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The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics in Two Township Schools in Gauteng Province, South Africa

By

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A thesis submitted in conformity with the requirements for the degree of Doctor of Philosophy

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ABSTRACT

Tablet technology technology is becoming an integral part of teaching and learning mathematics in township schools in South Africa. This is after concerns were raised in several reports about learners' underachievement in mathematics, thus, urging the Government to implement a potential solution to the poor quality of teaching and learning of mathematics. Despite increasing use of tablet technology in mathematics classrooms in the Province, there is lack of empirical evidence to show the benefits of using this type of technology in the teaching and learning of mathematics in township schools. This study sought to bridge this gap by exploring the pedagogical value of tablet technology in the teaching of mathematics in two township schools in Gauteng Province, South Africa. The qualitative case study research design was considered the most appropriate as it allowed eliciting rich data on the lived experiences of mathematics teachers. Data came from interviews with five purposefully selected mathematics teachers, observations of five mathematics lessons and the analysis of important documents such as the learners' marked work. Data were analysed thematically using an analytical tool developed from various theories underpinning modern teaching and progressive pedagogy. The findings of the study revealed that tablet technology gives township teachers access to various forms of media for meaningful teaching of mathematics concepts. The use of narrative media, interactive media, productive and adaptive media in particular promotes meaningful engagement in instructional mathematics conversation, and enables more reflective and adaptive mathematics teaching and learning. The study noted that the lack of supporting technological infrastructure and teachers' pedagogical knowledge to use educational applications, coupled with inadequate teachers' training in the use of tablets in teaching mathematics seriously constrain teachers' efforts to optimise the use of tablet technology in their teaching. Based on these findings, it is recommended that teachers should be provided with adequate technological support infrastructure and ongoing training on the use of tablet technology in mathematics teaching. The study provides a model for optimal use of tablet technology in mathematics teaching in poor township schools.

Key words: tablet technology, bundled technology, discursive and experiential events

DECLARATION

I declare that this is my own unaided work. It is submitted for the Doctor of Philosophy (PhD) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination to any other university.

Meschac Rafiki

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26 August 2019

DEDICATION

To my son Shimwa Blessing Rafiki (2 years 9 months) and my daughter Ashimwe Benié Rafiki (9 months), may this work inspire you when you start your own academic journey. To my dad and mom, I would like to thank you for your love and support. I appreciate the sacrifices you made to invest in my education.

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

Improving teaching and learning of mathematics is currently an issue of national priority in South Africa. This is after many reports raised concerns about ongoing underachievement in mathematics in the Government schools. In 1995, South African learners participated in the Trends in International Mathematics and Science Study (TIMSS) competition and came last (Howie & Hughes, 1998). South African learners also scored far below the international average in the TIMSS 1999, TIMSS 2003 (Siyepu, 2013), and TIMSS 2015 (Reddy et al., 2016) and in the Southern and East African Consortium for Monitoring Education Quality (SACMEQ III) competition (Spaull, 2011). High level of underachieving learners came from rural and township schools (Spaull, 2013a, p. 34). The reason is that rural and township schools are “dysfunctional and unable to impart the necessary mathematics knowledge and skills” due to the lack of access to quality teaching and learning materials (Spaull, 2013a, p. 34). Ongoing learners’ underachievement in mathematics necessitated a potential solution through which the quality of teaching and learning of mathematics could be improved. Hence, the South African Government initiated several technological interventions such as the Paperless project (Lupondwana & Coleman, 2019) and the Information Communication Technology for Rural Education Development (ICT4RED) initiative (Herselman & Botha, 2014) to leverage the adoption of tablet technology in the rural and township schools and other disadvantaged schools in the country. It is believed that access to tablet technology in such teaching and learning environments will result in significant changes to teaching and learning mathematics(Kganyago, 2019).This gave this study a unique opportunity to investigate how tablet technology transforms teaching and learning of sixth grade mathematics in township schools. Sixth grade was chosen because of the growing public concern about the teaching of mathematics at this grade level. Fleisch (2008) reported that the majority of sixth grade mathematics learners and teachers in South Africa do not have the support required to explore mathematics in a meaningful way, hence the present study sought to explore how the use of tablets helps to bridge this gap.

