objectives or do not provide learners with meaningful feedback (Jankowski, 2020).

3.2.6 Technological Pedagogical Knowledge (TPK)

Technological Pedagogical Knowledge (TPK) is the knowledge necessary to use technology with different teaching methods and strategies. Technological pedagogical knowledge is understanding how particular ICTs affect learners' learning and teacher teaching (Koehler & Mishra 2009). TPK is critical in this study because it enables teachers to plan and implement assessments that lead to mathematical understanding. For example, teachers need to know how best to integrate Kahoot! as an assessment tool into the senior phase mathematics to ensure compelling formative assessment opportunities for mathematical understanding. For this reason, in this study, teachers are trained during the workshop and equipped with skills and ideas (TPK) to integrate Kahoot! Gamification as an assessment tool.

3.2.7 Technological Pedagogical Content Knowledge (TPACK)

Technological Pedagogical Content Knowledge (TPACK) is a fundamental knowledge base that enables the effective utilization of technology in the classroom. It encompasses the integration of three key areas of expertise: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). TPACK is a conceptual framework that elucidates the interconnections, experiences, implications, and conditions within and between content, pedagogy, and technology (Mishra & Koehler, 2006). TPACK provides teachers with a comprehensive understanding of effectively integrating technology into their teaching practices. By combining content, pedagogical, and technological knowledge, teachers can create meaningful learning experiences for their learners. This knowledge base allows teachers to select appropriate technological tools and design and implement instructional strategies that enhance learner engagement and promote mathematical understanding. Through TPACK, teachers are equipped with the necessary skills to navigate the ever-evolving landscape of technology in education and ensure its successful integration in the classroom. It entails comprehending how pedagogy and technology can synergistically enhance learners' acquisition of pertinent content (Chai et al., 2011). It is crucial for teachers to possess more than just technological knowledge (TK) to employ technology proficiently in an authentic classroom setting (Thompson et al., 1998).

3.2.8 The rationale for using TPACK over other frameworks

Although the TPACK framework was ultimately chosen for this study, various theories were explored to guide the researcher in determining the appropriate data to be collected and analyzed. Numerous frameworks address the integration of ICT in mathematics assessment. These theories include but are not limited to, the Replacement, Amplification, and Transformation (RAT) framework (Hughes, Thomas, & Scharber, 2006), the Substitution, Augmentation, Modification, and Redefinition (SAMR) framework (Puentedura, 2006), and the TPACK framework (Koehler & Mishra, 2006). All three ICT frameworks share a common vision of integrating ICT into the teaching and learning context. They all acknowledge the need for adaptability to technological changes that impact pedagogical practices. The following sections discuss the RAT and SAMR frameworks and the rationale for not selecting them for this study. .

3.2.9 The rationale for using TPACK and the SCT theory in conjunction

Incorporating both the Sociocultural Theory and TPACK theory, helped the study to gain valuable insights from the complementary perspectives they offer. The Sociocultural Theory, rooted in the work of Lev Vygotsky, focused on the social and cultural dimensions of learning. It recognises that learning is a social process and that individuals construct knowledge through interactions with others. In the context of the study, this theory allowed for an exploration of how the use of Kahoot! gamification as an assessment tool can enhance learners' mathematical understanding through collaborative and interactive experiences. It helped us understand the role of social interactions, cultural norms, and collaborative learning in scaffolding mathematical understanding.

On the other hand, the TPACK framework emphasizes the intersection of technology, pedagogy, and content knowledge. It highlighted the importance of teachers' technological proficiency and their ability to effectively integrate technology into their pedagogical practices to enhance leaner learning outcomes. In the context of the study, TPACK provided a lens through which we can examine how teachers' understanding and use of Kahoot! as an assessment tool can support the teaching and learning of mathematics. It helps us explore the alignment between technological tools, pedagogical strategies, and mathematical content knowledge.

In terms of philosophical assumptions, the Sociocultural Theory focuses on the social and cultural aspects of learning, emphasizing the construction of knowledge through social interactions and cultural influences. Its ontological assumption is that knowledge is socially constructed, and its epistemological assumption is that learning occurs through participation in cultural practices. On the other hand, the TPACK theory is more concerned with the integration of technological, pedagogical, and content knowledge. While it does not explicitly address ontological and epistemological assumptions, it acknowledges the dynamic nature of knowledge and the importance of integrating technology, pedagogy, and content.

In conclusion, by integrating the Sociocultural Theory and TPACK theory, the study can provide a holistic and nuanced understanding of how the use of Kahoot! gamification as an assessment tool can scaffold learners' mathematical understanding. These theories complement each other by considering the social and cultural factors influencing learning while also exploring the effective integration of technology in pedagogical practices. The ontological, epistemological, and axiological assumptions of the study support a socially constructed and participatory approach to research.

3.2.10 The Replacement, Amplification, and Transformation (RAT) model

According to Kimmons (2016), the technology integration frameworks of Replace, Amplify, and Transform (RAT) and Substitution, Augmentation, Modification, and Redefinition (SAMR) are very similar. The first level is the replacement level. A digital tool replaces another format, such as when a learner marks vocabulary words in a word processor instead of circling them on a worksheet (Hughes et al., 2006). The task remains the same, but a different tool or medium is used. The second level is the reinforcement level. Here, a digital device is used to increase output or effectiveness, such as when Learners use word processing software instead of their hands to correct each other's writing (Hew & Brush, 2007). The task remains essentially the same at this level of technology use. Still, the capabilities of technology provide benefits to teaching or learning that cannot be achieved without technology. The third level is the transformational level. Digital technology transforms teaching methods, the learner's learning process, and how content is organized or presented (Hughes et al., 2006). Learners using Web authoring software to create hypertext-based stories is an example of transformation; this task would be impossible without this technology (Hughes, 2005). A qualitative assessment is conducted to determine the extent to which technology integration has impacted instructional practices such as;

- as teacher role, learner interaction, lesson preparation, learner interaction, and learner assessment,
- learner learning, and
- curriculum objectives to be achieved, learned or applied (Hughes et al., 2011).

The RAT model investigates the use of digital technology in educational practice, specifically whether these applications enhance, replace, or create new patterns (Hughes, Thomas, and Scharber, 2006). Cuban (1988) argues that digital technology should be used, without disturbing the basic features of the organisation, to make what already exists more efficient and effective. Technology as Transformation boosts the efficiency or productivity of instruction, learner learning, or curriculum (Hughes, Thomas & Scharber, 2006). Both ideas assume that technology affects what happens in the classroom, such as the development of simulations to assist people in understanding this effect and correctly using technology (Kimmons, 2016). Hughes, Thomas, and Scharber (2006) contend that teachers' reasoning and objectives, with specific goals in mind, guide their decision to adopt and use technology. They further emphasize the importance of connecting digital technology to the subject matter. Rather than emphasizing which technologies are used, RAT focuses on how they perform certain functions and activities, whether digital or analogue (Hughes, Thomas & Scharber, 2006). Teachers need to be familiar with the RAT framework to modify pedagogy and serve as an assessment framework for technology-enhanced lesson plans. The RAT framework is criticized as it removes the difficulty of interpreting context using concepts applicable in all settings, resulting in a reasonable universal norm. Teachers need precise models to provide clarity for learners integrating technology in different contexts, while researchers need clarity for evaluation purposes (Kimmons & Hall, 2016).

3.2.11 The Substitution, Augmentation, Modification, and Redefinition (SAMR) Framework

The SAMR model (Puentedura, 2006, 2014) has several levels. At the substitution level, one technology is substituted for another, such as writing a task using a word processor instead of pencil and paper. At this level, all previous traditional classroom activities are replaced by technology. At the modification level, only the tools are different; the task given to learners remains the same. The goal is the same, but augmentation uses a technology that is only slightly more functional than another. A modern word processor is an example of a tool that simplifies a task without fundamentally changing it. It has features such as spell check, grammar check, and copy and paste. The technologies used allow for significant changes in the work offered to learners. A group word processor like Google Docs is an example of how learners can simultaneously collaborate and work in real time by editing a shared document. So, at this level, the assumption is that technology will lead to better learning experiences that would not be possible with traditional methods. Thus, the teacher needs to decide if technology will allow for significant task redesign to improve the tasks while meeting the learning objectives of the third level, modification. The assigned task is completely recreated at the redesign level and may not resemble the original task. For example, the task of maintaining a public blog where learners write for the teacher and share their work with real readers worldwide. In such a redesign, teachers should engage Learners in learning and further investigate whether the redesign meets the intended learning standards (Puentedura, 2014).

According to Hamilton, Rosenberg, and Akcaoglu (2016), the main criticism of the SAMR model is its lack of context, rigid structure, and focus on the process of overuse of a technological product. Unlike TPACK, the SAMR model excludes context, which Hamilton, Rosenberg, and Akcaoglu (2016) argue needs to be included in any model of teaching and learning. Learning, teachers' pedagogy and practice, and learners' learning experiences are all contextual, so considering context allows for viewing multi-layered, complex educational environments. The authors emphasize the importance of understanding that there is no one size-fits-all solution to technology integration and use and that a model that does not consider context tends to overlook the complexity of technology adoption and use. According to Hughes, Thomas, and Scharber (2006), teachers' explanations and objectives with specific goals influence how they choose to adopt and use technology. The SAMR approach does not consider critical contextual elements such as technological infrastructure, resources and support, individual and group learner needs, and teacher expertise and support in digital technologies because it lacks context (Hamilton, Rosenberg, & Akcaoglu, 2016). Hamilton, Rosenberg, and Akcaoglu (2016) believe that while digital technologies are critical to learning success, they should not take precedence over other instructional strategies or tools as long as learning objectives are met. In addition, Rosenberg and Akcaoglu (2016) also believe that teachers need to be aware of the connections between instruction, technology, and learning to promote learner growth and development. If they understand this, teachers are better prepared to use digital technologies to support and enhance learner learning. Although the authors emphasize the importance of directly linking digital technologies to the subject, RAT focuses on how traditional or digital technologies fulfil specific roles and activities rather than what technologies are used (Hughes, Thomas, & Scharber, 2006).

3.2.12 TPACK applications in this study

TPACK is a conceptual framework that aims to incorporate technological knowledge into Shulman's (1986) Pedagogical Content Knowledge (PCK) framework. According to Shulman (1986, p. 9), "PCK goes beyond mere subject matter knowledge and encompasses the dimension of subject matter knowledge for teaching". Mishra and Koehler (2006) emphasize the modification of subject matter as the core of PCK, where teachers interpret the subject matter and find various ways to represent it and make it accessible to learners (Mishra & Koehler, 2006, p. 1021). The TPACK framework provides a productive approach to helping teachers integrate educational technology into the classroom by considering the different types of knowledge required and how teachers can develop this knowledge (Saal, 2017).

In this study, participants were selected based on their five years of teaching experience, which serves as one of the main criteria for possessing PCK. Consequently, the interventionist study employs workshops to create opportunities for professional PCK deliberations through social interactions and integrating Information and Communication Technology (ICT) to enhance formative assessment practices. To enhance learners' mathematical understanding, mathematics teachers need to focus on developing TPACK that enables them to think strategically when planning, organizing, implementing, critiquing results, and abstracting plans for specific mathematics content and diverse learner needs (Niess, 2008).

Teachers may effectively incorporate technology into their teaching practices using the TPACK framework, ensuring they have the knowledge and abilities to engage learners in meaningful learning experiences. Integrating ICT and social interactions through workshops provides a platform for teachers to enhance their professional PCK, ultimately improving their formative assessment practices. Moreover, a strong emphasis on developing TPACK among mathematics teachers is crucial for promoting strategic thinking and effective planning, organization, and implementation of mathematics activities that cater to the diverse needs of learners (Niess, 2008).

Furthermore, the TPACK framework plays a crucial role in evaluating teachers' knowledge, which can significantly impact their training and professional development opportunities, regardless of their experience level. It is essential for professional development programs to guide teachers in developing their knowledge and thinking in a way that takes into account the specific knowledge required for planning and organizing mathematics instruction (Niess, 2008). Moreover, Umugiraneza, Bansilal, and North (2017) argue that employing creative teaching strategies, such as technological simulation methods, is more effective than traditional chalk-and-talk techniques. Consequently, incorporating technology into mathematics assessment aims to enhance learners' proficiency. This highlights the relevance of the TPCK model in addressing the challenges identified by various scholars in investigating mathematics teachers' use of technology (Saal, 2017; Adnan & Tonduer, 2018; Neis, 2008).

Koehler et al. (2013) contend that teachers must possess technological, pedagogical, and content knowledge and be able to integrate all three forms of knowledge into their instructional practices for successful technology integration. As a result, Adnan and Tondeur (2018) argue that TPCK encompasses the foundational understanding of integrating technological skills and knowledge, as well as the content knowledge, learner knowledge, and pedagogy required for competent technology-based teaching in the classroom.

Mishra and Koehler(2006) address the importance of context in addition to the three domains of knowledge and the overlapping domains. They emphasize that knowledge realms cannot exist in isolation but are shaped by specific learning and teaching contexts (Mishra & Koehler, 2008). Mishra and Koehler (2006) further state that the use of digital technology in the classroom is influenced by factors such as subject, grade level, learner background, and available technology. Therefore, given its suitability for the research context, this study has adopted the well-tested and recommended TPACK model. Based on Mishra and Koehler's research, it is evident that integrating digital technology in the classroom is not a one-size-fitsall approach. The TPACK model provides a framework that can guide the successful integration of digital technology in the classroom by taking into account the specific learning and teaching contexts and the many impacting elements.

3.2.13 Limitations of TPACK

Rach and Ufer (2020) argue that teachers should move beyond mere empirical descriptions of knowledge practices and delve into the underlying principles that govern those practices. While TPACK offers valuable insights, it requires further development. In this case, the various forms of knowledge are not adequately theorized, which poses a problem for the theoretical framework and is referred to as knowledge myopia by Howard and Maton (2011). Many studies emphasize developing higher-order thinking skills and providing learners with epistemological access (Mishra & Kereluik, 2011). However, TPACK fails to address the specific content that needs to be covered in a lesson or how it should be effectively delivered. Studies on integrating ICT into instruction strive to consider the contextual factors that influence classroom usage comprehensively. Still, they often overlook the nature of the knowledge that learners are expected to acquire and the different forms it can take (Howard & Maton, 2011). The TPACK framework has faced criticism from several authors who highlight its main flaws, including a lack of contextualization, the exclusion of the learner-teacher relationship, variations across grade levels, and a dearth of guidance and pathways for acquiring TPACK (e.g., Cox & Graham, 2009; Archambaud & Barnett, 2010; Graham, 2011; Lo & Hew, 2021).

3.3 Summary

This chapter discussed TPACK theory and Vygotsky's Sociocultural theory, both of which serve as analytical and theoretical frameworks for this study. Crucial domains from these theoretical frameworks, such as social interaction, mediation, ZPD, and scaffolding, were broadly discussed. The main SCT principles employed for this study are social interactions, which involve the exchange of ideas between more knowledgeable and less knowledgeable individuals, and mediation through material tools, symbols and human beings. Lastly, the most popular concept is the Zone of Proximal Development (ZPD). The ZPD is the imaginary distance an individual can reach with mediation tools. All these tools are crucial in the learning process and for this study, as well as TPACK ' s: Content Knowledge (CK), Pedagogical Knowledge (PK), Technological Knowledge (TK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK)., although the study adopted two main domains Technological Pedagogical knowledge (TPK) and Technological Content Knowledge (TCK). The chapter also discussed the selection and application of these concepts in this study. Accordingly, the chapter also examined the RAT and SAMR models as viable frameworks for the research and why they were not used. The chapter concludes by reviewing the limitations of TPACK as an analytical framework. The following chapter addresses the design and research methodology of the study.

4 CHAPTER FOUR:RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

The previous chapter thoroughly examined and presented the theories employed in this study, specifically Sociocultural theory and the TPACK framework, which serve as the theoretical and analytical frameworks. This chapter serves as a comprehensive road map, outlining the methodologies and strategies utilized to collect data for this study and providing a rationale for their selection.

According to Sileyew (2019), methodology refers to the methods, techniques, or tools used to gather accurate and ethical data for a program and the methods, techniques, or strategies employed to modify the obtained data. Cohen, Manion, and Morrison (2000) emphasize the significance of technique in a study, as it aids researchers in comprehending the processes and products of scientific inquiry. For this study, a qualitative research design has been adopted. Lin (2020, p. 14) defines methodology as "the research process that shapes our choice and use of particular methods and links them to the desired outcomes." It encompasses the specific procedures or techniques employed to identify, select, process, and analyze information on the chosen topic.

This chapter serves as a comprehensive guide, outlining the methodologies and strategies employed to collect data for this study. It also provides a compelling rationale for selecting these methods, emphasizing the paramount importance of technique in comprehending the scientific inquiry process. Rahman (2020, p. 9) defines methodology as "a theory that determines which methods and techniques are appropriate and valid to understand, not only the products of an inquiry but the process itself, in the broadest possible terms." According to Camille and Stephanie (2020), the primary objective of the methodology is to assist researchers in comprehending the processes and outcomes of the study. This chapter effectively describes the research process, provides information about the method employed in conducting this research, and offers a sound rationale for utilizing this particular method.

Furthermore, this chapter elucidates the various phases of the study, encompassing the research design, research participants, data collection technique, and data analysis technique. Additionally, it delves into the qualitative research, case study, and research instruments employed in this study, namely workshop discussions, semi-structured questionnaires, reflective journals, observations, and focus group interviews. The chapter further explores the intricacies of data analysis, trustworthiness, triangulation, credibility, transferability, and confirmability while addressing how the current study's ethical considerations are meticulously met.

4.1 Interpretive Paradigm

A research paradigm provides the foundation for a researcher's worldview, influencing the interpretation of study data (Khatri, 2020). In this study, the aim was to explore and understand the phenomenon of integrating ICT in formative assessment through the perspectives and actions of the study participants. This approach served as a lens through which the researcher examined the methodological aspects of the study, informing the selection of appropriate research methodologies and guiding the data analysis process (Locke, Feldman, & Golden-Biddle, 2022).

The primary objective of this research, which employed an interpretive paradigm, was to gain a comprehensive understanding of the subjective realm of human experiences (Guba & Lincoln, 1989). To achieve this, it was crucial to delve into "the minds of the subjects under study and comprehend their experiences and interpretations" of conducting formative assessments using Kahoot! (Kivunja, 2017, p. 33), rather than solely relying on an observer's perspective. Efforts were made to grasp the perspectives of the individuals being observed. The focus of the research was to understand the experiences of the 10 participants regarding the investigated phenomenon. Therefore, at the core of this research lies the principle of the interpretive paradigm, which recognizes that knowledge is socially constructed (Bogdan & Biklen, 1998).

4.2 Qualitative Research Design

A research design is the “procedure for collecting, analyzing, interpreting and reporting data in research studies ” (Creswell & Plano Clark, 2007, p.58). Leavy (2017) defines research design as a structure informed by the research topic based on the research questions (Bradshaw et al., 2017). The approach employed in this research is qualitative. Qualitative research is designed to provide the researcher with a means of understanding a phenomenon (Doyle et al., 2020) by observing or interacting with the study's participants (Denzin & Lincoln, 2008). According to Neill (2007 in Yin, 2011, p. 188), the critical points of qualitative research are:

- The aim is a complete, detailed description.

- The design emerges as the study unfolds.
- The researcher is the data-gathering instrument.
- Subjective individual interpretation of events is essential, e.g., using participant observation, in-depth interviews, etc.
- Data are in the form of words, pictures, or objects.
- Qualitative data are more "rich," time-consuming, and less able to be generalized.
- The researcher tends to become subjectively immersed in a subject manner.

According to Reeves and Hedberg (2003, p. 32), the "interpretive" paradigm emphasizes the importance of contextualizing analysis " . This qualitative study was situated within an interpretive qualitative research paradigm and used a case study approach. The qualitative interpretive technique was used to study, investigate, and learn about social phenomena, to analyse the meanings people assign to specific behaviours, circumstances, events, or artefacts, or to understand a particular aspect of social life (Leavy, 2017). Qualitative approaches provide detailed descriptions of participants' mental processes and their tendency to focus on the "why" of phenomena (Creswell, 2003). Furthermore, when the researcher has little control over what is happening, qualitative designs answer the "how," "what," and "why" questions (Creswell, 2013) by generalizing through detailed descriptions of the setting and allowing the reader to draw comparisons between the study and their circumstances. A case study design was ideal for this research because it focuses on context and the lives and experiences of participants (De Wet, 2010). This study used meaning-oriented (than measurement-oriented) techniques such as participant observation or interviews based on an intersubjective relationship between the participants and the researcher.