Though of a narrow base, the present study sets the platform for more extensive studies that can be readily extrapolated.

1.2 The Statement of the Problem

Although the introduction of tablet technology in teaching and learning sparked the interest of many researchers, generally, there is still a scarcity of empirical studies exploring its pedagogical use in teaching and learning (Cheung & Slavin, 2012; Kyriakides, Meletiou-Mavrotheris, & Prodromou, 2016). In addition, discrepancies exist between its promissory and what is obtainable in some schools that have integrated it (Attard, 2013; Baker, 2019; Minshew & Anderson, 2015). In South Africa in particular, the use of tablets in schools is new, hence there are limited, if any, empirical research investigating its pedagogical use in teaching and learning mathematics in rural and township schools. The problem under investigation in the present study is how mathematics teachers in township schools are using tablet technology, the pedagogical value it adds to their teaching and the challenges affecting how they use it to improve practice. Understanding teachers' use of tablet technology, the value of tablet technology in teachers' teaching and the challenges affecting teachers' use of tablets is important as it can provide useful information to improve the current usage and future implementation of tablet technology in mathematics teaching.

1.3 Aim and objectives of the Study

The principal aim of the study was to explore teachers' perceptions and experiences of using tablet technology, and to ascertain the challenges affecting the pedagogical use of tablet technology in sixth grade mathematics in two township schools in Gauteng Province, South Africa. The following objectives helped to achieve the aim of the study.

1. To ascertain teachers' perceptions about the value of tablet technology in the teaching of sixth grade mathematics
2. Examine how teachers' perceptions are translated into pedagogical action in the actual teaching of sixth grade mathematics.

3. To explore the challenges that impact teachers' use of tablet technology in sixth grade mathematics

1.4 Research Questions

The study sought to answer the question: What is the pedagogical value of tablet technology in the teaching of sixth grade mathematics in South African township schools? In order to answer the main research questions three sub-questions were developed:

1. What are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics?
2. How are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics translated into pedagogical actions in the actual teaching of sixth grade mathematics?
3. What challenges impact teachers' use of tablet technology in the teaching of sixth grade mathematics?

1.5 Theoretical lens of the study

The conceptual framework for this study was informed by different theories in order to appreciate the complexities associated with the use of technology in teaching and learning. The study used social constructivism as the main guiding theory. According to Ernest (1998), social constructivism provides the basis for a better understanding of how mathematics is taught and learned. From the social constructivist perspective, a mathematics classroom ought to be an environment in which learners have opportunities to construct knowledge individually and collaboratively. In the teaching process, the teacher uses tools and signs to facilitate understanding of mathematics concepts, both written and spoken. Grounding the study in Laurillard (2002)'s conversational framework for effective use of technology provided the language to describe the value of tablet technology in the teaching events. The framework was used as a tool to analyse teachers' lessons in terms of the minimum pedagogical events of a classroom instruction. Meaningful learning theory provided control tools to examine whether teachers' perceptions about the value of tablet technology linked to them providing learners with improved mathematics learning experiences. Detailed information about the conceptual framework is provided in Chapter Two.

1.6 Significance of the Study

Qualitative studies such as this one are undertaken to contribute to theory, policy and practices (McMillan & Schumacher, 2014). The study collected primary data using multiple data collection tools to ensure that the evidence collected was rich, deep and sufficient. The analysis and interpretation of the data that were collected in relation to the conceptual framework that guided the study and current literature helped to expand the initial conceptual framework and to develop a theoretical model that can be used to guide the integration of tablet technology in mathematics teaching in township schools. This model may lay the foundation for other researchers to further extrapolate it in the quest to understand what is of value in the use of tablet technology in mathematics teaching in township schools and consequently contribute to the growing body of knowledge on this topic.