Although qualitative research is considered more interpretive, the researcher's biases, values, and judgments need to be more openly stated and considered when presenting data (Creswell, 2012). This study employed a qualitative approach by observing teachers' behaviours during social interactions in the workshops to gain insight into their perceptions and understandings shaping their formative assessment practices. In addition, the experiences of the teachers and the researcher during their participation in the study were documented through reflection journals. The researcher then conduct focus group interviews to understand the study's overall purpose. Keisha (2020, p.5) explains, "Qualitative researchers are interested in understanding how people interpret their experiences, how they construct their world, and the meaning they attach to their experiences." This study aims to uncover and understand teachers' pedagogical and technological perceptions and experiences with Kahoot! Gamification as an assessment tool and the factors that may facilitate or limit its use.

4.3 Qualitative Case Study

In this study, I chose a case study research design from qualitative research methodology because the scope of the case study is based on a phenomenon studied in depth in its natural context, the classroom (Yin, 2009). A case study is an in-depth analysis of a particular condition rather than a comprehensive statistical survey. It is used to reduce a broader research area to a simple topic of exploration or investigation (Yin, 2018). According to Yin (2018), case studies can explain, describe, or explore events or phenomena in the everyday contexts in which they occur to understand and explain causal links and pathways resulting from a new policy initiative or service development. Alam (2021) states that qualitative researchers tend to illustrate and explore social cases rather than social structures. Qualitative research is better suited to understanding the actual behaviour of human interactions, meanings, and procedures that determine the natural organizational environment. A case can be an individual, a role, a small group, an organization, a community, or even a nation (Miles et al., 2014, p.28). A case study is appropriate when the research question begins with 'how' or 'when', when the researcher has little control over the event, and when the focus is on a phenomenon in a realworld context (Andersen, 2013). A case study is always about gaining insight into processes, meanings, and motivations. This can enable us to understand better and explain more widespread cases (Roberts, 2009).

A qualitative research approach is the best approach for this study to obtain detailed participant feedback, as this approach is not generalizable (Yin 2014). As Creswell (2007) said, "We conduct qualitative research when there is a problem or question to be explored" (p. 39). In this case, the data and generalizations gained from the research are specific to the two schools and not representative of the district. "We also conduct qualitative research because we need a complex, detailed understanding of the topic" (Creswell, 2007, p. 40). This case study research explores teachers' perceptions and understandings of using Kahoot! as a formative assessment tool to enhance mathematical understanding. Therefore, the research problem needs to be understood from the perspective of the target audience, the teachers at the two schools. The answers and findings can never be guaranteed to represent larger populations (Roberts, 2012).

4.4 Research Site and Participants

4.4.1 Selection of Sites

The study was conducted in two selected schools in the Sarah Baartman district in Eastern Cape Province, South Africa. According to Cohen, Manion, and Morrison (2018), a sample in research refers to the population the researcher focuses on. Furthermore, Aspers and Corte (2019, p.17) recommend that a case study selection should "set boundaries: define aspects of your case(s) that you can study within limits of your time and means, that connects directly to your research questions, and that probably will include examples of what you want to study." This interventionist study sought to help enhance mathematical understanding through Kahoot! Gamification as a tool for formative assessment. As such, it meant that the chosen schools needed to;

(1) have access to ICT devices such as laptops, tablets, or mobile phones; and

(2) have access to the internet, and learners do have access to computers or mobile phones at schools

(3) be located in the Sarah Baartman district

(4) Offer Senior phase of mathematics subject. The two chosen schools are public schools close to each other.,

4.4.2 Selection of Participants

Only participants deemed to provide appropriate and valuable information using limited resources (Palinkas et al., 2015) were chosen for this study. According to Bertram and Christiansen (2015), purposive sampling means that the researcher selects individuals, groups, or objects using set criteria to be included in the sample. This study purposively selected ten senior-phase mathematics teachers from 2 schools in Sarah Batman District in the Eastern Cape Province. According to Patton in Marshall and Rossman (2011), the sample size for qualitative research can vary from 4 to 35. Therefore, the researcher believed ten was an appropriate sample size to ensure a reliable qualitative study. This included ten teachers, provided that if a teacher voluntarily dropped out of the study, the researcher could still obtain quality and reliable data from the remaining participants. The rationale for choosing a purposive strategy assumes that, given the study's goals, certain people hold different and

essential views about the ideas and issues in question and, therefore, must be included in the sample (Mason, 2002;
Robinson, 2014). Purposive sampling selects cases based on the researcher's judgment (Cohen, Manion, & Morrison, 2011). The researcher chose senior phase mathematics teachers based on their "close relationship to the research topic" (Neuman, 2014, p. 276). Ten teachers who taught mathematics in the senior phase were selected. Five years of teaching experience was also used to select participants. Teachers were required to access the Internet at their school, and they received laptops from the Eastern Cape Department of Education. Once teachers were selected, their respective schools became the study sites (Robinson, 2014).

A review of the selected teachers (see Table 2) showed that the selected teachers had a range of five to twenty years of experience. The purpose was to work with the senior phase mathematics teachers to explore using Kahoot! as a formative assessment tool to improve mathematical understanding and understand views and perceptions about using the tool in formative assessment.

Table 1

Participants' profile and initial perception of technology use in the assessment

Teacher (Pseudonym)	ICT available at school	Grade(s) teaching	Teacher perception about technology use in the assessment	Number of years teaching senior-phase mathematics
Tumi	Yes	6,7	Hesitant	20
Lolo	Yes	7	Excited	12
Mdu	Yes	7	Excited	6
Qhama	Yes	6,7	Hesitant	8
Zen	Yes	4,5	Excited	5
Ben	Yes	6,7	Scared	20
Bright	Yes	5,6,7	Reserved	19
Cre	Yes	7	Exited	13
Keke	yes	5,7	Nervous	7

4.5 Research Instruments

The following data-generating methods were used in this study: workshop discussions, semi structured questionnaires, reflective journals, observations, and focus group interviews. These data sources align with qualitative data sources, as Yin (2018) recommended for conducting case study research. I now discuss these tools in detail.

4.5.1 Semi-structured questionnaire

According to Rule and John (2011), "questionnaires are sets of field questions that the participants respond on their own or in the presence of the researcher" (p.66). Mouton (2012) suggests a semi-structured questionnaire is a data collection method that consists of a series of closed and open-ended questions and additional prompts. Although it takes time to develop a questionnaire, it is a cost-effective data collection method because it can be conducted without the researcher's presence and is more accessible for analyses (Cohen et al., 2011). However, in this study, some teachers asked to meet with the researcher to clarify other issues related to the questionnaire content. Following the meetings, Cre made the following observation:

> *"We are under a lot of pressure at work, and it is often unclear what purpose these forms serve; as a result, we are not too comfortable thinking they could be some monitoring tools that may reflect negatively on us. This meeting has allowed me to express myself freely and broadly understand the purpose of the whole study".[Cre]*

This arrangement eliminated one of the disadvantages of semi-structured questionnaires, namely intimidation. According to Cohen et al. (2011), a semi-structured questionnaire should be designed so that respondents are not intimidated. In addition, the researcher had ample time during the meetings to explain the purpose and value of answering all questions.

Although it was already pointed out during the school visits, the researcher also explained to the participants that participation in completing the questionnaires was voluntary and required the informed consent of the respondents. Before the start of the study, participants completed questionnaires (see Appendix A) that were used to collect data to answer the first research question, i.e., 'What are the senior phase mathematics teachers' perceptions on using Kahoot! Gamification as a formative assessment tool before this study?'.

4.5.2 Workshops Discussions

Workshop discussions are an essential part of any learning process. They provide a platform for individuals to share their ideas, opinions, and experiences with others. These discussions can be beneficial in various ways, including improving critical thinking skills, enhancing communication skills, and promoting teamwork.

The first benefit of workshop discussions is that they improve critical thinking skills. Individuals are forced to think critically about the topic when participating in discussions. Individuals must analyse the presented information, evaluate perceptions, and form opinions. This process helps individuals develop critical thinking skills essential in mathematics formative assessment (Cunningham, 2023). Workshops are popular in education because they reflect how reality is socially constructed (Lincoln & Guba, 1985; Vygotsky, 1978), meet participants' expectations of accomplishing something related to their interests, and provide researchers with insight into the meaning participants attach to social experiences (Spradley, 1979; Lain, 2017). Furthermore, workshops are specifically designed to achieve one research goal: to provide reliable and valid data (Lain, 2017; Baran et al., 2014). In addition, participants and workshop organizers expect a specific outcome (e.g., the creation of new knowledge, concepts, or (re)designs for a cause, process, or invention).

This collaborative nature of workshops enhances experiences and learning for both participants. Workshop discussions enhance communication skills. Individuals need to communicate their ideas clearly and effectively when participating in discussions (Houghton, Casey, Shaw, & Murphy, 2013). They need to listen to others, ask questions, and respond appropriately. This process helps individuals develop their communication skills, which are essential in any workplace. Effective communication is necessary for building relationships, resolving conflicts, and achieving common goals (Orngreen & Levinsen, 2017).

Furthermore, workshop discussions promote teamwork. When individuals participate in discussions, they work together to achieve a common goal. They need to listen to each other, respect each other's opinions, and collaborate to find solutions. This process helps individuals develop teamwork skills essential in any organization (Kang & Zhang, 2023). Effective teamwork is necessary for achieving organizational goals, improving productivity, and creating a positive work environment.

This study conducted three workshops with the ten senior phase mathematics teachers (study participants) to lay the groundwork for this study. In the first workshop, the rationale for the study was explained, and teachers were introduced to Kahoot! The second workshop focused on mathematical understanding. The workshop's objective was to help the participants understand the relevance and importance of mathematical understanding and how it can be achieved using Kahoot! Gamification. The discussions in the workshop extended to linking the Annual Teaching Plans (ATP), Lesson planning, formative assessment, and summative assessment. According to Lain (2017, p.160), workshops foster "engagement" between participants and the researcher through joint discussions and "constructive feedback," which is critical to their success. This engagement is often intense and can be likened to "prolonged engagement," which is considered one of the most important means of ensuring the credibility of the results of qualitative studies and maintaining trust between researchers and participants (Merriam, 1998; Ahmed & Asaraf, 2018). Participants from diverse backgrounds can collaborate in workshops and fully engage in learning (Orngreen & Levinsen, 2017). A researcher can collect data in this way by using a shared experience. Additionally, if a researcher needs information-rich data, workshops can be used to recruit study participants who have volunteered to participate (Creswell & Poth, 2017). Participants' prior knowledge of using ICT in teaching was documented through journal reflections in the first workshop, and this data helped to respond to the first research question.

The third workshop was conducted after the intervention to reflect on the research procedure, and members checked the findings. Data obtained in the last workshop proved valuable in formulating responses to the second, third, and fourth research questions.

4.5.3 Observations

According to Swain and King (2022), the researcher learns about behaviour and the meaning attached to that behaviour through observation. Rahman (2020, p.14) believes that observation enables the researcher to describe existing situations using the five senses, thus creating a "written photograph" of the case under study. She adds that "observation requires active looking, memory reinforcement, informal questioning, writing detailed field notes, and perhaps most importantly, patience." This idea is supported by Cohen et al. (2007), who assert that observation involves collecting live data in a natural setting. According to Cohen et al. (2018, p.71), this technique "provides an enormous amount of high-quality data and crucial insights into community dynamics." Using the observational method in this study allowed the researcher to examine participant behaviour in complex classroom learning situations and technology use (Swain & King, 2022). In addition, it enables the researcher to understand the problem and pay close attention to things that may be hidden or that participants could not mention in the interviews and questionnaires (Cohen et al., 2018).

The researcher collected data through non-participant observation during classroom visits in this study. This means the researcher was present at the scene but did not interact or participate (Brobst, 2016). Observations in a naturalistic setting "do not interfere with the participants or the activities observed" (Maxwell, 2013, p. 67). In non-participant observation, on the other hand, researchers do not participate in the observed activity but "sit on the side lines ' and observe. They are not directly involved in the situation they are observing. Workshops also allow for long-term observation (Lincoln & Guba, 1985). Lincoln and Guba (1985) believe that "sustained observation" enables a researcher to examine the issues and concerns relevant to a particular study "in-depth" (p.304). To conduct sustained observation, a researcher focuses on various relevant aspects of thorough research over a substantial and specific period, all of which contribute to establishing the study's credibility (Lincoln & Guba, 1985).

During the classroom activity, the researcher sat in the back seat. On the other hand, the researcher's presence may produce the Hawthorne effect (Levitt & List, 2011), in which learners behave differently because they are aware that they are being observed, which affects the quality of the data obtained. Although there are caveats about the extent to which observations provide high-quality data because the behaviour of the observed may change in the presence of the observer, Sekaran and Bougie (2016, p.127) assert that "observation can be used to determine whether what people say they can do and what they do match." Therefore, observational data were still valuable in answering the study's research questions. For this study, non-participant observation allowed the researcher to observe how the teacher assesses mathematics and how teachers use Kahoot! Gamification as a formative assessment tool to scaffold mathematical understanding.

4.5.4 Reflective journals

Reflective journals are adequate for personal growth and development (Bassot, 2020). They provide a space for people to reflect on their experiences, thoughts, and emotions to acquire insight into their behaviour and decision-making processes.

The primary advantage of reflective journals is that they provide a space for people to process their experiences (Bassot, 2020). Individuals can better comprehend their reactions and behaviours by writing down their thoughts and feelings. This can assist them in identifying trends in their behaviour and making changes that will result in more favourable outcomes.

Another advantage of reflective journals is that they can aid in developing critical thinking skills. Reflection journals are standard in many educational settings and essential for promoting understanding (Zilber, 2020). Individuals might learn to think more deeply and critically about their surroundings by studying their experiences and reflecting on their mental processes. This can lead to increased creativity, problem-solving abilities, and intellectual advancement.

Reflective journals can also be an effective tool for professional development. Individuals can find opportunities for improvement and establish growth initiatives by reflecting on their work experiences. This can enhance job satisfaction, increase productivity, and improve relationships with colleagues and management. According to Dunlap (2006), reflection journals serve the dual purpose of recording, tracking, and reflecting on one's teaching for assessment purposes.

In this study, the teachers and the researcher had the opportunity to record their opinions, pedagogical and technological experiences, and insights about the research activities (Cohen et al., 2018). The study employed reflective journals as a data collection method. It allowed teachers and researchers to reflect on their feelings, insights, and experiences related to their progress in integrating gamification technology into the formative assessment. Furthermore, according to Goker (2016), reflection is critical to teachers' professional development as it allows them to deal with issues as they arise and change their instructional practices.

4.5.5 Focus group discussion

A focus group is defined by Kotler (1991) as "a gathering of six to ten people who spend a few hours discussing a project, service, organization, or other entity." A focus group discussion is a qualitative research method involving a group discussing a specific topic or issue. A facilitator usually leads the group and asks open-ended questions to encourage participants to discuss their thoughts and experiences. Focus group talks are often utilized in market research but can also be used in social sciences and education. Focus groups are in-depth interviews that use relatively homogeneous groups to obtain information on topics specified by the researchers (Hughes & DuMont, 2002; Aiman, 2020) and to create an environment where participants feel comfortable expressing their views (Hennink & Hutter, 2011). The facilitator creates a discussion guide with open-ended questions and suggestions to promote participation. The facilitator directs the discussion and encourages all members to contribute their opinions and experiences during the focus group discussion. Typically, the debate is recorded and transcribed for study. The data gathered from the focus group conversation can be utilized to uncover themes and trends and acquire insights into the target population's attitudes and ideas (Bourgeois, 2016). Focus group discussions have the advantage of allowing for an in-depth investigation of a topic. Participants can express their thoughts and experiences, and the facilitator can offer follow-up questions to understand their comments better. Focus group discussions can also be used to test new concepts or theories. The collective, rather than the individual, is the focus of focus group questions. However, getting a sense of the saturation of the data requires a diversity of viewpoints, interests, and commitment to the topic, which can cause participant levels to vary. To prevent the discussion from digressing, the moderator, often the researcher, needs to rephrase or reframe the original question (Aiman, 2020).

A focus group can address research questions not addressed by other data sources (Cron, 2020). Questions may arise from responses from different data sources (Isome & Filtz, 2018). Focus groups can help refine other data sources or uncover alternative interpretations of questions (Williams, 2020). Aiman (2020) recommend using focus group interviews for experimental purposes, making them an obvious research method for this study. In addition, focus group questions allow participants to expand on their responses to interview questions and can provide more depth in answering questions than individual interviews (Sedlock, 2020). Focus group interviews were also used for triangulation.

In conducting the focus group interviews, the guidelines developed by Kotler (1991) and Dillon, Maddern, and Firtle (1993) were used, and the following principles were followed:

- Focus groups were selected to include no more than twelve or five individuals. The researcher felt that ten participants were the ideal number for this study so that all participants could interact and have their voices heard.
- The room for the focus group interviews provided a relaxed and comfortable environment. The room had comfortable chairs, was private, and was air-conditioned.

- No microphones or video cameras were used, as their use would have disturbed the participants. I used my cell phone to record the discussion with clear transcripts of the conversations. This decision was discussed, negotiated, and explained to each participant.

4.6 Data Analysis

Data analysis is the process of extracting the data to determine the result. Trent and Cho (2014) define data analysis as "Summarizing and organizing data" (p. 652). The process is based on the principle of ensuring the reliability of the results. Since there is no single way to achieve this, the researcher critically followed the advice of Dawadi (2020), who focused on thinking about objectives, research questions, theoretical framework, methods, and validity. Maxwell (2013) presented this as a linear and precise step-by-step process. Although data analysis and interpretation involved distinct functions such as transcription, organization, coding, analysis, and understanding, the process was complex, iterative, and reflexive rather than linear or systematic. Several sources influenced the codes, including research questions, focus group interview questions, theoretical framework, personal experiences, and the data. In this study, the researcher used a thematic analysis approach to identify, organize, analyse, and report patterns/themes within data (Lochmiller, 2021).

The notes written during the early stages of the data generation process were then used to draw up a data analysis and interpretation plan. After transcribing and cleaning the data, the researcher manually coded the transcripts to determine the codes and emergent themes. The researcher then imported all transcripts into NVivo software to easily organize and manage the data. The software is not used for data analysis or interpretation but for easy organization and management of the data.

The four phases of the analysis cycle applied to the transcripts were consistent: Coding, Conceptualizing, Categorizing, and Theorizing (Glaser & Strauss, 1967).

A step-by-step approach was used to analyse the interviews and diary entries as follows:

1. Coding, i.e., going through the transcripts sentence by sentence to identify anchors (words or phrases) that bring out key points in the data.
2. Conceptualization, which is grouping codes with similar content (where new concepts are core parameters of the data and codes can be viewed as dimensions of those concepts);

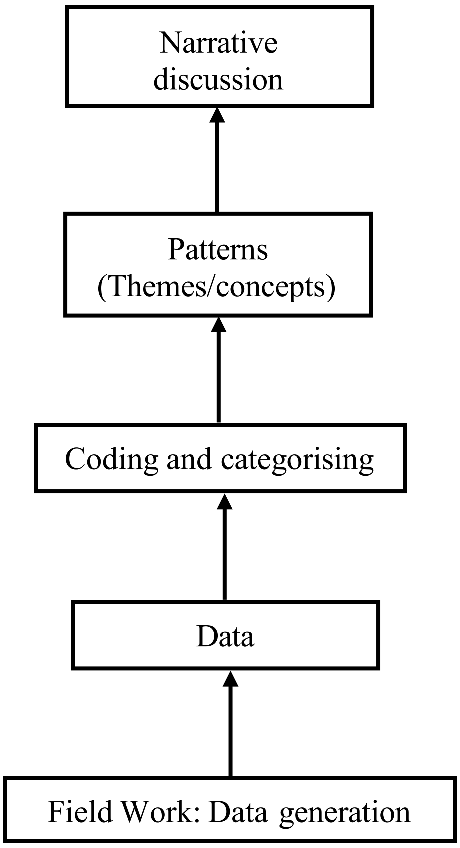
3. Categorization, which involves developing categories that roughly group concepts and represent the essential elements from which a hypothesis or theory can be developed and,

4. Theorizing is constructing a system of explanations for the significant concerns of the research subject.

The data analysis procedure followed the general process of inductive data analysis proposed by MacMillan and Schumacher (2006), as illustrated in Figure 5:

Figure 5

General Process of Inductive Data Analysis



Source: Adapted from McMillan and Schumacher (2006, p. 365)

This study quantitatively analyzed the data collected from the questionnaires using descriptive statistics. Descriptive statistics transforms or summarizes a data set into either a visual overview, such as a table or graph or a single or a few numbers that summarize the data (Bertram & Christiansen, 2014). The researcher used the two concepts of sociocultural theory: mediation tool and social interactions (Vygotsky, 1978) and components of TPACK that include the sense of technology on it, as adapted from Mishra and Koehler (2006), to serve as lenses for data analysis.