The study provides thick descriptions of the use of tablet technology in the studied schools including teachers' voices through direct quotations from the interviews to help the reader understand what it is like to teach sixth grade mathematics with tablet technology in the studied schools. Good practices and bad practices were teased out so that teachers may know what to do and not to do when using tablet technology in sixth grade mathematics teaching. The findings of the study may help the participants to better understand their own practices and to improve those practices. In addition, schools that were studied are in the broader spectrum of township schools that are currently integrating tablet technology in mathematics teaching as part of the Gauteng paperless project. Evidence accumulated in this study may help to improve the practices of mathematics teachers in township schools who are new to the use of tablet technology in instructional mathematics conversation.

Lastly, the findings of the study shed light on the challenges affecting teachers' use of tablet technology in sixth grade mathematics. It raised concerns about teachers' lack of knowledge about the e-Education policy and the lack of school based ICT policies in the studied schools. The school leadership and policy makers will possibly take the findings and the recommendations of the study into consideration to devise ways to make e-Education policy available in the classroom and to induct teachers in effective strategies for its effective implementation.

1.7 Chapter Summary

In this chapter I presented the background of the present study, focussing on the current state of mathematics education in South Africa, and the move to tablet technology as an attempt to improve the quality of teaching and learning mathematics in rural and township schools in the country. I will elaborate on this in more details in Chapter Two. In this chapter I also stated the research problem, the research aims and objectives and the research questions. The significance of the study and the theoretical underpinnings were also elaborated on. The next chapter focuses on the review of related literature that will help to illuminate the understanding of the value of tablet technology in teaching and learning of mathematics.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This study explored the pedagogical value of tablet technology in the teaching and learning of sixth grade mathematics in township schools in South Africa. This chapter explores the literature relating to this topic. The chapter starts with the background of the study focussing on the importance of mathematics in the information society in order to create a context for the use of technology in mathematics teaching and learning. The chapter proceeds to explore responsive technological mathematics initiatives currently available in South Africa. It then analyses the characteristics that are intrinsic to tablet technology to support the development of mathematics skills. Furthermore, it explores related work, identifies the research gaps and ends with the conceptual framework for the study.

2.2 The background of the study

Mathematics is important in the world today as it allows producing critically needed scientist, engineers, and technological professionals (Kujenga & de Vries, 2012). The ability to master and apply mathematical knowledge and skills in everyday situations is an important factor driving the economic growth and social progress (Valero, 2017, p. 118). This is manifested in newly industrialised countries like South Korea and Singapore where mathematics is regarded as a fundamental pillar of nation building and has contributed to enormous economic explosions. In 1960, for example, South Korea had the same per capita gross national product as many African countries such as Ghana. However, in 2012, South Korea ranked as the 10th biggest economy in the world, with a per capita gross national product that was 10-times higher than Ghana's (Chung, 2014). In 1970, Singapore's per capital gross domestic product was about USD 300, but in 2009, it had grown to USD 39 000 (Organization for Economic Co-operation and Development, 2011). The rapid economic development of these countries happened because of a strong focus on mathematics education (Chung, 2014; Lee, Goh, & Fredriksen, 2008).

Chung (2014) explained how mathematics education developed in South Korea and how it contributed to the country’s socio-economic goals. Between 1950 and 1960 South Korea regarded mathematics as a standard for academic excellence. South Korean learners had to have a very good score in mathematics to be admitted into prestigious colleges. Between 1970 and 1980, there was a paradigm shift in thinking about the role of mathematics in the country’s development. Mathematics became a pillar for economic development. Learners had to have a strong mathematics background to be admitted into engineering courses. During this period, the country had a high need for engineers because of the growing economy. From 1990 onwards, mathematics became a pillar for growing the economy with much focus placed onto basic science research.

Singapore is also a newly industrialised country owing its fast economic growth to a strong focus on mathematics and science education (Lee et al., 2008). Between 1959 and 1978, Singapore was in a survival driven education phase and every citizen had to be literate in reading and numeracy. This phase was followed by an efficiency-driven phase during which learners were given multiple pathways to choose from with the aim of producing a highly skilled and trained work force, engineers in particular. A good knowledge of mathematics was a requirement to be admitted to engineering studies. From 1997 the country entered into the ability-based, aspiration driven education phase during which the focus was on innovation, creation and research (Organization for Economic Co-operation and Development, 2011). It is important to note that Singapore learners came first in the Third International Mathematics and Science Study (TIMSS) 2003 competitions (Mullis, Martin, Gonzalez & Chrostowski, 2004). This has pushed many independent schools in the USA to start implementing the Singapore Mathematics curriculum. These schools believe that using the Singapore curriculum will help to teach the necessary mathematical knowledge and skills that learners need to succeed in today’s society (Naroth & Luneta, 2015). While this is a positive effort, these schools should ensure that they have teachers who are competent enough to teach this curriculum; otherwise, it will be like putting new wine into old wineskins.

In the South African context, mathematics is regarded “crucial for individual freedom and economic development and a gateway to science, medicine, commerce, engineering and other vital parts of the economy”(Goldstein, 2012). Mathematics is as critical knowledge that South African learners need for them to participate meaningfully in the 21st century economy (Goldstein, 2012). Hence, in the school curriculum (Department of Basic Education (DBE), 2011), much time is allocated to mathematics so that teachers have enough opportunities to engage learners in mathematics knowledge construction. In sixth grade, for example, the Curriculum and Assessment Policy Statement (CAPS) allocates six hours a week to the teaching and learning of mathematics. In the CAPS mathematics is the second most important subject after the home language subject, which has seven hours a week allocated to it. Teachers must use this allocated time to develop learners' mathematical knowledge in five content areas (see Figure 1), which are: Numbers, operations and relationship; patterns, functions and algebra; space and shape; measurement; and data handling. Within the five content areas (Department of Basic Education, 2011) learners will learn the following:

- Learn the correct use of the language of mathematics;
- Develop number vocabulary, number concept and calculation and application skills;
- Learn to listen, communicate, think, reason logically and apply the mathematical knowledge gained;
- Learn to investigate, analyse, represent and interpret information;
- Learn to pose and solve problems; and
- Build an awareness of the important role that mathematics plays in real life situations, including the personal development of the learner (Department of Basic Education (DBE), 2011, p. 11).

WEIGHTING OF CONTENT AREAS			
Content Area	**Grade 4**	**Grade 5**	**Grade 6**
Numbers, Operations and Relationships*	50%	50%	50%
Patterns, Functions and Algebra	10%	10%	10%
Space and Shape (Geometry)	15%	15%	15%
Measurement	15%	15%	15%
Data handling	10%	10%	10%
	100%	**100%**	**100%**

* The weighting of Number, Operations and Relationships has been increased to 50% for all three grades. This is an attempt to ensure that learners are sufficiently numerate when they enter the Senior Phase.

Figure 1 Weighting of mathematics content areas (DBE, 2011, p. 12)

Figure 1 indicates the weighting of content areas in the intermediate phase. It is clear that the numbers, operations and relations content area weighs the most in the CAPS. This is because the understanding of number sense is cognitively foundational for the construction of advanced mathematical knowledge (Clements & Sarama, 2011). Griffin (2004), and Sharon A Griffin, Case, & Siegler (1994) found that learners who develop the understanding of number sense at an early age are more likely to succeed in school mathematics and beyond. Conversely, children who do not get the chance to develop this fundamental mathematical knowledge are at risk of lagging behind in mathematics development. Griffin et al (1994) also asserted that all children have the potential to develop a deep understanding of mathematics if given the opportunity to develop number sense at early age. Learners who lag behind can be given remedial intervention through effective teaching, which involves exploring and discussing key concepts, making connections between different concepts, developing their understanding at an appropriate pace, and following an appropriate conceptual and developmental sequence (Griffin, 2004). This is in line with the CAPS that also suggests that teachers mediate the construction of mathematical knowledge through learner-centred pedagogies that involve “observing, representing and investigating patterns and qualitative relationships in physical and social phenomena and between mathematical objects themselves” (Department of Basic Education, 2011, p.8).