4.7 Data Triangulation

In research, triangulation involves using multiple methodological resources or procedures (Denzin, 2009; Merriam & Tisdell, 2016). Triangulation involves using various methods to provide coherent bases for empirical conclusions (Noble & Heale, 2019). Beveland and Lindgreen (2010; Yin, 2018) offer three measures to improve the quality of case studies: access to raw data, explanation of negative cases, and evidence of data triangulation. Triangulation assumes multiple strategies and viewpoints are needed to fully understand and explain a problem (Archibald, 2016). The effectiveness of triangulation methods is based on the premise that the weakness of one data collection method is offset by the compensating strength of the other method (Bryman, 2020). Thus, triangulation aims to overcome potential weaknesses or inherent biases and problems that may occur with particular forms and validate findings by converging multiple sources and diverse perceptions representing reality in a specific context. In addition, it helps avoid the subjectivity of specific methods, such as interviews, over others. The most important advantage of using multiple sources and data collection methods is developing "converging lines of inquiry" (Yin, 2014, p. 94).

Figure 5 shows the types of triangulation proposed by Harrison, Reilly, and Creswell (2020) and the six suggested by Cohen et al. (2018). Following Harrison, Reilly, and Creswell (2020), the table explains how data triangulation was performed in this study.

Table 2

Triangulation of data collection

Harrison, Reilly, and Creswell (2020, p.29),	**Cohen et al. (2018)**	**Data triangulation source in the study**
Data triangulation, which includes (time, space, and person);	Time triangulation	Ten senior phase mathematics teachers from different backgrounds and two schools). Allowing the researcher to collect different views and reflections from diverse perceptions besides his own.
	Space triangulation	
	The combined level of triangulation	

Investigator triangulation	Investigator triangulation	During this study, the researcher submitted one research paper to journals, and reviewers' and editors' comments served to help validate the study.
Theory triangulation	Theoretical triangulation	Vygotsky's Sociocultural Theory and TPACK theory
Methodological triangulation	Methodological triangulation	semi-structured questionnaires; focus group interviews; observations; journal reflections

4.8 Research Evaluation

The five criteria for research evaluation listed by Guba and Lincoln (1989, p. 49); validity, reliability, credibility, transferability, and confirmability - were considered in several ways to ensure the credibility of this study's research methods and conclusions. Johnson and Onwuegbuzie (2004) identified four types of criteria: credibility (replacing the quantitative concept of internal validity), transferability (replacing the quantitative notion of external validity), dependability (replacing the quantitative idea of reliability), and confirmability (replacing the quantitative concept of reliability) These standards, which academic professionals and the general public recognize, are critical components of a well-conducted study. Johnson and Onwuegbuzie (2004) proposed a new framework for evaluating research studies. They identified four criteria that replace traditional quantitative concepts: credibility, transferability, dependability, and confirmability.

Credibility replaces the quantitative concept of internal validity. It refers to the extent to which a study's findings are believable and trustworthy. To establish credibility, researchers need to ensure that their methods are rigorous and their findings are supported by evidence. This includes using appropriate sampling techniques, controlling for extraneous variables, and using reliable and valid measures. Transferability replaces the quantitative notion of external validity. It refers to how a study's findings can be applied to other contexts or populations. To establish transferability, researchers must describe their methods, participants, and the study's context.

This allows readers to determine whether the findings relate to their situations.

Dependability replaces the quantitative idea of reliability. It refers to the consistency and stability of a study's findings over time and across different researchers. Researchers need to document their methods and procedures to establish dependability so that others can replicate their study. They also need to be transparent about any changes to the study design or procedures during the research.

Confirmability replaces the quantitative concept of objectivity. It refers to the extent to which a study's findings are free from bias or personal interpretation. To establish confirmability, researchers need to be transparent about their biases and assumptions and document their decision-making processes. This allows readers to evaluate the extent to which the findings are based on objective evidence. The five criteria for research evaluation listed by Guba and Lincoln (1984) and the four criteria proposed by Johnson and Onwuegbuzie (2004) form the foundation for assessing the credibility and quality of research studies. By adhering to these criteria, researchers can contribute to the advancement of knowledge and make meaningful contributions to their respective fields.

4.8.1 Validity

The extent to which a research instrument can measure what it intends to measure is called its validity (Trochim & Donnely, 2006; Richard, van de Schoot, Depaoli, King, Kramer, Märtens, Tadesse, and Yau (2021). The accuracy with which a method measures the target variable is called its validity. When a study has high validity, its results correspond to the actual properties, characteristics, and variations of physical or social reality (Surucu & Maslakci, 2020). The high reliability of a measurement can be an indication of its validity. Whiston (2012) defined validity as obtaining data appropriate for the measuring instruments' intended use. This means that measurement tools such as semi-structured questionnaires, focus group interviews, observations, and diary reflections are designed to capture the issues the researcher wants to investigate. Mohajan (2017) distinguishes seven validity types: internal, external, critical, constructive, content, predictive, and statistical. The correlation of questions is referred to as internal validity (i.e., cause and effect questions) and the extent to which causal inferences can be drawn.

External validity refers to the extent to which the data collected can be generalized to a larger population or setting. Comparing study responses to accepted measures of the concept under study is called criterion validity. Construct validity determines the validity of abstract concepts and traits such as perceptions, attitudes, and knowledge. Construct validity concerns the extent to which the instrument measures the concept, behaviour, idea, or quality — a theoretical construct it purports to measure. In other words, it is concerned with distinguishing between participants with and without the measured behaviour or characteristic. Content validity Bollen (1989) defined "content validity" as a qualitative form of validity that tests whether the expressions in the measurement instrument represent the phenomenon being measured. Consistent with this definition, the content validity of a measurement instrument can be described as a validity study that reveals the extent to which each element of the tool serves its purpose. The predictive validity of a study refers to its ability to predict a future event. Statistical validity is the degree to which the conclusions of a research study can be considered accurate and reliable as a result of a statistical test. To achieve statistical validity, researchers need to collect enough data and use an appropriate statistical approach to analyse that data (Eker, 2020).

The goal of this study was to meet all defined forms of validity. The first step in achieving validity was ensuring the study was designed properly. This involved identifying the research questions, selecting the appropriate research design, and choosing the right sample size. The research questions were clear and specific, and the research design was appropriate. The sample size was large enough to ensure that the results represent the population being studied (Ecker, 2020). The second step in achieving validity was ensuring reliable data collection. Standardized procedures ensured that the data was collected consistently, reducing potential errors. Consistent data collection ensures reliable results can be replicated (Pandey & Pandey, 2021). The third step in achieving validity was ensuring accurate data analysis. Accurate data analysis entailed using appropriate statistical methods to analyze the data, ensuring the results were statistically significant, and minimalising the potential for errors (Duchatelet & Donche, 2022).

Appropriate statistical methods ensure that the results are accurate and reliable. Statistical significance ensures that the results are not due to chance. Minimizing errors ensures that the results are valid and can be trusted (Lemon & Hayes, 2020). The fourth step in achieving validity was ensuring the results were reported accurately. Accurate data reporting in this study involved presenting the results clearly and concisely, using appropriate tables and graphs, and providing a detailed description of the methods used (Adu, 2019). Clear and concise reporting ensures that the results are easily understood and interpreted. The study used tables and graphs to represent the results, making them visually understandable, followed by detailed descriptions of the methods used, ensuring that the results could be replicated.

The researcher took notes during the research process to evaluate its effectiveness and to have accurate records of the participant's responses to ensure the validity of the research. Furthermore, before analysing and developing the case studies, the researcher sent the transcribed interviews to the participants to confirm the accuracy of the data (respondent validation). In addition, as mentioned earlier, the researcher conducted data triangulation.

4.8.2 Reliability

The stability and consistency of the measurement instrument used are called reliability. In other words, reliability is the ability of measurement instruments to produce similar results at different points in time. Of course, due to differences in the use of the measurement instrument and changes in the population and sample, the same results may not be obtained each time Pandey and Pandey (2021). On the other hand, a strong positive correlation between the results of the measurement instrument indicates reliability Surucu and Maslacki (2020). The reliability of the measurement instrument is an essential aspect of the positive impact of the study.

Therefore, researchers need to ensure that the measurement instrument used is reliable.

The researcher is responsible for describing the environmental changes and how they may have affected the study. In this study, the researcher enlisted the assistance of his research supervisor, who has experience coding transcribed data, to verify the reliability of the coding system's development of categories and subcategories. The researcher provided data collection and analysis information, developed a coding system, created categories and subcategories, and explained the procedures he used in his data analysis to other researchers.

4.8.3 Credibility

Lincoln and Guba (1985) assert that various strategies for dealing with credibility include prolonged engagement, triangulation of data collection, and sustained observation. In this study, the researcher stays in the same environment as the participants. The researcher was well immersed in the participants' environment, spending time with them and learning about and understanding their background to some degree. Since this was a naturalistic study, the researcher strived to establish a less formal relationship with the participants so that they could move freely in their natural environment without feeling threatened by the researcher. The context in which the data was collected was created through continued participation.

. To ensure the credibility of the findings, the researcher used multiple data collection instruments, such as semi-structured questionnaires, focus group interviews, diary observations, and classroom observations, to obtain answers to the research questions (Stahl & King, 2020). The researcher also pilot-tested the instruments. The focus group interviews provided the researcher with information that could not be obtained through observation. To ensure credibility and trustworthiness, the researcher also examined the data to determine if the views expressed by the interviewers reflected the experiences and opinions of the participants outside of the interview or if they were simply a reflection of the interview setting (Stahl & King, 2020). Following Harrison, Reilly, and Creswell (2020), the data collected were triangulated into four stages (see Data Triangulation). The study could be biased from the teachers' side (sample). Teachers may have been dishonest in the interviews and observations, shown the researcher methods they do not usually use, and responded to avoid the researcher judging them as colleagues.

4.8.4 Transferability

The richness of the descriptions in the study and the amount of detail about the context in which the study took place are used to assess transferability (Duchatelet & Donche, 2022). The qualitative researcher can increase transferability by thoroughly describing the research context and critical assumptions. The person who wishes to "transfer" the findings to another context is then responsible for determining if the transfer is appropriate. Transferability in this paper is how well the study enables readers to decide whether similar processes will work in their setting (McKenney & Reeves, 2021). This study attempted to ensure transferability by using research methods used in other studies, suggesting that a similar study could be conducted in the future.

4.8.5 Confirmability

The term used in qualitative research, which corresponds to validity in quantitative research, refers to the degree to which the results of a study can be confirmed when the same situation is reversed (Morgan, 2022; Surucu & Maslakci, 2020). According to Williams and Moser (2019), conformity in qualitative research is synonymous with objectivity in quantitative research. In both cases, it involves the concept of neutrality or the degree to which the research is unbiased concerning its procedures and interpretation of results (Holmes, 2020). While quantitative studies strive for objectivity, qualitative researchers are concerned with whether the data they collect and their conclusions would be confirmed by others studying the same situation.

As a result, qualitative studies shift the focus from the researcher's objectivity to the consistency of the data and interpretations (Roller, 2019). Confirmability is a component of trustworthiness that occurs when credibility, transferability, and dependability are realized (Lincoln & Guba, 1985). To achieve conformity in this study, the researcher also followed study procedures. Interviews were used as an effective data collection method in this study because they were conducted when the researcher was alone with the respondent. Qualitative research is full of subjectivity. Since the confirmation test is similar to the reliability test, it can be conducted simultaneously. In this context, the researcher also asked for permission to use his phone to record all interviews, and the researcher showed respect for the participants and their perceptions. The study met the standard of confirmability when the research findings resulted from the research process (Intan, 2023).

According to Tobin and Begley (2004), the researcher's findings and interpretations need to show how the interpretations and conclusions were reached to be confirmed. Interpretations were discussed in this study, and conclusions were drawn based solely on the data collected. The findings and interpretations of this study were deduced from the generated data as supported by Korstjens and Mose (2018), who advocate that the findings and interpretation should be grounded on data. The findings of this study were based on the opinions and experiences of the participants rather than the researcher’s point of view. The documentation of every procedure undertaken was essential for constant examination and scrutiny to achieve confirmability.

4.8.6 Trustworthiness

Lincoln and Guba (1985) founded the trustworthiness criteria to evaluate qualitative research. The five strategies to establish trustworthiness include credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). The strategies are intertwined and interdependent and serve as alternatives to the conventional, quantitative measures for quality, such as internal validity, external validity, reliability, and objectivity. Credibility is the replacement for internal validity and is rooted in the truth value, which asks whether the researcher has developed and articulated a certain level of confidence in the findings based on the phenomenon under study (Lemon & Hayes, 2020). Participants were invited to validate their interview transcripts, contributing to research credibility (Creswell, 2014). The truth value derives from an in-depth exploration of the human experience as it is performed by the participants (Krefting, 1990; Lemon & Hayes, 2020). In other words, truth is derived from the participant's lived experiences, which does not necessarily lead to universal truths but rather an in-depth understanding of that person's unique reality.

During the workshops, the researcher needs to create a conducive environment for sharing perceptions within the workshop, as well as a research tool with which other participants may wish to discuss their perceptions. While in the focus groups, collaborative interactions created a good "rapport" (Bernard, 2006, p. 387) with participants, positively impacting trustworthiness. One such strategy is the researcher's immersion in the data (Burdine, Thorne & Sandhu, 2021). Finally, confirmability tests whether interpretations and conclusions are based on participants' lived experiences, are free of the researcher's biases, and objectively reflect the phenomenon under study. Researchers should use the techniques to investigate and generate new knowledge while maintaining reliability (Rose & Johnson, 2020).

Nevertheless, researcher bias can compromise the reliability of studies (Maxwell, 2013), and researcher reflexivity is an essential strategy for reducing bias (Roulston, 2010; DeVault & Gross, 2012; Edwards & Holland, 2013; Hesse-Biber, 2014). Lincoln, Lynham, and Guba (2011). The researcher's reflexivity allows them to be aware of their biases and assumptions, their role in the research process, their influence on and interaction with participants, and their power over the data (Creswell, 2014; Edwards & Holland, 2013; Hesse-Biber, 2014). As a result, field notes and journal entries helped preserve research procedures and decisions in this study.

Ethics, encompassing the moral principles that govern human behavior, plays a vital role in research (Coeckelbergh, 2021). In the context of research, ethics involves adhering to what is legally and morally acceptable (Coeckelbergh, 2021). It is essential to establish norms of conduct that differentiate between right and wrong, as well as acceptable and improper behavior (Bertram & Christiansen, 2014). Ethical considerations are particularly crucial when human or animal participants are involved in research (Bertram & Christiansen, 2014).

4.9 Ethical Considerations

In this study, ethical considerations were prioritized to ensure the well-being and respect of the research participants (Bell, 2014; Brooks, te Riele & Maguire, 2014; Farrimond, 2013). The emphasis was placed on informed and voluntary consent, as well as confidentiality and access to information (Bell, 2014; Brooks, te Riele & Maguire, 2014; Farrimond, 2013). The aim was to protect participants from any potential unjust criticism that may arise from their involvement in the study (Mthethwa, 2015).

To uphold these ethical principles, this study strictly adhered to all relevant ethical standards and protocols. The research protocols aligned with the policies and procedures established by the Eastern Cape Department of Education (Appendix E, Study Approval Letter), the Rhodes University Ethical Standards Committee, and the Education Department Higher Degrees Committee (see Appendix F, Ethics Approval Letter). The study was conducted under the supervision of experienced researchers, Dr. Clement Simuja and Dr. Clemence Chikiwa, who ensured compliance with ethical guidelines and provided guidance throughout the research process.By adhering to these ethical standards and protocols, this study demonstrated a commitment to respecting and protecting the rights and well-being of the research participants. Ethical considerations were given the utmost importance to ensure the integrity and credibility of the research findings.

4.9.1 Informed Voluntary Consent

Before participating in the study, participants were informed of the expected benefits and risks of participation. The information and consent letter (see Appendix G, Letter to Participants) met the ethical standards and requirements of Rhodes University. The information and consent letter outlined the purpose of the research, procedures, potential benefits and risks, data use, identity protection, and other information necessary for informed consent. Before signing, the researcher carefully reviewed the information letter and obtained permission from each participant to ensure they understood it, discussed the interview process and research procedure, and answered questions. In addition, the researcher informed the participants that they had the right to refuse to answer questions or withdraw their consent to participate in the study at any time (Wiles, 2012). Participants were invited to review their interview transcripts in person or via electronic communication toward the end of the study. All documents and publications related to this study, including this thesis, will be distributed to participants in the future. Participation in the study was completely voluntary and free of coercion.

4.9.2 Gaining access

Before conducting research in the target schools, the researcher required approval from the Eastern Cape Department of Education (Chief Director for Planning, Monitoring, and Research Coordination; Cluster Chief Director; District Director; Curriculum Chief Education Specialist; School Principals and Teachers) (Cohen et al., 2018). All relevant stakeholders received letters explaining the research title, objectives, methods, and benefits of the study to the schools and teachers. The researcher's commitment to participant anonymity, data confidentiality, and the target schools and names were also explained. Letters were acknowledged after they had gone through official channels. (See Appendix H, "Letter to the School Principal").

4.9.3 Confidentiality

Confidentiality and privacy are crucial aspects of any research study involving human participants. Rhodes University has established protocols to safeguard participants' confidentiality and privacy throughout research (Vivek, 2022). Rhodes University has established protocols researchers follow to safeguard participants' confidentiality and privacy. These protocols include obtaining informed consent from participants, ensuring that identifiable information is anonymized, storing data securely, and limiting access to data to authorized personnel only.

The researcher also obtained ethical clearance from the Rhodes University Ethics Committee before conducting research involving human participants. Rhodes University recognizes that research involving human participants can be sensitive and personal. Participants may share personal information they do not want to be disclosed to others. Therefore, confidentiality and privacy are essential to protect participants' rights and well-being. According to Wiles

(2012), confidentiality refers to protecting participants' personal information, while privacy refers to protecting participants' right to control access to their personal information.

In post-study emails to thank participants for their study involvement, participants were invited to select pseudonyms for anonymity in study publications. Several participants requested that their names represent them, presenting an ethical dilemma. While participants need power in the decision-making that determines their representation in this research, my moral responsibilities are outlined by the ethical standards and protocols from the Rhodes University Ethical Standards Committee and the Education Department Higher Degrees Committee. Therefore, the researcher acknowledged participants' preferences, declined with apologies, and referenced ethical standards. All data (written transcripts) from research instruments have been kept safe at Rhodes University and will be destroyed after five years. All electronic files are stored in a password-protected computer by my research supervisor.

4.10 Summary

This chapter defines qualitative research using a case study and places it within the paradigm of qualitative interpretive research. It describes the research site, the sample, and its selection. It also explains the rationale for the chosen methodology, including its advantages and disadvantages. Then, the research design section describes the research instruments, which include semi-structured questionnaires, journal reflections, observations, and focus group interviews. This chapter discusses data analysis, triangulation, and research evaluation, focusing on trustworthiness, credibility, transferability, and confirmability. The chapter concludes with a discussion of the ethical implications of the study. The following chapter focuses on the results of the current study.