Despite the much value placed on mathematics subject, as Chapter One indicated, South Africa faces the challenge to raise learners’ performance in mathematics, especially learners from the previously disadvantaged schools. Spaull (2013) attributed the lower performance in mathematics in such educational settings to unequal distribution of educational opportunities within South African schools. He asserted that South Africa has two school systems: The smaller system that accommodates 20–25% of all learners and includes the wealthiest and better performing learners, and the larger system that accommodates 75–80% of all learners and includes poorest and lower performing learners. Therefore, there are 75–80% young South Africans who may not be able to compete for prestigious jobs and access education in first-class higher institutions that require a strong background in mathematics. This may also limit the possibility to meet the country's demand for scares skills especially in the areas of science and engineering.

Papanastasiou (2000) identified other internal and external factors affecting South African learners' achievement in TIMSS assessments. On one hand, he relates the internal factors to the language of mathematics questionnaires and the quality of the questionnaire items. In (Papanastasiou, 2000)'s view, most South African learners fail mathematics papers because of unfamiliar words and complex sentences used in the questionnaires. In his view, black South African learners are more vulnerable than their white counterparts who are first language English speakers. This may be true. A study that involved 342 bilingual learners from lower income communities in Latin America found that there was a positive relationship between language speaking abilities and numeracy skills (Méndez, Hammer, Lopez, & Blair, 2019). Language helps learners to develop mathematics proficiency by providing tools for expression of mathematical thinking and the understanding of mathematical concepts (Kleemans, Segers, & Verhoeven, 2011). (Papanastasiou, 2000)'s view, may also not be true and insufficient to fully explain the consistent lower performance of South African learners in international mathematics competitions. There are learners from other countries who do well in TIMSS competitions even though English is not their first language; South Korea is a typical example. Nearer to home, learners from Mozambique, Kenya, Uganda and Tanzania outperformed South African learners in the SACMEQ III (Spaull, 2011), and English is also not their first language.

External factors, on the other hand, relate to the learners' attitude toward mathematics, their socio-economic status, and the educational background of the family. The study

(Papanastasiou, 2000) noted that learners who have a positive attitude toward mathematics do better than their counterparts who have developed a negative attitude toward the subject. The study also noted that learners who have access to various technological resources and books at home do better in mathematics than those who do not have these resources. This concurs with Bourdieu's theory of social capital in which social privilege has a significant effect on academic performance (Bourdieu, 2011).

In view of the above, although learners' performance might be constrained by limited access to resources, the SACMEQ III report demonstrated that schools could still do better with the resources available. In the SACMEC III, South Africa lagged behind poorer countries that have fewer resources (Spaull, 2011). Therefore, there is a need to shift the focus into the classroom to understand how teachers are teaching the subject and how learners are engaging with the content. How teachers teach mathematics is crucial since they can teach in ways that do not engage learners in the learning process and thus limits learners to construct mathematical knowledge. The study by Carnoy, Chisholm, and Baloyi (2008), in which 30 sixth grade mathematics teachers from different schools in South Africa participated, found that the majority of sixth grade mathematics teachers taught the subject in a circumscribed, conventional way that made learners' construction of mathematical knowledge difficult. However, current educational reforms require teachers to become facilitators of knowledge by constructing learner-centred teaching and learning environments in which learners are engaged in collaborative and authentic mathematics tasks (Adler, 2000). It is widely accepted that learners learn better when they are actively involved in the learning process and when teachers provide opportunities for individual and collaborative construction of knowledge. The SACMEQ III report showed that only 32% of mathematics teachers in South Africa have the desirable content knowledge (Spaull, 2013); this means that about 68% of mathematics teachers do not have the relevant content knowledge. Of course, teachers cannot teach effectively the content they have not mastered. Therefore, ongoing under performance in national and international mathematics assessments by learners might link to the way teachers are teaching mathematics content.

Based on the much value placed on mathematics subject as the above indicates, any pedagogical tool believed to support the development of early mathematics knowledge and skills cannot be resisted. In South Africa in particular, for the government seeking to provide equal opportunities to develop mathematics knowledge and skills, especially in historically disadvantaged schools, any intervention believed to upscale support to mathematics teachers and learners in such educational settings would be welcomed. Technology is believed to create intriguing opportunities for the development of early mathematics literacy (Pitchford, 2015). It offers news forms of teaching and learning that transcend traditional teaching (Goodwin, 2012; Sætre, 2013; Sinclair & Pimm, 2015). Hence many schools in South Africa and outside South Africa are adopting it as an alternative or additional pedagogical way to support the development of mathematics knowledge and skills. The next section discusses different technological interventions currently available in South Africa to improve teaching and learning of mathematics.

2.3 Technology as a potential pedagogical way to improve mathematics teaching and learning

With recent technological innovations and the wide dissemination of digital devices, many countries worldwide are introducing computers in mathematics classrooms (Hardman, 2005; Misfeldt, Andresen, & Lee, 2014). According to Resnick (2002, p. 32), “these new technologies have the potential to fundamentally transform how and what people learn. Just as advances in biotechnology made possible the green revolution in agriculture, new digital technologies make possible a learning revolution in education”. The South African Government also hopes technology will help to improve instructional practices in the country. In 2004, it launched the White Paper on e-Education to support the use of technology in schools in the country (National Department of Education, 2003). In the White Paper on e-Education (National Department of Education, 2003), technology is regarded as a transformative tool that, if used effectively, will achieve the national educational outcomes while transforming South African schools into a model of 21st century teaching and learning environment. The White Paper stated that the use of technology in the classroom promotes “learner-centred learning; active, exploratory, inquiry-based learning; collaborative work among learners and teachers; and creativity, analytical skills, critical thinking and informed decision-making” (DoE, 2003, p. 13). It offers promissory of radical pedagogical change, a change from teacher centred to learner-centred, and a pedagogical practice in which learners are not passive receivers of information but use technology to construct their own knowledge. This is clearly stated in the following.

> ICTs can play an important role in the transformation of education and training. ICTs can enhance educational reform by enabling teachers and learners to move away from traditional approaches to teaching and learning. In a transformed teaching and learning environment, there is a shift from teacher-centred, task-oriented, memory-based education (with technology at the periphery), to an inclusive and integrated practice where learners work collaboratively, develop shared practices, engage in meaningful contexts and develop creative thinking and problem-solving skills (DoE, 2004, p. 17).

It is clear from the above statement that the South African Government believes that access to ICT in schools will result in teachers improving their teaching and learners improving their learning. Hence many technological initiatives have been initiated to provide schools with technology, predominantly mobile technology, to support teaching and learning in the core subjects like mathematics. Some of the responsive technological initiatives are explained bellow.

2.3.1 Mindset

Mindset technological initiative provides teachers and learners with digital content through different platforms like online video tutorials, DVDs, Pdf files and air broadcast (Cortoos, Levec, & Jeans, 2015). However, the impact of Mindset intervention on the teaching and learning of mathematics has not been documented yet. My visit to Mindset headquarters revealed that now there is no mechanism in place to identify the followers of its air broadcast, how frequently they followed the broadcast, and what learning gains this intervention has brought about.

2.3.2 Nokia Mobile Mathematics

Nokia Mobile Mathematics is another technological intervention launched to increase achievements in mathematics. The program is embedded in the MiXit social platform and runs on mobile cell phones that have MiXit capability. The program is integrated with the Moodle learning management system to enable teachers to monitor their learners' use of the program and thereby diagnose their progress in mathematics. The program aims to promote independent mathematics learning from anywhere and at any time of the day. By using the service learners have access to locally developed mathematics content, including short mathematics theories, worked examples and answered questions drawn from a database of approximately 10 000 questions (Roberts & Vänskä, 2011).

While Nokia Mobile Mathematics seems to have promising prospects, research in the schools where the project was implemented as a proof of concept (Roberts, Spencer-Smith, Vänskä, & Eskelinen, 2015) found that only 21% of learners used the service regularly. Furthermore, only 48 of the 72 teachers (66%) who registered for the service made use of it. Some of the reasons for not using the service included lack of capable handsets, lack of access to internet, and some learners found the service boring (Roberts et al., 2015). The low number of teachers and learners who used the service cautions that rolling out the project countrywide might not be feasible. A study on the status of information and communication technologies (ICT) in education in South Africa (Meyer & Gent, 2016) showed that lack of access to hardware and internet connectivity, which were the major constraints in the Nokia Mobile Mathematics project, still haunt many schools in the country and particularly township schools.