This chapter outlined the methodological approach and research design explored in this study, underpinned within the interpretive research paradigm through a case study approach. It provided every step taken in the research process to reach the outcome of this study. The research questions assisting in answering the overarching question were stated. This was followed by a clear discussion of the sampling technique used in selecting participants. The research site and accessibility, as well as the positionality of the researcher, were detailed. The data-gathering techniques were outlined: the semi-structured questionnaires, journal reflections, observations and semi-structured interviews, and the rationale behind such choices. Data analysis was also made explicit. The trustworthiness of this study, with a focus

on credibility, dependability, transferability, and confirmability, was addressed. Furthermore, this chapter referred to how ethical principles were adhered to. The techniques discussed in this chapter assisted in obtaining the current study's findings in the succeeding chapter five.
To ensure rigour in this study, several steps were taken. Firstly, the researcher engaged in a thorough literature review to gain a comprehensive understanding of the interpretive paradigm and its application in research. This helped establish a solid theoretical framework for the study. Secondly, the selection of research methodologies was carefully considered, aligning with the interpretive paradigm's principles. Qualitative methods, such as interviews and observations, were employed to capture the rich and nuanced experiences of the participants.

Data analysis followed a rigorous process. Qualitative data were analyzed using thematic analysis, allowing for the identification of key themes and patterns in participants' experiences and interpretations. The researcher maintained an open and reflexive stance, acknowledging their own biases and assumptions throughout the analysis process. Triangulation of data sources and member checking were used to enhance the credibility and trustworthiness of the findings.

By adopting the interpretive paradigm and implementing rigorous research practices, this study aimed to provide a comprehensive understanding of the integration of ICT in formative assessment from the perspectives of the study participants. The recognition of the socially constructed nature of knowledge and the rigorous methodological approach employed contribute to the overall rigor and validity of this research endeavor.

5 CHAPTER FIVE: RESULTS OF THE STUDY

5.1 Introduction

The previous chapter outlined the methodological techniques used in this qualitative case study, including the research paradigm, research technique, participants, and how they were chosen. It provided an extensive description of what was being studied and why, what, how, why, and when the data collection instruments were used. This chapter presents and analyses the findings obtained using semi-structured questionnaires, workshop discussions, journal reflections, lesson observations, and focus group interviews as data sources to assist respondents in expressing their perceptions and experiences based on their perceptions and experiences of using Kahoot! The findings reported in this chapter were derived from the data collected. This chapter summarises the four research phases, discussing and analysing the gathered data. The researcher presents and analyses the study results thematically based on the data obtained.

5.2 Research activities

The following summary of research activities in phases below informed the subsequent data generation and analysis.

5.2.1 Phase 1

Hand-delivered semi-structured questionnaires were distributed to participants at their respective schools. Before conducting the study, the goal was to lay the groundwork for the study by learning about teachers' perceptions and attitudes toward using ICT for teaching and learning. Within three days of receiving the questionnaires, all ten participants responded. The information gathered at this stage helped answer the first research question of the study.

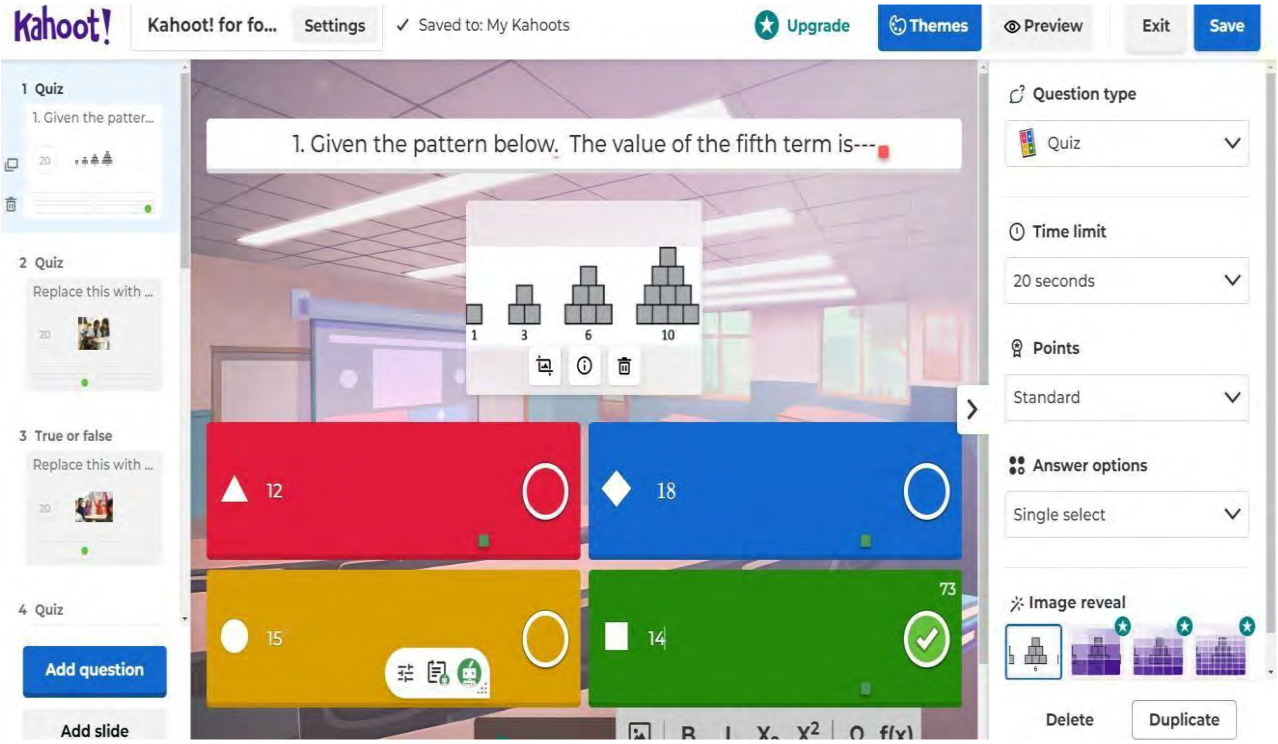
5.2.2 Phase 2

The researcher held an orientation workshop with the teachers to lay the groundwork for this study. This workshop attempted to explain to the participants the rationale for the study, the research procedure, and any ethical concerns. Participants in this workshop were introduced to technological knowledge on downloading and installing Kahoot!, a gamification program on laptops and mobile phones. However, during the workshop.

Teachers were also taught how to use Kahoot! for formative assessment in mathematics.

Figure 6

Teachers' Sample Kahoot!



Participants' questions about clarity were addressed. The second workshop concentrated on mediating and scaffolding mathematical understanding. The researcher guided the teachers to create fraction representations using web-based images representing the three common fraction concepts of ordering, comparing, and simplifying. In the third workshop, we discussed and reflected on participants' experiences with Kahoot! as a formative assessment tool.

5.2.3 Phases 3

During this phase, the researcher observed how the participating teachers integrated Kahoot! Gamification into their classrooms. The researcher had initially planned to observe ten lessons, five from each of the two schools, but ended up observing three teachers, two from one school and one from the other, because teachers had indicated that their schedules were getting tighter since they were planning and preparing for the first quarter summative assessment.

5.2.4 Phase: 4

Phase 4 of the study was intended to include all participants, but due to ongoing workshops in the department, only six could attend. The focus group was held so the researcher could learn the participants' perceptions on the enabling and constraining factors of using Kahoot! Gamification as a formative assessment tool to scaffold mathematical understanding. The data collected in this phase was intended to help answer the third research question. It also allowed participants and researchers to reflect on the entire process and their perceptions; reflections were recorded.

5.5 Data Generation and Analysis

The data generated during the semi-structured questionnaires, focus group interviews, diary reflections, workshop discussions, and classroom observations used to collect data for this study allowed for data triangulation. Triangulation was used to examine the data more comprehensively and to integrate and answer all of the study's research questions. This qualitative analysis of my case study explores how SP teachers use Kahoot! Gamification as a formative assessment tool to scaffold mathematical understanding.

Ten senior-phase mathematics teachers from the Sarah Baartman district schools participated in this study. A diverse group of teachers supports the study's perceptions regarding age, subject area, and experience. Teachers shared valuable and engaging perceptions on this topic. I used pseudonyms for the teachers to ensure adherence to ethical issues such as confidentiality, privacy, and anonymity.

5.5.1 Profile of Participants

Table 1 (see Chapter 4.4.2) provides the pseudonyms of the participants (teachers), the number of years of mathematics teaching experience, teacher ICT competency, the grades they teach, and their years of experience. Tumi, Mdu, Zen, Bright, and Qhama were from **School A**, and Lolo, Ben, Cre, Keke, and Sipho from **School B**.

5.6 Findings for the research questions

5.6.1 Teacher's Perceptions on the use of Kahoot! as a formative assessment tool

The semi-structured questionnaire aimed to understand the senior-phase mathematics teachers' perceptions of using Kahoot! Gamification as a formative assessment tool before this study. The data collected was essential for answering question one: What are the senior phase mathematics teachers' perceptions of Kahoot! Gamification as a formative assessment tool prior to this study? (see Table 3 below). In addition, the semi-structured questionnaire addressed contextual factors such as the type of ICT available in their schools, teachers' level of competence and ICT integration in the school, and the enabling and constraining factors in integrating Kahoot! Gamification in formative assessment was essential in answering the third research question: What are the enabling and constraining factors of using Kahoot!

Gamification as a formative assessment tool to enhance mathematical understanding in senior phase classes?

Table 3

Perceptions of teachers before and after the study

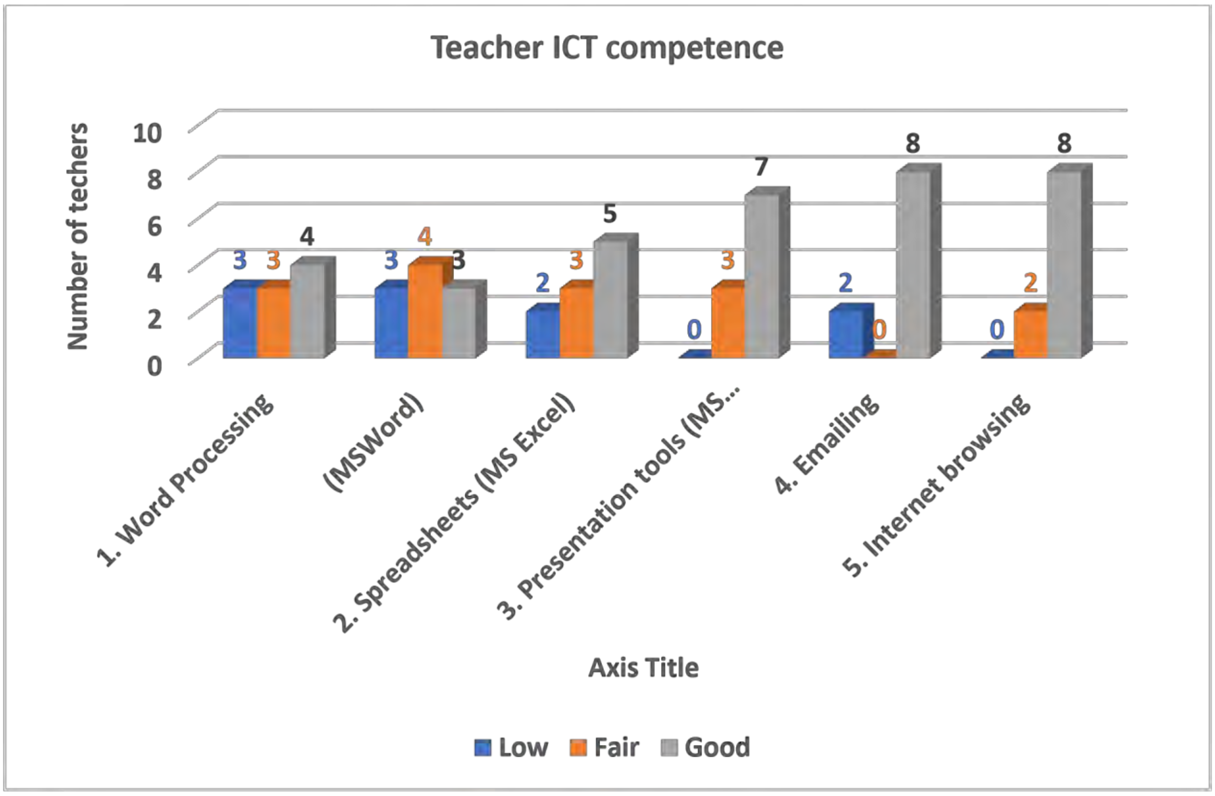
Teacher (Pseudonym)	Teachers' initial perception of technology use in the assessment	Teachers' initial perception of technology use in the assessment
Tumi	Hesitant	Positive
Lolo	Excited	Very confident and appreciative
Mdu	Excited	Works very well, and I am happy
Qhama	Hesitant	Comfortable
Zen	Excited	More comfortable and equipped
Ben	Scared	Positive
Bright	Reserved	Appreciative and equipped
Cre	Excited	More confident
Keke	Nervous	More comfortable
Sipho	Reserved	More confident

The observation in this regard was that both schools have inadequate infrastructure for ICT integration. School A has unlimited Wi-Fi and a library with laptops, a projector, and tablets that learners and teachers can use. School B has network coverage for cell phones but has no WIFI services. Teachers buy data and hotspots on their laptops. Despite the lack of Wi-Fi, teachers use DBE laptops, and the school has a projector. Learners have smartphones that can only be brought into the school by prior arrangement with the teacher. These contextual factors and teachers' perceptions were critical to the study because they helped the researcher decide whether the selected schools were appropriate for the ICT study.

Equally important as the availability of ICT resources was the need to establish TK and teacher's competence in basic ICT programs, which were prerequisites for themes such as TPK (using Kahoot! gamification as a formative assessment tool), creating placement guides, and promoting mathematical understanding. The following excerpt from the questionnaire shows teachers' responses to the ICT skills questions. Figure 7 summarises responses, showing most teachers believe they have moderate to good skills in using basic ICT programs, except for spreadsheets, where most reported low skills.

Figure 7

Extracted from Questionnaire, Section C, Q.1: Appendix A. Teacher ICT competence

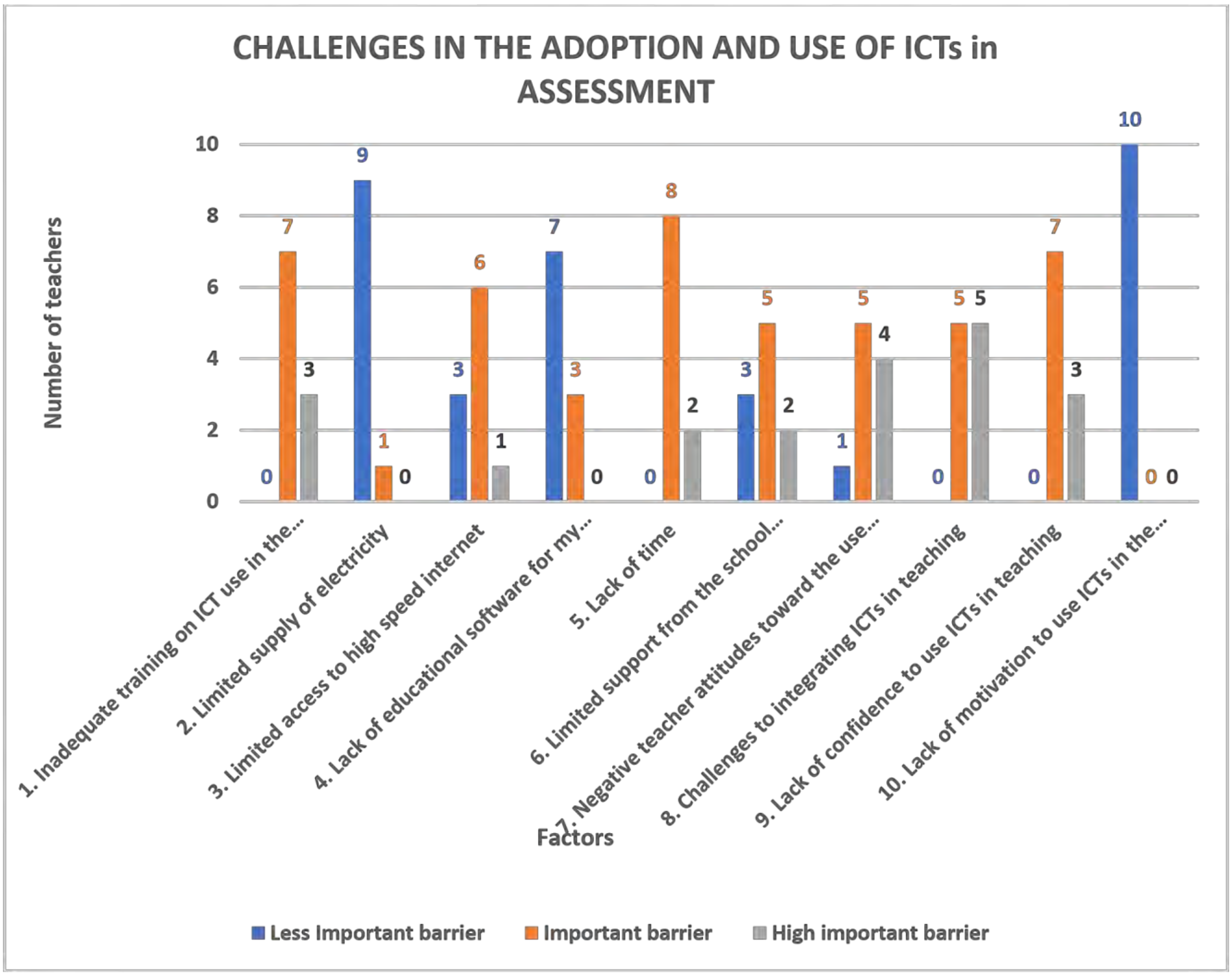


However, this had no bearing on the study as web browsing was the main program used for Kahoot! Gamification. The results also showed that most teachers reported being proficient in email and internet browsing. McNulty (2023) states that ICT skills are critical for teachers to design their lessons effectively and efficiently, assess effectively, develop professionally, and ultimately benefit their learners. Teachers needed ICT skills in various hardware and software domains to do this successfully. For novice users, Kahoot! Gamification offers simple stepbystep instructions and tutorials. A discovery option (https://create.Kahoot!.it/discover) allows teachers to search for Kahoot! (s) related to their chosen content (Xezonaki, 2023; Fuchs, 2022).

Figure 8

Extracted from Questionnaire, Section C, Q.1: Appendix A: Part F:

BARRIERS/CHALLENGES IN THE ADOPTION AND USE OF ICTs in ASSESSMENT



The analysis of the ten questions from Section C of the semi-structured questions based on the teachers' responses presented above revealed two main themes, high and low-impact barriers/challenges, which I discuss below.

5.6.2 High-impact Barriers to ICT Integration

Data analysis has revealed that teachers consider inadequate subject-specific training and lack of time as high-impact barriers to integrating ICT into their teaching practices. High-impact barriers or challenges impede meaningful educational experiences, necessitate learner action and participation, and contribute to the learner's lifelong learning (Harell & Bynum, 2018; Bowman et al., 2020). From Figure 8, the most common high-impact barriers include inadequate subject-specific ICT training, lack of time, negative teacher attitudes toward using ICTs in teaching and learning, challenges to integrating ICTs in teaching, and lack of confidence to use ICTs in education.

5.6.3 Inadequate subject-specific ICT training

Most teachers mention that one of their challenges was inadequate subject-specific training. According to Edmondson (2003; Coombs, 2023), it was necessary for teachers that the skills they were being asked to learn were applied to their experiences and applied to the assessment, teaching, and learning of mathematics. The following participant statements in this study highlighted the challenge of insufficient subject-specific training:

> *"All of the ICT workshops I attend continue to cover MSWord basics; however, we frequently have to start from scratch, identifying the software and hardware and learning how to turn on the laptop. Because of the repetition, we are discouraged from attending the workshop "* Zen.

Qhama further stated:

> *"The training on the use of specific ICT in teaching mathematics is important because it allows us as teachers to learn present using abstract technology concepts to learners vividly. For example, we can learn how to form our fractions in words. However, when we attend workshops, we are treated like clerks and must create only relevant spreadsheets for finance. Why not teach us how to create simple mark sheets?".*

Inadequate subject-specific training is a significant barrier to ICT integration. Many teachers lack the skills and knowledge to incorporate technology into their lessons effectively. This can lead to a lack of confidence and reluctance to use ICT, resulting in missed opportunities for enhancing learning. To overcome this barrier, teachers must receive ongoing professional development and training in using ICT.

5.6.4 Lack of time

Lack of time is another significant barrier to ICT integration. Teachers have limited time to plan and deliver their lessons, and incorporating technology can be time-consuming (Maja, 2023). This can lead to a reluctance to use ICT, as teachers may feel it takes away valuable teaching time.

On lack of time, Tumi commented that;

> *" Our greatest challenge is teaching multiple subjects. We may want to modify the departmental lesson plans from time to time based on the needs of the learners, but having to sit and draw those lesson plans, mark them, and still do other administrative duties while adhering to the pace setters' time frames is a lot of work".*

Furthermore, Lolo stated that;

> *"Not all school management welcomes the use of ICT in the classroom. I have experiences where using a projector and playing videos was viewed as a sign of incompetency in the content on the part of the teacher as such as young teachers, and sometimes we are sceptic of using ICT in the classroom".*

To address this barrier, schools must provide teachers with the necessary resources and support to integrate ICT into their teaching practices effectively.

5.6.5 Negative teacher attitudes toward using ICTs in teaching and learning.

Teachers' attitudes toward ICTs determine whether or not they will adopt them or not; their beliefs influence those attitudes. Convictions in this category include normative, self-efficacy, and pedagogical convictions. Normative convictions refer to the social norms and expectations teachers perceive from their colleagues, administrators, and society. If teachers believe their peers and superiors value using ICTs in education, they are more likely to adopt them. On the other hand, if they perceive that their colleagues and administrators do not prioritize using ICTs, they may be hesitant to adopt them.

Pedagogical factors refer to teachers' teaching methods and strategies to impart knowledge to learners. For example, respondents indicated clashes with management because of different teaching styles and ICT adoption for teaching and learning. For example, Zen commented that;

"Sometimes young teachers want to use ICT in teaching and learning since they are more inclined towards constructivism, but the older generation believes more in teacher-centred education and dislike it when new things are introduced".

Self-efficacy convictions refer to teachers' beliefs in their ability to use ICTs effectively in their teaching. If teachers feel confident using ICTs, they are more likely to adopt them. However, if they lack confidence in their skills, they may be reluctant to use them. Therefore, providing teachers with adequate training and support is essential to enhance their self-efficacy. The teachers' responses revealed that they recognized the importance of using ICT in teaching and learning mathematics. However, they were sceptical about its adoption because of negative media reports from other schools, behavioural problems in learners, and a lack of school ICT policies.

Mdu stated that;

"We cannot deny that our learners love technology and learn better as they are so motivated during technology lessons. However, our challenge as schools are using cell phones, which disrupts teaching and learning. For when learners are used as drug mules, and we find learners bringing drugs to school because communication is made easier with social networks, and sometimes learners misbehave and then take pictures or record videos of things happening either in school or the classroom that end up destroying the reputation of the teacher and that of the school."

Teachers demonstrated self-efficacy in the discussions by identifying challenges associated with ICT integration, such as subject-based training and learner-disciplinary problems. Further, they suggested solutions more consistent with learner normative factors by recognising the effect of social and societal norms on the educational system. Cultural norms, for example, could impact school teaching and learning. Certain subjects may be deemed more essential than others in some societies, e.g. the labelling of mathematics as a complex subject. As a result, school curricula may reflect these cultural norms. Furthermore, societal norms can influence learner and teacher conduct. Learners, for example, are required to be polite to their teachers in several cultures, and cell phone use at home is controlled and restricted to certain times.

Kahoot! serves multiple purposes, such as teaching mathematical content, creativity, communication, and skills and behaviours (Wannapiroon & Pimdee, 2022); it can also attract learners' attention by changing the classroom atmosphere (Li, 2022).

"I noticed that when engaged in play, some things would typically become a teacher's responsibility, like discipline, time management, and feedback. Whereas with games, learners are quick to know the rules, and they are on time, a skill they need a lot in assessment when writing" Zen

Mdu further elaborated;

"The part I liked most as I moved around during the discussions was listening to the learners' arguments as they debated the correct answer. As a teacher, it gives you a chance to hear the thinking behind their solutions, and the best part is that the misconception is immediately cleared, meaning by the time they do their classwork, learners will be clear on the content".

Bright stated that:

"The fact that there are rules to be followed in a game and learners can follow them is a fundamental basis for instruction. Seeing them caution each other and resolving conflicting opinions thereby work peacefully together, creates a conducive learning environment for teaching and learning".

The teacher's statements showed that Kahoot! provides players with problem-solving, social interaction, and cooperative learning in a face-to-face classroom environment (Bawa, 2019). The learners are actively engaged in the teaching and learning process and encouraged to learn.
It is easy to remember, as learning is fun because it creates a competitive environment (Tiwari, 2022).

As a result, teachers may employ disciplinary procedures that are consistent with these social norms and design cellphone policies for their schools. These would help alleviate fears expressed by Mdu and Zen, who expressed fears about using ICT for teaching and learning because they believed that it disrupts teaching

5.6.6 Teacher's Assessment Practices

Establishing the teachers' assessment practice before the research was paramount as it helped with the workshop's planning and gave the researcher a general view of the assessment practices practised by the participants from which conversations about assessment emanated. See the table below:

Table 4

Extracted from Questionnaire, Section C, Q.1: Appendix A: Part G: Teacher's Assessment Practices

	Tumi	Lolo	Mdu	Qhama	Zen	Ben	Bright	Cre	Keke	Sipho
How often do you formatively Assess your learners, e.g., in a week?	5	5	5	5	5	5	5	5	5	5
What forms of Feedback do you use?	Peer feedback	marking	Peer feedback	Peer feedback	marking	Peer feedback	Peer feedback	marking	marking	Peer feedback
What factors hinder assessment at your school?	Workload	Big classes	workload	workload	workload	Teaching multi subjects	Workload	Teaching multi subjects	workload	Teaching multi subjects

The data from Table 4 laid a basis for workshop discussions on themes such as summative and formative assessment, assessment feedback, errors and misconceptions, and gamification.

It is a teacher's obligation to ensure that learners acquire knowledge and progress in their studies. This can be achieved in part through assessing their work and providing feedback. However, with the rising workload and administrative duties that come with the job, assessing individual learners daily might be challenging. Teachers expressed concerns about multi subject and grade teaching, negatively impacting their ability to give adequate formative feedback.

Based on the data in Table 4, all participants administer formative assessment daily. However, forms of Feedback varied, with most teachers using peer feedback.

In elaboration, Bright stated that;

> *"By peer feedback, we mean that after writing, the learners exchange their books, and the teacher gives them the memo. They then put x for wrong answers and tick the correct answers. The books are then collected and given to the teacher to append their signature. Parents are also encouraged to sign the learners' book regularly".*

Tumi further stated:

"Our workload and other administrative duties do not allow us to grade individual learners daily because sometimes you teach many subjects at different grades or have a lot of other administrative duties. Such exercises are done so that you comply with the subject regulations. Otherwise, you get in trouble with the departmental officials.".

Recognizing that assessing learners daily is more than just following subject regulations is crucial. It also ensures that learners receive prompt feedback on their work, which can enhance their mathematical understanding. However, with so many other duties, it might be challenging to find time to analyse every learner's work daily.

Although some teachers indicated that they occasionally mark their learners' work, they contended that they did not put too many thought processes in the processes, such as learner errors and misconceptions.

In elaborating, Cre states that;

"It is always to blame and label our learners as not understanding mathematics when we are shocked by the summative assessment results, but honestly, there is a lot we do not do right as teachers. For example, I am one person who frequently does my marking, but I haven't been exposed to the notion of analysing their errors and misconceptions to inform my practice, but mostly for them to know how they are doing".

While teachers may not be able to evaluate each learner's work critically daily, they can provide timely feedback and ensure learners' educational growth. This may necessitate prioritizing their workload and finding more effective ways to complete administrative responsibilities. The teachers ’ ultimate goal ought to be to deliver the highest level of instruction possible for learners, and assessing learners and giving them immediate that enables them to rectify their errors and misconceptions is vital.

5.7 Pedagogical and technological experiences in using Kahoot! Gamification to scaffold mathematical understanding.

This study explored the teachers' use of Kahoot! Gamification to scaffold mathematical understanding. The gathered data was relevant in answering the second and third research questions. Data from the interviews, journal reflections, and lesson observations were analysed to answer the second and third questions. The themes of knowledge acquisition, retention and improvements and suggestions were prevalent in the responses of all ten participants. Eight participants mentioned scaffold, mediation, attention, concentration, interaction, and engagement. While six mentioned adaptability to learner environments. Finally, nine participants indicated the themes of fun, enjoyment, and assessment could be manipulated to suit learner backgrounds and environments and enabling and constraining factors.

5.7.1 Scaffolding and Mediation

One of the themes that emerged from the data analysis was the importance of scaffolding and mediating when using Kahoot! assessment. Teachers found that providing support and guidance to learners was critical to enhancing mathematical understanding. This included providing clear instructions, modelling how to use the platform, and offering feedback throughout the assessment. Eight teachers felt that the mediation tools in the Kahoot! platform offered improved opportunities for scaffolding mathematical understanding. More so, the interactive nature of the forum and workshops enabled the teachers to experiment, think more carefully about the assessment objectives, and focus when answering a Kahoot! game to avoid mistakes in front of their peers and to win. Ben stated that;

> *"I noticed that I took more time in learning and practising than usual since I was more engaged and actively learning than sitting with a pile of past exam papers, doing cut and paste."*

The results further revealed distinct sub themes themes discussed earlier (see chapter 2.2) as indicators of mathematical understanding: giving examples and non-examples of ideas, utilizing and choosing particular procedures or operations, applying problem-solving algorithms, connections and representations, communication, reasoning, proof, and problem solving (NTCM, 2000). The data analysis also revealed that Kahoot! assessment could promote learning and mathematical understanding. Teachers found that the platform allowed them to assess learner knowledge and understanding in real time, which helped them to adjust their teaching accordingly.

5.7.2 Time is a critical factor when administering the Kahoot! assessment

The teachers received prior training on how to use Kahoot! to ensure they could properly use the platform. Teachers struggled with time management during the Kahoot! Gamification practice is partly because of partial internet browsing skills. In the pre-exercise, some also needed more time to solve given tasks. This observation highlighted the importance of adjusting the time allocation per question in future assessments. During classroom observation, where Kahoot! was used as a 15-minute pre-test, learners' performance was inadequate, which could be attributed to their inability to manage time in Kahoot! assessment. Teachers found that the time given to complete the assessment impacted learner performance. Some learners struggled to keep up with the pace of the assessment, while others finished quickly and became disengaged.

5.7.3.2 Communication, reasoning, interaction and engagement, and comparison

Seven participants said Kahoot! allowed them to compare, discuss, and justify their answers. Four of the seven teachers talked about how they solved problems by allowing them to explain why a particular answer was correct.

> *" The exercise enabled me to see the missing link in my classroom after marking. It has enriched me on the importance of creating opportunities for communication and discussion to enable mathematical understanding. Moreover, it provides opportunities for learners to correct each other's errors and misconceptions before it's too late" Cre.*

Cre's comment also highlighted the theme of social interaction from the research's Theoretical Framework (see Chapter 3.2.1). Kahoot! created a fun environment where teachers and learners were interested in fractions. Participants found Kahoot! to be a more appealing learning method than traditional methods. Furthermore, Kahoot! promoted social interaction among participants and in their classrooms.

Using Kahoot!, nine teachers discussed themes of joy, excitement, fun, and enjoyable experiences. Compared to a traditional math class, Kahoot!'s features, such as using a mobile device, music, and bright colours, helped learners feel more positive and engaged.

> *"Seeing the excitement and joy on the learners' faces when I announced that we would use cell phones in the next lesson was heart-warming." Cre.*

Lolo further stated,

> *"The learners were interested in the mathematical content because Kahoot! created a fun atmosphere."*

The platform allowed for increased interaction and engagement among learners, providing opportunities for collaboration and competition. Additionally, learners were more engaged and motivated when the assessment was enjoyable by incorporating music, sound effects, and colourful graphics.

Teachers revealed that Kahoot! assessment could be manipulated to suit learner backgrounds and environments. They found that they could customize the assessment to meet the needs of their learners by adjusting the difficulty level of the questions and incorporating culturally relevant content.

5.7.7 Enabling and constraining factors of using Kahoot! Gamification to scaffold mathematical understanding.

The data analysis revealed enabling and constraining factors that impacted the use of Kahoot! assessment in the classroom. Teachers found that factors such as access to technology, learner motivation, and subject-relevant teacher training all played a role in the success of the assessment. The enabling and constraining factors for using Kahoot! Gamification to scaffold mathematical understanding was examined using data from focus group interviews, journal reflections, and workshop discussions.

The data analysis revealed sub-themes that provide insight into using Kahoot! assessment in the classroom. These themes highlight the importance of scaffolding and mediating, time as a critical factor, learning and mathematical understanding, fun and enjoyment, attention and focus, interaction and engagement, assessment can be manipulated to suit learner backgrounds and environments, and enabling and constraining factors. By understanding these themes, teachers can effectively use Kahoot! assessment to promote learning and engagement in the classroom.

5.7.7.1 Convenient and accessibility

The participants had a colossal consensus on Kahoot! being easy to use. Teachers can create quizzes and discussions in minutes, and learners can participate with just a few clicks. This means that teachers can spend more time teaching and less time preparing materials, which benefits teachers with large classes or who teach multiple subjects. Another reason why Kahoot! is so convenient that it can be accessed from anywhere at any time. All a learner needs is a smartphone or computer with an internet connection, and they can participate in

Kahoot! quizzes and discussions. This means that learners can learn at their own pace and on their schedule, which is particularly useful for learners with busy schedules or who live in remote areas.

Kahoot! is also highly accessible, meaning learners of all ages and abilities can use it.

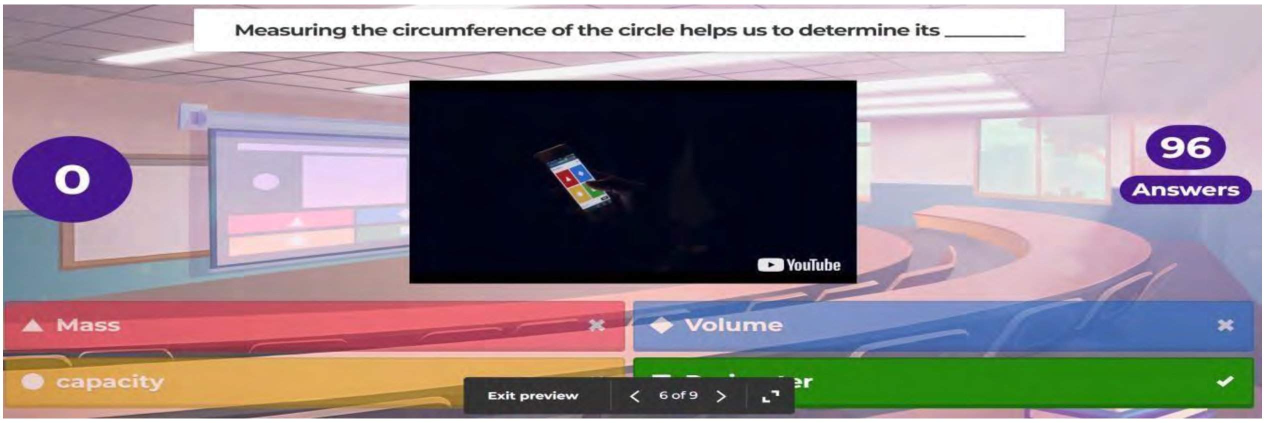
> *"I have always been uncomfortable when one mentions ICTs, and it was worse this time because this was going to be extended to the classroom. My initial reaction was to run as fast as you could! But I am glad I stayed because the platform was straightforward and engaging. I found myself practising even on my phone when I was not busy. Indeed, sometimes fear is only in our minds" Tumi.*

In addition, Qhama said;

> *"Since the orientation, I have been mostly glued to my phone, experimenting with other mathematical concepts with this platform. I find it very helpful as it helps me get other questions from other professionals globally. This is one very convenient platform for teaching and learning for our learners since they are a generation that loves technology."*

Kahoot! has a 5/5 stars rating for usability (Li, 2022; Candan & Basaran, 2023). Kahoot!'s Inclusion and Accessibility Policy states the principles of diversity and inclusion and the goal of being perceivable, usable, and understandable for all users, including those using assistive technologies, according to the Web Content Accessibility Guidelines (WCAG) (Candan & Basaran, 2023). Kahoot! allows teachers to insert images, videos (See Fig 9), and voice recordings (for subscribed users).

Figure 9
Kahoot! With video attachment



These features are essential for visualization and convenient for math teachers, as they allow them to contextualize Kahoot! so that learners can do something to enrich mathematical discussions and improve mathematical understanding. The platform is designed to be user friendly, with simple instructions and intuitive navigation. This means that even young learners can use Kahoot! without difficulty. Another reason why Kahoot! is so accessible is that it can be customized to meet the needs of individual learners. Teachers can create quizzes and discussions tailored to each learner's learning needs, meaning they can learn at their own pace and in their own way. This is particularly useful for learners with learning disabilities or who struggle with traditional teaching methods.

Participants reported that Kahoot! fostered interactivity and engagement through answering questions and participating in discussions, unlike conventional classrooms, where a few extraverted learners often dominate discussions. Kahoot! encourages interaction and collaboration with peers, information, and content.

> *"You know your learners' moc. There are those who always choose to keep to themselves so much that, as a teacher, you need to probe them consistently for them to participate. I was shocked when I used this platform because they became too active and excited. They needed no convincing at all. You could see them engaging in their small groups while keeping their eyes on the scoreboard. The many changing numbers would have easily confused me as an adult, but you could see the excitement as they kept track of the changing scores determined to outshine the other groups". Cre*

Anonymity on the scoreboard has also helped learners learn.

> *"I think one advantage of the platform was to allow learners to choose a different name. We have learners who are too forward and look at others' scores and maybe laugh loudly, which can intimidate others. Anonymity helped everyone to remain in the game and track themselves against unknown opponents. Although learners might discuss the names after the game, they are however kept safe and not intimidated during play, and they still reserve the right not to tell their game name," Tumi.*

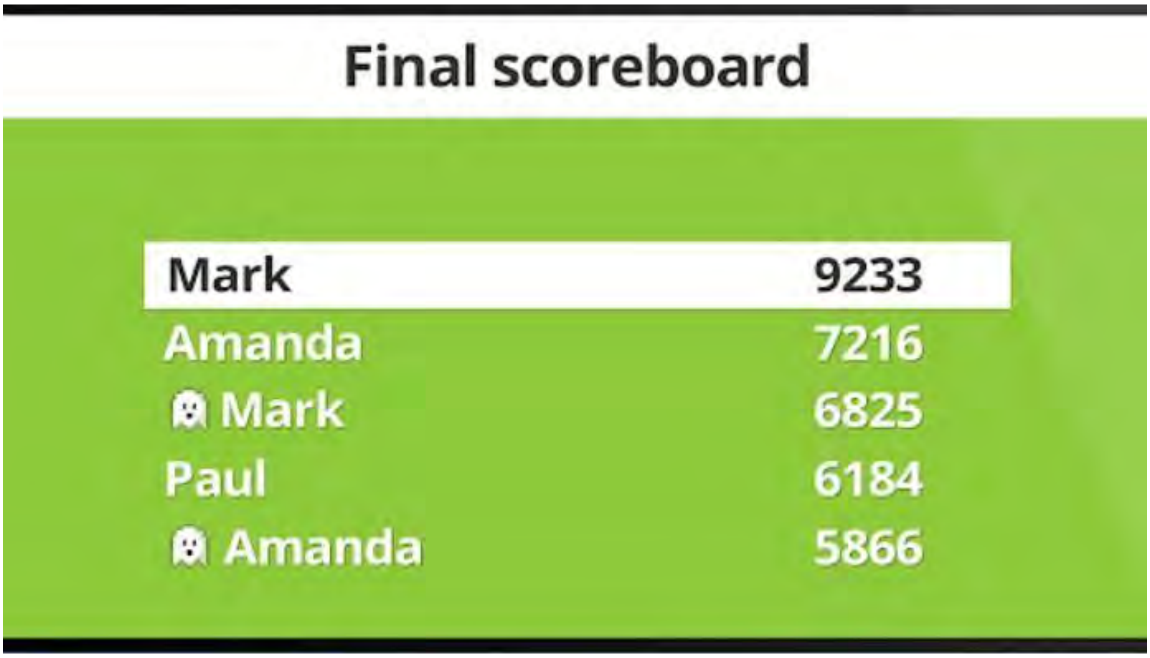
The researcher concluded that while anonymity can be perceived as a negative aspect of participating in technology-mediated learning environments, allowing learners to enter a name of their choice into the system each time they participate can promote deep and enriching participation. Anonymous participation in a learning environment can encourage greater participation by providing a sense of security and privacy (Kapp, 2012; Calafato, 2022).

5.7.7.2 Positive Competitiveness and Motivation

Positive competitiveness is the idea of competing with others healthily and positively. Kahoot! This is achieved through leaderboards (See Figure 10) and points. Learners are ranked based on performance, and the leaderboard is updated in real-time. This creates a sense of healthy competition among learners, motivating them to perform better and score higher.

Figure 10

Kahoot! leader board



The respondents showed Kahoot! to be good at competitiveness and motivation. Kahoot! games are designed to be fast-paced and engaging, which keeps learners interested and motivated to participate. The competitive nature of the games also encourages learners to strive for excellence and do their best. Learners earn points for correct answers in Kahoot!, which can be redeemed for rewards such as badges and certificates. This motivates learners to learn and gives them a sense of accomplishment and recognition.

> *"Kids love games; it is worse how you see them glued up on the phones, even the youngest ones who cannot read find their way to their favourite applications. Their love for technology and competition makes them motivated and very persistent as they can try many times until they get something right." Qhama*

Motivation is the driving force that makes learners want to play, get to the end of the game, and complete the learning. Badges are used as rewards at checkpoints throughout the game. Kahoot! is designed as a competitive game that draws learners' attention with its speed and touchable adaptability.

> *"I liked that the game is accessible even away from the classroom, so as long as a child has a smartphone, the link to the game, and data, they can always practice even at home. We struggle with learners regarding homework because some stay with illiterate parents. Besides, not everyone is comfortable with mathematics. The platform offers learners excellent opportunities to continue learning in the way they are taught as the correct answers are done and shown the way the teacher wants" Sipho.*

The teachers' responses show that Kahoot! could be essential for continuous assessment and school-home connection and provide opportunities for independent study. Learners can choose to learn individually or work in groups. Consequently, Kahoot! can play a fundamental role in establishing solidarity among learners and reinforcing learners' creativity in learning. Kahoot! made learning fun and engaging by creating a sense of healthy competition, teamwork, and reward.

5.7.7.3 Feedback (teacher and peer)

The participants stated feedback is an essential component of learning. It helps learners understand their strengths and weaknesses, identify areas for improvement, and develop critical thinking skills. In Kahoot!, feedback comes in two forms: teacher and peer feedback (See Chapter 2.2.3). Both types of feedback are crucial for learner success and should be utilized to their fullest potential. The first type of feedback in Kahoot! is teacher feedback. Two participants could use the assessment summary on Kahoot! Gamification, which they found very useful and quick compared to having to mark and then do question-by-question analysis by the teacher. Teachers also noted that they could use Kahoot! to create quizzes and assessments that provide immediate feedback to learners. This feedback can be in the form of correct or incorrect answers, explanations of why an answer is correct or incorrect, and suggestions for improvement.

Teachers can also use Kahoot! to track learner progress and identify areas where learners may need additional support. The second type of feedback in Kahoot! is peer evaluation. Kahoot!

allows learners to create and share their quizzes with their classmates. This allowed learners to receive feedback from their peers on their understanding of a topic. Peer evaluation can help learners identify gaps in their knowledge and better understand the material. It also encouraged collaboration and communication among learners. Both types of feedback in Kahoot! are valuable for learner learning. Teachers' assessments provide expert guidance and support, while peer evaluation encourages learner collaboration and communication. However, it is essential to note that feedback should be constructive and specific. Vague or overly critical feedback can be demotivating and hinder learner progress.

5.7.7.4 ICT technical and network glitches

One of the main constraining factors of Kahoot! Gamification is technical glitches. Teachers reported that the platform experiences technical issues such as slow loading times, freezing, and crashing. These technical glitches can disrupt the lesson flow and cause frustration among learners and teachers. Another constraining factor of Kahoot! Gamification is network glitches. Teachers reported that the platform requires a stable and strong internet connection. However, Kahoot! may not work as intended in areas with poor internet connectivity, which can lead to lesson delays and cause frustration among learners and teachers.

Lessons generally flowed smoothly in School B because the library's projector was fixed on the ceiling, and the uncapped Wi-Fi was stable. However, in the one lesson observed in School A, the researcher had to assist with setting the projector as the screen was dim. The network was also suitable for Telkom and Vodacom users and a bit slow for MTN users.

> *"What I dislike about Kahoot! is the connection. Sometimes, Kahoot! can be slow and have errors in running due to network instability. I think we need Wi-Fi connection as a school for such purposes as not every learner can afford data always." Bright*

From the participants' responses, the biggest challenge in playing Kahoot! is the connection challenges depending on the users' network. This means that Kahoot! needs a strong Internet connection to run smoothly and without interruptions

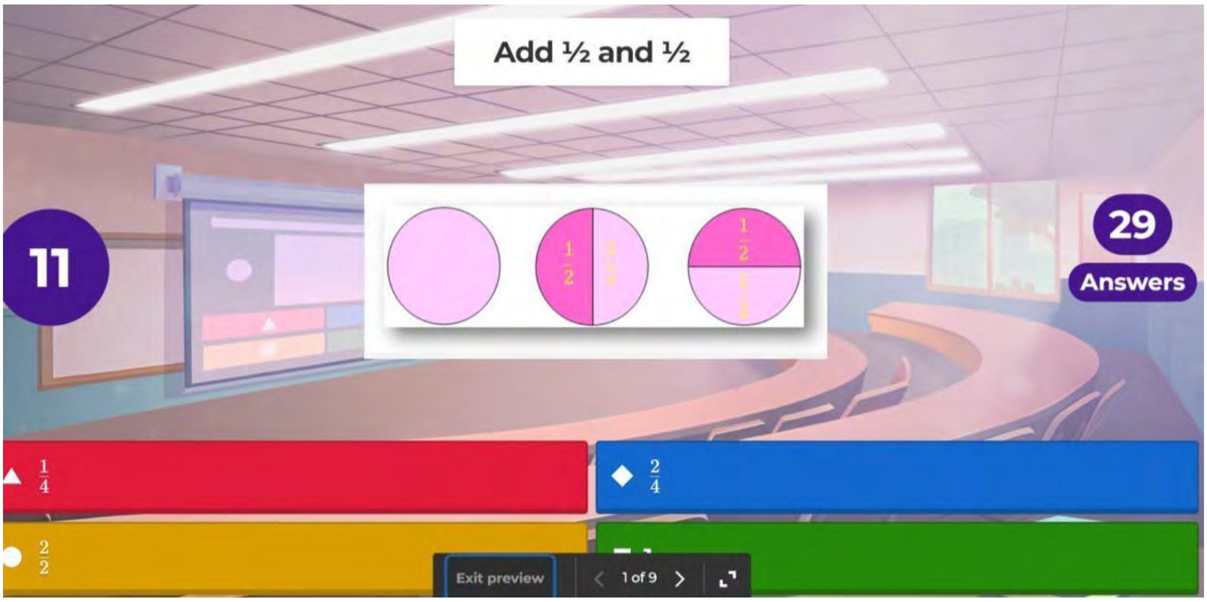
5.7.7.5 Anxiety in answering the questions due to the timer

The timer in Kahoot! can also be a constraining factor. The timer (see Fig 11) that Kahoot! has built into each question is one of its features that encourages competition among learners in answering the questions. Most teachers praised this feature. However, one felt that learners might not have enough time to think, and their answers may be wrong due to the timer causing anxiety and fear, thereby making them lose focus. Playing Kahoot! triggered this anxiety in two of the study participants.

> *"I am one person who likes to take my time when doing something, and I quickly get anxious when put under pressure. The timer for me exerts pressure to finish the tasks, which may make learners like me fail the assessment not because they did not know the content but because of the anxiety" Mdu.*

Figure 11

A question with the timer counting down from 15 seconds



While Kahoot! Gamification has many benefits in education, but it also has constraining factors that must be considered. Technical and network glitches can disrupt the lesson flow and cause frustration among learners and teachers. The timer can also cause anxiety in some learners, leading to incorrect responses and negatively impacting the learning experience. As such, it is crucial for teachers to be aware of these constraining factors and to have backup plans in place in case of technical issues. By doing so, they can ensure that Kahoot! Gamification is used effectively and enhances the learning experience for all learners.

5.8 Summary

This chapter discussed the research findings guided by the three research questions. The first research question focused on the senior phase mathematics teachers' perceptions of using Kahoot! Gamification as a formative assessment tool before this study. The second is how senior phase mathematics teachers use Kahoot! Gamification to scaffold mathematical understanding. The third is the enabling and constraining factors of using Kahoot! Gamification as a formative assessment tool to enhance mathematical understanding in senior phase classes. Data generated through semi-structured questionnaires, focus group interviews, non participatory observations, and journal reflections were all at the centre of this chapter. The results were presented according to themes from the data analysis based on the research questions. The following chapter discusses the findings, considers some implications, concludes this study, makes some recommendations, and further explores avenues for future research based on the analysis.

6 CHAPTER SIX: DISCUSSION OF FINDINGS

6.1 Introduction

The previous chapter reported on the findings of this study. In this chapter, the researcher presents a discussion of the findings. The findings are contrasted with prior literature that was reviewed in Chapter Two. This research study aimed to explore SP teachers' use of Kahoot! Gamification as a formative assessment tool to scaffold mathematical understanding. The research was undertaken with ten senior phase mathematics teachers from the Sarah Baartman district. The literature review revealed that gamification has been used as a formative assessment tool in various educational settings and for its advantages, such as learner motivation and rapid feedback. However, the use of gamification in mathematics education has been limited.

The findings of this study contribute to the existing literature by providing evidence of the effectiveness of Kahoot! Gamification as a formative assessment tool in mathematics education. In this chapter, the researcher presents and discusses a summary of the main findings. The chapter begins with a discussion of the perceptions of the senior phase teachers based on the findings from the semi-structured questionnaire on the perceptions of the ten teachers on using Kahoot! Gamification as a formative tool. Then, some implications of the study are considered. Conclusions are drawn from the study regarding the use of Kahoot! as a formative assessment tool.

6.2 Discussion of key findings

The main findings are presented and discussed (see Chapter 5) as per the deliberations of the semi-structured questionnaire, focus group interview, journal reflections, and observed lessons.

6.2.1 Perceptions of senior phase mathematics teachers on using Kahoot! Gamification as a formative assessment tool.

Perception is the cognitive process through which we interpret events and phenomena in our environment, gaining meaning and understanding of the world (McClelland, Norris, DomineyHowes, & Govender, 2021). In education, teachers' perceptions play a crucial role in integrating information and communication technology (ICT) to enhance the teaching and learning of mathematics. According to Rose (2023), the successful integration of technology hinges on teachers' perceptions of its value as a tool for improving learners' mathematical understanding.

This discussion is based on analysing responses from a semi-structured questionnaire (see Appendix A) administered before the research's commencement. The semi-structured questionnaire sought to answer the research question (RQ).

RQ1: What are the senior phase mathematics teachers' perceptions of using Kahoot! Gamification as a formative assessment tool prior to this study?

The study revealed that most selected senior phase mathematics teachers had a positive perception of using Kahoot! Gamification as a formative assessment tool. Their acceptance of game-based assessment was influenced by their perspectives on integrating technology in the classroom. However, nearly sixty percent of the participants lacked computer training, although they had some familiarity with technology through smartphone usage and self-exploration. The participants found Kahoot! Gamification easy to use, similar to previous studies by Plump and LaRosa (2017).

The lack of expertise and low self-efficacy were identified as factors restricting the classroom usage of game-based learning technology. Teachers cited insufficient subject-related ICT expertise, limited access to technology, and resistance from older generation teachers in school management as challenges. Similar views were found in the research conducted by Schader, Zheng, and Young (2006). These findings align with previous studies on teachers' perceptions of games and ICT integration in mathematics instruction, which highlight challenges such as lack of expertise, anxiety towards technological innovations, limited resources, and lack of support.

Despite these challenges, all participants recognized the learner-centered nature of Kahoot! Gamification and its ability to better meet the needs of learners. The immediate performance summaries provided by Kahoot! allowed teachers to assist and reach out to a larger number of learners compared to a traditional teacher-centered approach. However, concerns were raised about potential overuse of Kahoot! and its suitability for learners who struggle with technology or have learning difficulties.

Teachers acknowledged the potential of ICT integration in teaching and learning but expressed concerns about incidents in other schools, behavioral problems in learners, and a lack of ICT policies. Factors hindering teacher readiness and confidence in using ICT support included attitudes, expertise, lack of autonomy, and a lack of knowledge to evaluate the role of ICT in the classroom. Additionally, a lack of learning resources, curricula, and materials incorporating ICT was identified.

In conclusion, senior phase mathematics teachers generally held a positive perception of using Kahoot! Gamification as a formative assessment tool. Despite some concerns, teachers appreciated the engagement and feedback that Kahoot! provided to learners. Therefore, Kahoot! Gamification can be a valuable addition to teachers' formative assessment toolkit, as long as it is used appropriately and in conjunction with other assessment methods.

6.2.2 Teacher Assessment Practices Prior to the study

The study findings showed that although all the participants consistently gave classwork, some relied on peer marking with exchanged memorandums and no discussion, which the research found inadequate. Peer marking is standard practice in education but is not always effective. Firstly, the peer marking described by the participants with exchanged memorandums did not allow learners to receive feedback from their peers or the teacher. The focus was on whether the answer was correct or wrong. The participants noted that feedback is an essential part of the learning process, which helps learners to identify their strengths and weaknesses. When appropriately used, peer feedback can be a very effective strategy. However, not all feedback improves learner performance (Gomez & Bernet, 2019; Podolsky & Darling-Hammond, 2019).

Learners who rely on memorandums miss the opportunity to engage in collaborative engagements with their peers, which can benefit their learning. A year-long study by Lambert, Sugita, Yeh, Hunt, and Brophy (2020) conducted on Oscar, a fifth-grade learner with autism, examined the influence of the classroom activity system on his participation in mathematical reasoning and discourse before and after a classroom intervention targeted to improve learner engagement by making participation norms more explicit. Before the classroom intervention, Oscar did not participate verbally in small-group or whole-group mathematical discussions. After the classroom intervention and additional scaffolds such as increased peer accountability and collaborative strategy shares, Oscar increased his verbal and nonverbal participation in small- and whole-group discussions. Through our year-long study, Oscar shifted from a learner who did not speak in math class to one who explained his mathematical thinking in multiple contexts. We call for additional qualitative research in mathematics that seeks to understand the unique participation of autistic learners, seeking an understanding of how to include these learners in the Standards for Mathematical Practice.

The respondents' post remarks showed that peer marking with exchanged memorandums does not promote critical thinking. Learners who discuss their work are forced to think critically about their ideas and arguments. The National Council of Teachers of Mathematics (2014, p. 5) has set meaningful learning as a critical goal of mathematics teaching: " An excellent mathematics program requires effective teaching that engages learners in meaningful learning through individual and collaborative experiences that promote their ability to make sense of mathematical ideas and reason mathematically " . The National Council of Teachers of Mathematics (2014) further recommends the use of concrete aids and collaborative working practices in the teaching of real-world contexts. The Sociocultural theory of learning underpins social interaction approaches. Collaboration learning approaches such as class discussion, group work, involvement, and communication are recommended in many studies (Hofmann & Ruthven, 2018; Smith & Mancy, 2018; Sharoff, 2019; Cao, 2023).

70% of the respondents stated that feedback goes beyond ticking correct answers and putting a cross on the wrong ones. Brookhart (2011, p. 2) affirms, "Feedback can be very effective when done well. The strength of formative Feedback lies in its two-pronged approach that simultaneously addresses cognitive and motivational factors. Good feedback gives learners the information they need to understand first where they are learning and, secondly, what they need to do next - the cognitive aspect. Once they know what to do and why, most learners develop a sense of control over their learning - the motivational factor. The research shows that to improve learners' mathematics understanding, teachers should treat their errors and misconceptions as an opportunity to stimulate conceptual and procedural understanding (Larrain & Kaiser, 2022; Kshetree, Acharya, Khanal, Panthi & Belbase, 2021; Trigueros, Sandoval & Lozano, 2020).

Respondents stated that because of the rapid feedback, they are better equipped to work with their learners. The research findings indicated that teachers now had a broader perspective on understanding learners' errors and misconceptions as valuable learning resources that can promote a deeper and broader understanding of mathematical content and potential catalysts that stimulate reflection and exploration (Hu, Son & Hodge, 2021). Teachers who analyse them not only diagnose learners' learning difficulties and provide them with numerous opportunities to learn from their mistakes (Wijaya, Retnawati, Setyaningrum & Aoyama, 2019) but also significantly improve their instructional practices (Oke & Fernandes, 2020).

The teachers also accumulate an extensive reservoir of potential errors and develop strategies to help learners overcome the errors that would otherwise persist for several years without appropriate pedagogical intervention. The research findings resonate with Larrain, Macarena, Kaiser, and Gabriele (2019).

6.2.3 RQ2: How do senior phase mathematics teachers use Kahoot! Gamification to scaffold mathematical understanding?

During the research study, four mathematics classroom-based observations were conducted to understand how senior phase mathematics teachers use Kahoot! Gamification to scaffold mathematical understanding. The observations provided insights into the strategies employed by teachers to enhance learners' learning experiences. Here are the observations with examples of activities:

Observation 1:

During this observation, the teacher used Kahoot! to introduce a new mathematical concept to the learners. The teacher created a Kahoot! quiz with multiple-choice questions that covered various aspects of the concept. The learners actively participated in the quiz, answering questions and competing against each other. Through this activity, the teacher scaffold the learners' mathematical understanding by providing immediate feedback and explanations for the correct answers. The use of Kahoot! facilitated an engaging and interactive learning experience, promoting active participation and knowledge retention.

Observation 2:

In this observation, the teacher used Kahoot! as a formative assessment tool to check learners' understanding of a previously taught mathematical topic. The teacher created a Kahoot! quiz with a mix of questions that assessed different aspects of the topic. The learners played the quiz individually, and their responses were displayed in real-time on the classroom screen. The teacher used this opportunity to identify common misconceptions and provide targeted interventions to address those misconceptions. By using Kahoot! as a formative assessment tool, the teacher scaffold the learners' mathematical understanding by identifying areas of improvement and guiding them towards conceptual clarity.

Observation 3:

During this observation, the teacher utilized Kahoot! to facilitate a collaborative learning activity. The teacher divided the learners into small groups and assigned them different mathematical problems to solve. Each group created their own Kahoot! quiz based on the assigned problem, incorporating multiple-choice questions that required critical thinking and problem-solving skills. The groups then exchanged quizzes and played each other's Kahoot! quizzes. This activity encouraged peer learning and collaboration, as learners discussed and debated the solutions. The teacher actively participated in the discussions, providing guidance and clarification when needed. Through this collaborative Kahoot! activity, the teacher scaffold the learners' mathematical understanding by promoting teamwork, communication, and deeper conceptual understanding.

Observation 4:

In this observation, the teacher used Kahoot! as a review game to reinforce previously learned mathematical concepts. The teacher created a Kahoot! quiz with review questions covering different topics within the curriculum. The learners played the quiz in teams, competing against each other to answer the questions correctly in a limited time. The teacher used this review game to assess the learners' retention of knowledge, reinforce key concepts, and provide immediate feedback on their performance. The teacher scaffold the learners' mathematical understanding by revisiting and consolidating their knowledge in an engaging and competitive environment by using Kahoot! as a formative assessment game, .

These classroom observations provided valuable insights into the various ways senior phase mathematics teachers use Kahoot! Gamification to scaffold mathematical understanding. Through the use of interactive quizzes, formative assessments, collaborative activities, and review games, teachers were able to engage learners, provide immediate feedback, address misconceptions, and promote deeper conceptual understanding.

6.2.4 Enabling and constraining factors

RQ3: What are the enabling and constraining factors of using Kahoot! Gamification as a formative assessment tool to enhance mathematical understanding in senior phase classes?

The research found various perceptions which summed up three broad factors: inadequate teacher training, lack of time, and negative teacher attitudes toward ICTs. The teachers were never exposed to Kahoot! as a formative assessment tool but were willing to learn. However, they expressed scepticism because of their previous experiences with ICT workshops. Barriers such as underestimating or overestimating teachers' prior knowledge, frequent changes in facilitators that prevented a close working relationship between facilitators and teachers, and teachers' not responding to messages were all concerns teachers expressed about workshop facilitators were echoed. The workshops were not differentiated enough to meet the needs of teachers who were less confident while enhancing the skills of those who were very experienced ICT users (Ganouli, Murphy, & Gardner, 2004; Coombs, 2023; McMahon, 2021).

On lack of time, the teacher sentiments confirmed other scholars' findings that teachers identified the most significant barriers to ICT use as a lack of time available in classes and their planning schedules and the lack of a national policy on ICT use in schools. (Kozma, McGhee, Quellmalz & Zalles, 2004; Nikolopoulou & Gialamas, 2015; Singhavi & Basargekar, 2019; Nikolopoulou, Gialamas & Lavidas, 2022). The strict time restrictions set out in the curriculum document leave little room for teachers to experiment with content or teaching methods, have an opportunity to reteach a lesson if deemed necessary or have the ability to deviate from the set content. As an unintended consequence, teachers may view ICT integration as another additional task requiring their time.

Some of the enabling factors of using Kahoot! as a formative assessment platform investigated by Nadeem and Falig (2020) were also confirmed in this study. The researchers used a questionnaire and focus group discussion to obtain learners' feedback on the effectiveness of Kahoot! questions in improving their self-directed learning. The results showed a consistently positive evaluation of Kahoot! questions on three dimensions: effective feedback, classroom environment, and development of learners' metacognitive skills, the three essential components of self-directed learning. Other studies also show that Kahoot! helps to motivate learners and provide teachers and learners with immediate feedback on their learning progress (Bicen & Kocakoyun, 2018; Chaiyo & Nokham, 2017; Hanus & Fox, 2015; Ismail & Mohammad, 2017; Kapp, 2012; Lee & Hamer, 2012; Medina & Hurtado, 2017; Medina & Medina, 2017). The results of the studies are consistent with the "Feedback (teacher and peers)" theme in the current study.

The platform proved highly effective in designing and helping teachers design assessments that foster learners' metacognitive skills, such as self-regulatory learning skills. Therefore, the results are consistent with the "improved learning experience," "critical thinking skills," and "positive competitiveness" themes in the current study. Kahoot! Enabled teachers to adapt assessments to the level of the learners to allow for scaffolded instruction (Hanus & Fox, 2015). This study did not identify challenges other than those discussed in Theme 8 (see Chapter 5) when examining the constraints of using Kahoot! as a formative assessment tool. Previously reported constraints included teacher resistance (du Plessis & Webb, 2012), technical issues with ICT and the network (Nguyen & Yukawa, 2019; Makhdum, Khanam, Faisal, & Sandhu, 2023), and anxiety when answering questions due to the timer (Wang & Tahir, 2020; Shaker, Hurst, & Marshall, 2021). Anxiety was only identified as a possible factor by a teacher but was not experienced by other teachers and learners. These constraints did not occur in this study, most likely because the research sites and participants were intentionally selected.

6.2.5 Pedagogical and technological experiences in using Kahoot! Gamification.

The theme of pedagogical and technological experiences in using Kahoot! Gamification to scaffold mathematical understanding emerged from extensive comments provided by participants during focus group interviews. Participants unanimously stated that gamification could be effectively integrated into all aspects of a lesson, including whole-class assessments, group activities, and individual work. Notably, participants highlighted that Kahoot! Gamification could be employed at any phase of a lesson. For instance, it could be used during the introduction to assess learners' background knowledge and help teachers tailor the content accordingly. The immediate feedback and analysis provided by Kahoot! allowed teachers to address learners' errors and misconceptions, facilitating effective planning for subsequent lessons. Additionally, at the end of a lesson, Kahoot! Gamification helped teachers consolidate key concepts and emphasize important aspects such as problem-solving strategies and mark allocation.

Integrating technology into pedagogy is crucial for an innovative approach to teaching and learning, as it harnesses the synergy between the two. However, the level of teachers' expertise in gamification technology plays a significant role in determining how they integrate Kahoot! into their subject matter instruction. Interestingly, the study revealed that most participants had never used gamification technology for assessment, indicating a gap in their technological experiences. This finding underscores the importance of exploring the use of Kahoot! Gamification as a formative assessment tool to enhance mathematical understanding.

The participants' feedback consistently highlighted the positive impact of gamification on learners' retention of mathematics. Learner motivation was identified as a vital factor within

Kahoot! Gamification. The integration of ICT has led to a positive shift in learners' attitudes towards mathematics, which is often characterized by low morale. The non-threatening environment provided by Kahoot! during formative assessments reduced learners' fear and anxiety associated with traditional assessment methods. Engaging in Kahoot! quizzes allowed learners to try their best without the fear of answering questions in front of the entire class. This conducive environment not only improved learner engagement and collaboration but also motivated them to actively participate and reduced disciplinary issues.

Furthermore, the social contributions of Kahoot! were highlighted, aligning with Vygotsky's Sociocultural Learning theory. Participants acknowledged that collaborative learning settings, facilitated by Kahoot!, promoted growth within the zone of proximal development (ZPD). The platform fostered social interaction, collaborative learning, and a competitive and engaging environment. The training and classroom application of Kahoot! effectively improved class engagement through social interactions involving all learners. The participants also emphasized that games, such as Kahoot!, as formative assessment tools, increased learner engagement, motivation, and attention in the classroom.

The study participants reported that learners' social skills improved as they worked well in groups and pairs, fostering better teamwork and cooperation. Learners' confidence levels in mathematics also increased significantly, leading to more active participation and a willingness to take risks in learning new concepts. The incorporation of music and pictures further enhanced learners' attention, aligning with previous research on the benefits of audio-visual materials in creating a conducive learning environment. The observed increase in concentration, enthusiasm, and curiosity among learners demonstrated the effectiveness of visual teaching methods in promoting mathematical understanding.

Overall, the pedagogical and technological experiences of using Kahoot! Gamification to scaffold mathematical understanding highlighted the positive impact on learner motivation, engagement, collaboration, and confidence. The integration of gamification technology, specifically through Kahoot!, provided a non-threatening and interactive environment that facilitated effective formative assessments and fostered social interactions and collaborative learning. Additionally, the use of audio-visual materials enhanced learners' attention and facilitated the construction of knowledge. These findings underscore the importance of leveraging gamification tools like Kahoot! to enhance mathematical understanding in the classroom.

6.3 Summary

The study results were contrasted with previous literature reviewed in Chapter Two. It is worth noting that the findings corroborated those of several previous studies, as discussed earlier. It is also encouraging to note the positive teacher attitudes towards ICT integration in general and Kahoot! in particular for formative assessment. The results were drawn from the generated qualitative data discussed in line with this study's theoretical framework and literature review. In addition, the findings from Chapter Five were discussed based on the research questions posed at the beginning of this study. Also, the discussion shows that these findings align with several studies reviewed and discussed above. The findings revealed that the participants had a positive attitude and supported the utilization of Kahoot! Gamification technology as a formative assessment tool in their classrooms. The next and final chapter presents the study ' s conclusions and recommendations of the study and also provides suggestions for further studies. Most teachers were optimistic about the gamification of Kahoot! and their experiences with it. It would be intriguing to investigate how Kahoot! Gamification affects the performance of participating teachers. The results and recommendations of the research study are presented in the following chapter.

7 CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

The findings of the study were discussed in the previous chapter. This final chapter summarizes the findings of the study. It begins with a summary of the study, then follows a summary of each chapter of the study, and, efficaciously, an overview of the research findings. Limitations of the study and a conclusion follow. In addition, recommendations are made for using Kahoot! as a platform for formative assessment to enhance mathematical understanding. Finally, avenues for further research are explored.

7.2 Summary of the study

The study explored SP teachers using Kahoot! Gamification as a formative assessment tool to scaffold mathematical understanding. To achieve this goal, the following research questions were asked:

1. What are the senior phase mathematics teachers' perceptions of using Kahoot! Gamification as a formative assessment tool prior to this study?
2. How do senior phase mathematics teachers use Kahoot! Gamification to scaffold mathematical understanding?
3. What are the enabling and constraining factors of using Kahoot! Gamification as a formative assessment tool to enhance mathematical understanding in senior phase classes?

The study was designed as qualitative research using a case study methodology. The rationale for choosing a qualitative research design and a case study approach was explored and supported. Ten mathematics teachers from two schools in the Sarah Baartman District were selected using a purposive sampling method. The criteria for selecting research sites and participants were detailed. The following research instruments were used in this study: a semi structured questionnaire, focus group interviews, non-participant observation, and diary entries. Vygotsky's (1978) Sociocultural theory and Thompson and Mishra's (2006) theory of Technological, Pedagogical, and Content Knowledge (TPACK) served as theoretical and analytical frameworks, respectively.

7.3 Summary of the Study Chapters

7.3.1 Chapter One

The first chapter of the study provided context and background information that provided an overview of the study. The problem statement and research question were well-defined, and their importance was justified. In addition, the purpose and significance of the study were adequately stated. Important terms were also defined to provide context for their use.

7.3.2 Chapter Two

The second chapter is based on the most recent and relevant literature. The research questions from chapter one guided the method for reviewing the literature. The research used credible electronic databases such as Google Scholar and the RU Library. Kahoot! games, assessment, formative assessment, and mathematical knowledge were the focus of the literature review. The majority of the studies evaluated indicated that using Kahoot! for formative assessment improves mathematical understanding.

7.3.3 Chapter three

The third chapter dealt with the theoretical and analytical foundations that underlie this study. This chapter introduces Vygotsky's Sociocultural and TPACK theories as theoretical and analytical frameworks. This chapter also explained why these ideas were selected and how they were applied in this study. In addition, this chapter explored the RAT and SAMR models as potential frameworks that could have been chosen and highlighted why these models were not used in this study. Finally, in this chapter, the researcher acknowledged the limitations of the TPACK model used as an analytical framework.

7.3.4 Chapter 4

The fourth chapter describes the research design and places it within the paradigm of qualitative interpretive research using a case study approach. The decision to use a qualitative design using a case study technique was addressed and defended. The sample size and sampling criteria were also described and justified. In addition, the advantages and disadvantages of the data collection methods used were discussed. Semi-structured questionnaires, journal entries, observations, and a focus group were used to collect data. This chapter demonstrated how the study is consistent and coherent, such as how the methodology is appropriate to the research question and how the design and implementation of the method apply to the research questions and data analysis. Furthermore, the chapter examined the process of thematic data analysis, triangulation, and study evaluation, focusing on trustworthiness, credibility, transferability, and confirmability. The chapter finishes by discussing the study's ethical implications.

7.3.5 Chapter 5

The fifth chapter presented the study's findings, based on data collected through semi structured questionnaires, focus group interviews, observations, and journal reflections. The study's results were presented clearly and appropriately, following the methodology. The results were organized by themes from the data analysis based on the study questions. Considering the importance of reliability, great effort was made to reflect the teachers' comments in their own words so that readers could be convinced that the data collected led to the results reported by the researcher.

7.3.6 Chapter 6

The sixth chapter contains a discussion of the results of the study. The results were compared to the previous literature discussed in chapter two. Both previous results that agree with the conclusions of this study and previous results that question the results of this study were mentioned. The discussion of the results demonstrates insight and originality by identifying ramifications and making appropriate and valuable recommendations. This chapter fully answers the research questions, and the study's conclusions are applicable given the methodology and relevant data offered and addressed in this chapter.

7.3.7 Chapter 7

This study concludes with chapter seven. The chapter provides an overview of the entire study. It also provides an overview of the significant research findings from which conclusions are drawn and recommendations for future research.

7.4 Summary of key research findings

This study's key findings are presented in relation to the research questions and the themes that emerged during data analysis.

7.4.1 Perceptions and Attitudes of Teachers Towards the Use of ICT Integration

According to the study results, most teachers have positive perceptions and attitudes toward using Kahoot! Gamification for formative assessment. Teachers believe that ICT improves the quality of teaching and learning and stimulates visualization, which improves mathematical understanding. The study also found that teachers are sceptical about ICT integration due to insufficient ICT knowledge and subject-specific training. The study found that most teachers favour using Kahoot! in formative assessment.

7.4.2 Pedagogical and technological experiences of SP mathematics teachers in using Kahoot! gamification for formative assessment

In this study, I investigated teachers' pedagogical and technological experiences with Kahoot! Game to promote mathematical understanding. On the one hand, the most crucial finding was that teachers had an enjoyable experience. According to the teachers, Kahoot! provides several benefits, including more collaboration and interaction, a better learning experience, and immediate feedback.

7.4.3 Enabling and constraining factors in using Kahoot! gamification for formative assessment

The enabling factor in this study was Kahoot! Gamification is convenient and accessible for novice and professional users, promotes immediate feedback for both the teacher and learners, fosters collaboration and interaction, and has some limitations, such as ICT and network interference.

7.5 Limitations of the study

Although great care and rigour were exercised in the preparation and conduct of the study, there are limitations. The reader should note that although the study's sample size was sufficient. However, because purposive sampling rather than random sampling was used, the results cannot be generalized to all schools across the country but are limited only to the ten participating teachers and two schools.

7.6 Conclusion

The study titled "Exploring Senior Phase Teachers' Use of Kahoot! Gamification as a Formative Assessment Tool to Scaffold Mathematical Understanding" yielded significant insights into the utilization of Kahoot! Gamification in senior phase mathematics classrooms. Through a comprehensive investigation of three key research questions, the study shed light on noteworthy findings.

Firstly, the study examined the perceptions of senior phase mathematics teachers regarding the use of Kahoot! Gamification as a formative assessment tool. The findings revealed that teachers expressed positive attitudes towards this innovative approach, recognizing its potential to engage learners and enhance their learning experience.

Secondly, the study delved into the practical utilization of Kahoot! Gamification by senior phase mathematics teachers to scaffold mathematical understanding. The findings demonstrated that teachers employed various strategies and techniques within the Kahoot! platform to facilitate learner comprehension and foster a deeper understanding of mathematical concepts. This highlighted the versatility and effectiveness of Kahoot! as a tool for scaffolding learners' mathematical learning.

Lastly, the study explored the enabling and constraining factors associated with the use of Kahoot! Gamification as a formative assessment tool in senior phase classes. The findings identified factors such as teachers' pedagogical knowledge and skills, learner engagement and motivation, technological infrastructure, and time constraints as influential in the successful implementation of Kahoot! as a formative assessment tool. The study provided compelling evidence of the positive impact of Kahoot! Gamification as a formative assessment tool for enhancing mathematical understanding in senior phase classrooms.

The study employed a rigorous research methodology, adopting a case study approach within a qualitative, interpretive paradigm. Data was collected through multiple methods, including semi-structured questionnaires, focus group interviews, observations, and journal reflections. Ten senior phase mathematics teachers from two schools participated in the study, ensuring a diverse range of perspectives. This rigorous approach to data collection, along with the diverse participant pool, enhanced the reliability and generalisability of the study's findings. The comprehensive data obtained through these robust methods offered valuable insights into the perceptions, practices, and enabling and constraining factors associated with using Kahoot! Gamification as a formative assessment tool in senior phase mathematics classrooms.

Overall, the study's findings highlighted the efficacy of Kahoot! Gamification as a formative assessment platform in facilitating the scaffolding of mathematical understanding. These significant insights contribute to the existing body of knowledge and provide practical implications for teachers aiming to enhance mathematical comprehension within senior phase classrooms

7.7 Recommendations for Practice

This study provides valuable information for teachers to consider when designing visual mediation tools for teaching mathematics and learning with ICT. It is necessary to create a mathematically rich, exciting, and visual environment for learners and scaffold them on the path to mathematical understanding.

- Increasing teachers' access to education technology and the internet could allow them to develop technology competencies.
- Continuous professional development programs at all levels, such as school, circuit, regional and national levels should aim to inculcate tangible measures towards the integration of technology in teaching at all phases of teaching.
- This study recommends that in addition to in-service training, teachers should be provided with subject-specific training. This training should include the use of technology pertinent to the instruction of specific subjects. Such training could increase their competency in integrating technology into their teaching strategies.
- Teachers, at a personal level, should be motivated to embrace the integration of emerging technologies apart from smartphones, such as personal laptops and internet devices at home, and engage in educational technology programs such as Digital Skills, etc.

7.8 Recommendations for future research

The study focused on using Kahoot! Gamification in formative assessment by the teachers. It made deductions on the learners through observations and teacher reflections, which left an avenue for further research on learner perceptions regarding using Kahoot! Gamification as an assessment tool. Furthermore, this study was qualitative. A future study could use a mixed methods approach that includes both qualitative and quantitative methods. The quantitative design would help better quantify learner performance by comparing learners' cumulative performance on formative and summative assessments. Therefore, it is recommended that another study be conducted to determine whether Kahoot experimentally! Formative assessments positively or negatively impact learner performance in summative assessment.

Based on the analysis of teacher reflections, it was determined that there is a need to examine SP teachers' pedagogical and technological experiences regarding formative assessment. The result would help researchers fully understand the nature of the crisis in mathematics teaching and learning and contribute to the debate on how best to improve mathematics achievement in South African schools.

Given that not all schools have ICT facilities and not all learners have smartphones, it would be interesting to have a study that explores adapting Kahoot! Gamification to such areas, especially schools with many learners, for immediate feedback.

Finally, while the current study was conducted on a small scale, future empirical investigations might be conducted at macro levels (district, provincial, or national) with a more significant sample of teachers and learners to yield more detailed and generalisable conclusions.

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Appendices

Appendix A: Semi - structure questionnaire

Date: ___________________

Introduction

This is an M Ed research questionnaire designed to obtain views based on your formative assessment experience using a Gamification Technology**.** Kindly be open and as accessible as possible. Be assured that absolute confidentiality will be adhered to, and your details will never be revealed to a third party. Please answer all questions to the best of your knowledge. Your responses will be kept entirely confidential. Thank you for your participation.

Instruction

Read each question carefully. Possible answers follow the questions. For each question you read, there are indications of the number of possible choices. Tick in the appropriate box(es) next to the answer of your choice. Kindly respond to **ALL QUESTIONS** to the best of your ability. Your honesty will be appreciated**.**

SECTION A: BACKGROUND INFORMATION

How many years of work experience do you have in teaching mathematics? Indicate by ticking an **(x)** in the spaces provided.

Five years to 10 years	
More than ten years	
What grade(s) are you teaching?	

SECTION B: AVAILABLE INFORMATION AND COMMUNICATION TECHNOLOGIES (ICTs) INFRASTRUCTURE AT SCHOOL

For this study, ICTs refer to technology used in teaching and learning, such as tablets, computers, the internet and data projectors.

1. Are the following facilities available at the school you are teaching? Respond by putting an **(X)** under the appropriate heading.

Available for teaching and learning	**Yes [1]**	**No [2]**
1. A computer laboratory		
2. Computers/laptops for teachers' use		
3. Internet connectivity		
4. Tablets		

Comment on any issues raised above.

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SECTION C: TEACHER COMPETENCE AND ICT USE IN ASSESSING THE LEARNERS

1. Information and communication technologies (ICT) competency
   Rate your level of ICT skills by putting an **(X)** under the appropriate heading.

	Excellent	**Good**	**Fair capability**	**Low capability**	**No capability**
1. Word Processing (e.g. use of programs like MSWord)					
2. Spreadsheets (e.g. use of programs like Excel)					
3. Presentation tools (e.g. use of programs like PowerPoint)					
4. Emailing					
5. Internet browsing					

Comment on any issues raised above.

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2. How often do you use the following computer applications in your teaching? Put an **(X)** under the appropriate heading.

Computer applications	**All the time**	**Often**	**Sometimes**	**Seldom**	**Never**
1. Use of presentation tools (e.g. PowerPoint)					
2. Use of electronic pictures					
3. Use of internet browsing					
4. Use of audios					
5. Use of the spreadsheets (e.g. Excel)					

Comment on any issues raised above.
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3. To what extent do you use information and communication technologies (ICTs) when assessing the learners?
   Indicate your response with an **(X)** appropriately.

ICTs integration	To a large extent	To a reasonable extent	To a small extent	Not at all
1. I am aware of ICTs available for assessing the learners.				
2. I use various ICTs to assess the learners.				
3. I have access to ICTs that I use for assessing the learners.				
4. I know how to use ICTs in my teaching to assess the learners.				
5. I use ICTs to engage learners actively.				
6. I use ICTs to promote learner-to-learner interaction (e.g. interaction between learners) during the lesson.				
7. I have adequate ICT skills to use technology to assess the learners.				

Comment on any issues raised above.
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Part D: Teacher perception of technology use in assessment

1. What are your views on using technology in assessing learners' content learning?
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2. What are the advantages of using technology in assessing learners' content learning?
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3. What are the disadvantages of using technology in assessing learners' content learning?
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Part E: Usefulness of technology in assessment practices

1. What is your perceived usefulness of using technology to assess learners' content learning? Give a reason.
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Are you aware of any technology-based games used to assess learners' learning?
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	Not an important barrier at all	Less important barrier	Important barrier	High important barrier	Very high important barrier

1. Inadequate training on ICT use in the teaching of my particular subject					
2. Limited supply of electricity					
3. Limited access to high-speed internet					
4. Lack of educational software for my particular subject					
5. Lack of time					
6. Limited support from the school management team					
7. Negative teacher attitudes towards the use of computers in teaching and learning					
8. Challenges to integrate ICTs in teaching					
9. Lack of confidence to use ICTs in teaching					
10. Lack of motivation to use ICTs in the classroom					

Part F: BARRIERS/CHALLENGES IN THE ADOPTION AND USE OF ICTS ASSESSING LEARNERS

1. How significant are the following barriers to adopting and using ICTs in your school?

   Indicate by putting an **(X)** appropriately.

Comment on any issues raised above and suggest possible solutions to the challenges that you are facing in the integration of ICT in your school.

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Part G: Teacher's Assessment Practices

How often do you formatively assess your learners, e.g. in a week?

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What forms of feedback do you use?

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What factors hinder assessment at your school?

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Appendix B: Observation tool

OBSERVATION TOOL

The observations will have the exact duration of the lesson period and will occur once with each teacher within the classroom environment. I will be a non-participant observer, and I will be observing the following aspects:

- The way teachers conduct their lessons.
- What tools (for example, technologies) do they use to interact with learners
- How the teacher will be handling or operating these tools

Part A Teachers Profile

Current profession…………………… **Position……………………………………………**

Age …………….. **Gender…………………………………….…...**

Years of teaching experience … **Grades taught……………………………………**

Topic……………………… **Lesson focus……………………………………….**

Social- interactions	
Measure	**Notes**
Learner interactions.	
Learner activities promoted participation.	
Learner's opinions considered.	

Questions and responses from learners were considered.	
The teacher encourages learners' participation.	
The teacher allows learners to talk more.	
Teacher's Pedagogical Knowledge	
Measure	**Notes**
Consider the learner's prior knowledge.	
The teacher demonstrates to learners how to carry out Games.	
Teacher's clarity of instructions	
The teacher ensures that all learners have logged in and participated in games.	

Teacher's Technological Knowledge	
Measure	**Notes**
The teacher selects and generates appropriate q that are suitable for the content.	
The teacher demonstrates confidence inusing gamification technology to teach.	
The teacher uses it with little or no problems.	
Mathematical Understanding	
Indicators	**Notes**
Classifying objects	
Giving examples and non-examples of ideas	
Choice of procedure and application	
Applying problem-solving algorithms or algorithms	

Observer's name______________________**Date** ___________**Signature**_____________

Teacher's name_______________________**Date**___________**Signature** _____________

Appendix C: Journal Reflection

Journal Reflection on Daily Activities Date:

Instruction: Answer all the following questions
Instruction: Please reflect on the following points Topic:

Lesson focus:

Time:

Instruction: Please reflect on the following points

1. Briefly outline what you have learned so far from your participation in the study

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2. Please explain how you scaffold learners' mathematical understanding of mathematical content using Kahoot.

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3. Please indicate what you do to make learners understand what you teach using Kahoot.

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4. Please write about how you know that learners have mathematically understood the taught content.

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4. Briefly explain your views on the need to use Kahoot to mediate learning of mathematics content (specify topic). ……………………………………………………………………………… ………

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5. Briefly highlight what you find as enablers and constraints in making use of Kahoot in the mediation of assessing mathematics

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Appendix D

Focus group interview questions

Interview Code: _________________________Date and time: _________________________

Introduction

I, Silence Balele, am a part-time learner doing a Master of Education in Mathematics Education at Rhodes University, South Africa (Learner No 13b7924). I am researching using gamification technology to mediate the learning of Fractions in Mathematics. Would you be comfortable sharing your thoughts with me**?**

Please take note of the following:

- This interview may take 30 minutes to 40 minutes to complete all the questions.
- You are not forced to answer all the questions.
- If you are not comfortable with a question, please indicate so.
- Please inform me during our conversation if you can no longer continue being interviewed.
- Please indicate whether you need a short break during the interview.
- I will be recording your voice if you allow me to do so.
- I will take notes, including quotes from what you say.
- Before, during, and at the end, feel free to ask me questions you would like clarifications about this study.

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1. In your lesson presentation, how did you use Kahoot to enhance mathematical understanding for your learner?
2. How did you experience using Kahoot gamification in your classroom to scaffold mathematical understanding?
3. What did you find challenging in your use of Kahoot gamification?
4. Based on your experience using Kahoot gamification as a formative assessment tool, what do you think was advantageous, and what do you think was disadvantageous about its use in your teaching?
5. Do you feel using Kahoot has made your assessment of mathematics content for mathematical understanding easier? Explain your answer.
6. From your experience of teaching using Kahoot, what factors do you think;

   (a) Can we encourage teachers to use Kahoot in their teaching?
   (b) Inhibit teachers from using Kahoot in their formative assessments.

7. Was the training on using Kahoot before interacting with learners adequate for you to teach using Kahoot? Explain
8. In your view, what should be done to effectively use Kahoot in teaching and formative assessment of mathematics in particular?
9. What are your views about how technology influences teaching?
10. Is there any information you would like to share related to this interview that I have not captured in my questions?

Appendix E1: Mathematical Understanding Indicators

Characteristics	**Indicators: A teacher with an excellent mathematical understanding**
Connections	- Likes to see how mathematical concepts are related - Connects new knowledge to old and vice versa - Realises topic interconnectedness - Recogni ses and is keen to understand new learner strategies
Representation	- uses multiple forms of representation in expressing their thinking/ concept (words, drawings or pictures, charts or other graphs . . .) - uses representation(s) to help others know exactly what they were thinking, how they figured it out, and how the problem was solved.
Communication	- can explain their thinking clearly and concisely. - Seeks clarification. - When others come up with new ideas, ask them to explain or try to figure out why that makes sense. -

Reasoning and proof	- Can use data to make, test, or argue a conjecture. - They can adequately explain the reasons behind their mathematical thinking and can do more than explain the procedure or summarise the answer. - Uses a variety of reasoning methods and proof. - Listens to others' mathematical thinking
Problem-solving	- shows confidence in solving problems. - Demonstrates persistence when encountering a complex problem and does not give up. - He knows what to do when given an unfamiliar problem and can switch strategies if one is not working. - Has an unofficial list of problem-solving strategies to call upon when solving problems?

National Council of Teachers of Mathematics (NCTM, 2000).

Appendix E2: Indicators of Scaffolding

Prior knowledge	**To enhance mathematical understanding through scaffolding, a teacher should be able to:** - activate learner's prior knowledge through (Pre-tests, lessons taught, or quick questions) - connect prior knowledge with new knowledge
Modelling	- be able to model/demonstrate to the learners how things are done - grab learner's interest/ attention through creativity and using multiple representations (see indicators of mathematical understanding).
Provide appropriate scaffolds	- to break the task into more minor understandable parts - of communication (see indicators of mathematical understanding) **Social interaction:** - Cooperative learning (Johnson and Johnson, 2009). A cooperative learning study must have five essential characteristics: **positive interdependence, individual accountability, face-to-face promotive interaction, interpersonal and small group skills, and group processing** (Johnson and Johnson, 2007; Sharan, 2015) - Ask questions: Questions must fall into six categories, as outlined by the Revised Bloom's Taxonomy, and should help learners to **remember, understand, apply, analyse, evaluate and create** (Bloom, 2001).
Consolidation	- learners independently demonstrate mastery of new knowledge

Appendix E3: Indicators of Mediation

	To enhance mathematical understanding through mediation, a teacher should be able to:
Active participation and shared conduct	- Develop and encourage a sense of self-confidence, cooperation, teamwork, learner participation, turntaking, and respect for others' opinions. (Cooperative Learning). - Mediators should support active learner participation, reciprocal support, tolerance, and confidence in their learners. -
Classroom management	- Discourage impulsive behaviour - Regulation and control of conduct

(Williams and Burden, 1997).

Appendix E: Eastern Cape Department of Education Approval letter

Province of the
EASTERN CAPE
EDUCATION

CORPORATE PLANNING, MONITORING, POLICY AND RESEARCH COORDINATION

Steve Vukile Tshwete Complex, Zone 6 Zwelitsha, 5608, Private Bag X0032, Bhisho, 5605 REPUBLIC OF SOUTH AFRICA
Enquiries: **Ms. F. Pakade Tel: 040 608 7170/4001** , **Fax :040 608 4372. Email:** [illegible]
Website: www.ecdoe.gov.za

Date: 08 December 2022

Mr. Silence Balele

Rhodes University

Lucas Avenue

Makanda

6139

Dear Mr. S Balele

PERMISSION TO UNDERTAKE A MASTERS RESEARCH: EXPLORING SP TEACHERS' USE OF KAHOOT GAMIFICATION AS A FORMATIVE ASSESSMENT TOOL TO SCAFFOLD MATHEMATICAL UNDERSTANDING.

1. Your application to conduct the above-mentioned research involving twelve (12) participants from two (2) selected primary schools of the Sarah Baartman District under the jurisdiction of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:

   a. there will be no financial implications for the Department;

   b. institutions and respondents must not be identifiable in any way from the results of the investigation;

   c. you seek parent's consent for minors;

   d. it is not going to interrupt educators' time and task;

   e. the research may not be conducted during official contact time;

   f. the research may not be conducted during official contact time, provided that an arrangement to do research at the school including getting inside a classroom has been arranged and agreed upon in writing with the Principal and the affected teacher/s;

   g. you present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Cluster and District Directors before any research is undertaken at any institutions within that particular district;

   h. you will make all the arrangements concerning your research;

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i. should you wish to extend the period of research after approval has been granted, an application to do this must be directed to Chief Director: Corporate Strategy Management;

j. you present the Department with a copy of your final paper/report/dissertation/thesis free of charge in hard copy and electronic format. This must be accompanied by a separate synopsis (maximum 2 – 3 typed pages) of the most important findings and recommendations if it does not already contain a synopsis;

k. you present the findings to the Research Committee and/or Senior Management of the Department when and/or where necessary;

l. you are requested to provide the above to the Chief Director: Corporate Strategy Management upon completion of your research;

m. you comply with all the requirements as completed in the Terms and Conditions to conduct Research in the ECDoE document duly completed by you;

n. you comply with your ethical undertaking (commitment form);

o. You submit on a six-monthly basis, from the date of permission of the research, concise reports to the Chief Director: Corporate Strategy Management.

2. The Department reserves a right to withdraw the permission should there be non-compliance to the approval letter and contract signed in the Terms and Conditions to conduct Research in the ECDoE and/or legal requirements to do so.

3. The Department will publish the completed Research on its website.

4. The Department wishes you well in your undertaking. You can contact the Mrs. Fundiswa Pakade on the numbers indicated in the letterhead or email fundiswa.pakade@ecdoe.gov.za should you need any assistance.

T. MASOEU
CHIEF DIRECTOR: CORPORATE STRATEGY MANAGEMENT

FOR SUPERINTENDENT-GENERAL: EDUCATION

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Appendix F: Principals' Permission Letters

Appendix B - Permission seeking letter to the school Principal for authorisation

Makhanda
6140

Dear Sir/ madam

Request for permission to conduct educational research exploring SP teachers' use of Kahoot Gamification as a formative assessment tool to scaffold mathematical understanding.

I, Silence Balele, a Masters of Education student registered at Rhodes University in South Africa (13B7924), humbly request access to conduct a case study in your school. Your school is among the sampled rural secondary schools in the Sarah Baartman district. The research topic is: "Exploring SP teachers' use of Kahoot Gamification as a formative assessment tool to scaffold mathematical understanding." The participants will be selected from teachers with a minimum of 5 years of mathematics teaching experience. The investigation is planned to take place in three phases. Phase 1: They will be given questionnaires to complete. Phase 2: 3 workshops will be conducted, one on Kahoot as a formative assessment tool, one on mathematical understanding, and another where we will discuss and reflect with the participants on their experiences with Kahoot as a formative assessment tool. Phase 3: The researcher will visit some sampled schools, monitor if the collected data is a true reflection, and observe some participants as they integrate ICT in their classrooms. Phase: The participants will be grouped, and focus group interviews will be conducted. The research will be conducted in October/November 2022.

The participants will be involved voluntarily, for they will not receive any incentives for being part of the study; instead, they may benefit as far as mathematics teaching and assessment is concerned. Informed consent will be requested from the District Director, Principals, and the teachers at the participating schools. The collected data from this research will be published as the Rhodes University full thesis, and the identity of each participant, together with their views, will be treated with a high degree of anonymity.

This research has been approved by the Rhodes University Ethical Standards Committee and the Education Department Higher Degrees Committee. During the research, any concerns may be directed to the Rhodes University ethics committee, ethics-committee@ru.ac.za
Please feel free to contact me at (+27)765354953, s.balele@ru.ac.za, or my supervisor, Dr. Clement Simuja c.simuja@ru.ac.za

Thank you in advance for offering me this developmental opportunity.

Yours sincerely,

Silence

School Stamp

FIKIZOLO PRIMARY SCHOOL
P.O. BOX 774
GRAHAMSTOWN 6140

PRINCIPAL: ....

DATE: ....

Approved by:
Ms Z. L. KATE
Name of the Principal

Signature

Appendix B - Permission seeking letter to the school Principal for authorisation

Makhanda
6140

Dear Sir/ madam

Request for permission to conduct educational research exploring SP teachers' use of Kahoot Gamification as a formative assessment tool to scaffold mathematical understanding.

I, Silence Balele, a Masters of Education student registered at Rhodes University in South Africa (13B7924), humbly request access to conduct a case study in your school. Your school is among the sampled rural secondary schools in the Sarah Baartman district. The research topic is: "Exploring SP teachers' use of Kahoot Gamification as a formative assessment tool to scaffold mathematical understanding." The participants will be selected from teachers with a minimum of 5 years of mathematics teaching experience. The investigation is planned to take place in three phases. Phase 1: They will be given questionnaires to complete. Phase 2: 3 workshops will be conducted, one on Kahoot as a formative assessment tool, one on mathematical understanding, and another where we will discuss and reflect with the participants on their experiences with Kahoot as a formative assessment tool. Phase 3: The researcher will visit some sampled schools, monitor if the collected data is a true reflection, and observe some participants as they integrate ICT in their classrooms. Phase: The participants will be grouped, and focus group interviews will be conducted. The research will be conducted in October/November 2022.

The participants will be involved voluntarily, for they will not receive any incentives for being part of the study; instead, they may benefit as far as mathematics teaching and assessment is concerned. Informed consent will be requested from the District Director, Principals, and the teachers at the participating schools. The collected data from this research will be published as the Rhodes University full thesis, and the identity of each participant, together with their views, will be treated with a high degree of anonymity.

This research has been approved by the Rhodes University Ethical Standards Committee and the Education Department Higher Degrees Committee. During the research, any concerns may be directed to the Rhodes University ethics committee, ethics-committee@ru.ac.za
Please feel free to contact me at (+27)765354953, s.balele@ru.ac.za, or my supervisor, Dr. Clement Simuja c.simuja@ru.ac.za

Thank you in advance for offering me this developmental opportunity.

Yours sincerely,

Silence

Approved by:

L. WEPENER

Name of the Principal

Signature

School Stamp

Appendix G: RU Ethics

RHODES UNIVERSITY
Where leaders learn

Rhodes University, Education Faculty
Research Ethics Committee
PO Box 94, Makhanda, 6140, South Africa
Tel: +27 (0) 46 603 8393
Fax: +27 (0) 46 603 8028
email: e.rosenberg@ru.ac.za

https://www.ru.ac.za/researchgateway/ethics/

6 December 2022

Dr Clement Simuja

Education Department

C.Simuja@ru.ac.za

Dear Dr Clement Simuja and Mr Silence Bakele

Re: Exploring Senior Phase teachers' use of Kahoot Gamification as a formative assessment tool to scaffold mathematical understanding

APPLICATION NUMBER: 2022-5912-7184

This letter confirms that your research ethics application has been reviewed and **APPROVED** by the Education Faculty Research Ethics Committee (EF-REC). Your permission letter(s) where applicable have been received and you are free to proceed with your study.

Approval is granted for 1 year. An annual progress report is required in order to renew approval for an additional period. You will receive an email notifying you when the progress report is due.

Should any substantive change(s) be made during the research process, that may have ethical implications, you should notify the Education Faculty REC Chair via email. This includes changes in investigators. The REC Chair will advise as to whether a new application is necessary.

Do keep this clearance letter secure and accessible throughout your study and after its completion. It will be needed when a thesis is examined and when publications are submitted to journals.

Please also submit a brief report to the REC Chair on the completion of the research. This can be done via email. The purpose of this report is to indicate whether the research was conducted successfully and whether any ethics-related matters arose that the committee should be aware of, in order to guide future studies.

Sincerely,

ERosenberg

Prof Eureta Rosenberg

Chair: Education Faculty Research Ethics Committee

Appendix H: Permission seeking letter to teachers (Participants)

Mr/Ms ...
... Junior Secondary School
Makhanda 6140

Dear Sir/Madam

Request for participation in educational research exploring SP teachers' use of Kahoot Gamification as a formative assessment tool to scaffold mathematical understanding.

I, Silence**,** a Masters of Education learner registered at Rhodes University in South Africa (13B7924), humbly request you to participate in a research project conducted in the Sarah Baartman District. Your school is among the sampled junior secondary schools in Sarah Baartman district. The research topic is: "Exploring SP Teachers' Use of Kahoot Gamification as a formative assessment tool to scaffold mathematical understanding." The identified problem is that the Department of Education continually trains teachers on integrating ICT in teaching mathematics for mathematical understanding. Yet, in the literature I have reviewed, no study has been conducted to explore how senior phase teachers in the Sarah Baartman District who attended technology skills training integrate technologies in their assessment.

The participants will be selected from teachers with a minimum of 5 years of mathematics teaching experience. The investigation is planned to take place in three phases. Phase 1: They will be given questionnaires to complete. Phase 2: 3 workshops will be conducted, one on Kahoot as a formative assessment tool, one on mathematical understanding and another where we will discuss and reflect with the participants on their experiences with Kahoot as a formative assessment tool. Phase 3: The researcher will visit some of the sampled schools, monitor if the collected data is a true reflection, and observe some participants as they integrate ICT into their classrooms. Phase: The participants will be grouped, and focus group interviews will be conducted. The research will be conducted in October/November 2022.

Participation in this research study is entirely voluntary, and you can withdraw any time you wish. I humbly request your permission to take videos of class presentations to use for data analysis. I will ensure that your identity and views will be treated with a high degree of confidentiality and anonymity, and the data that will be collected will not be used for other purposes apart from this study.

The Rhodes University Ethical Standards Committee and the Education Department Higher Degrees Committee have approved this research. During the research, any concerns may be directed to the Rhodes University ethics committee, ethics-committee@ru.ac.za

Please feel free to contact me at (+27) 0765354953, s.balele@ru.ac.za or my supervisors, Dr Clement Simuja c.simuja@ru.ac.za and Dr Chikiwa cchikiwa@gmail.com.

Yours Sincerely

Silence Balele