2.3.3 Provincial Technological Initiatives

Mathematics teachers are also getting access to technology through ICT projects that are implemented by their provincial Departments of Education. In the Eastern Cape province, mathematics teachers have access to computers through the Khanya project (Du Toit, 2005). In January 2015, the Gauteng Department of Education also launched a massive paperless classroom project that aims to transform traditional classrooms in the province into paperless smart classrooms. Through the project learners in Gauteng rural and township, schools are provided with access to tablet computers, internet, and smart boards. The project is expected to cost R17 billion (Kganyago, 2019). Tablet technology has been touted to have the potential for anywhere learning and to offer more interactive educational resources than desktop computers do (Goodwin, 2012) and this might justify the move to tablet technology in the Gauteng province. In my view, it is hard to guarantee that the paperless classroom project will be successful in schools where early interventions have failed, unless more targeted support is provided to schools and teachers. In 2001, the province initiated a massive Gauteng Online School Project to build the province-wide school computer network, but the project failed before its promises could be realised. In most schools computers were lost because of burglary and theft (Rasool, 2011), and apart from that, most teachers were not trained to use the computers in their teaching practices; the computers were used by learners to download music and to play games (Mtshal & ndaba, 2011). The Intel ® Teach to the Future, a technological initiative similar to Gauteng Online, launched in 2003 also produced disappointing results (Thomson & Wilson-Strydom, 2005). Wilson-Strydom, Thomson, and Hodgkinson-Williams (2005)'s study on the extent to which South African teachers who completed the Intel ® Teach to the Future training program had integrated technology into their teaching practices revealed that 33% of the teachers had never used technology-integrated lessons even though the technology was available in the school. The same study also revealed that 48.5% of teachers had used the technology more than once per month while 13, 3% had used it about once a month. Miller, Naidoo, Van Belle, and Chigona (2006) found that when teachers used the technology, the use was limited to developing ICT skills as opposed to using technology to engage learners in higher-order thinking. This is consistent with the Second International Technology in Education study (Law, Pelgrum & Plomp, 2008) and (S. J. Howie & Blignaut, 2009) who also found a very limited use of technology in mathematics and science education in South Africa. The low uptake of technology by teachers as indicated in the studies above cautions that the paperless classroom project might not succeed in transforming teaching and learning mathematics using tablets.

The ICT for Rural Education Development (ICT4RED) project was also undertaken from 2012 to 2016 to leverage the use of tablet technology in 26 rural schools in the Cofimvaba

District in the Eastern Cape Province (Ford, Botra, & Rerselman, 2014). It was a joint initiative between the South African Department of Science and Technology, the South African Department of Basic Education (DBE), the Eastern Cape Department of Education, and the South African Department of Rural Development and Land Reform (Botra, Rerselman, & Ford, 2014). The project was successful in empowering teachers in schools where it was implemented as a proof of concept to use tablet technology in teaching mathematics and science subjects. Unfortunately, the project did not expand to other schools due to the lack of e-readiness in many schools across the country. The process is currently underway to develop an e-readiness framework which, once implemented in all the schools in the country, then a countrywide implementation of the ICT4RED will follow (Dlamini, Meyer, Marais, & Ford, 2017). All these initiatives are there to support the vision of the White Paper on e-Education.

It is clear from the above that the South Africa Government has made significant effort to provide the historically disadvantaged schools in the country with tablet technology in the effort to improve teaching and learning in core subjects like mathematics. However, this does not guarantee that classroom practices will be transformed. Cuban (2009) indicated that teachers do not automatically choose to use technology or change their teaching practices simply because the technology is available. In his view, schools are complex social structures different from corporate organisations where technology was quickly adopted. He gave as evidence examples of schools in Northern California's Silicon Valley where teachers were supplied with the latest technology and provided with multiple opportunities for training in computer skills in order to transform their teaching practices. However, teachers used the technology far less in the classroom than they did at home, and when they used the technology it was to amplify traditional teaching practices.

The literature identifies the reasons why teachers may resist the technology or be slow to harness it to transform classroom practices. According to the Technology Acceptance Model (TAM) (Davis, 1989), end users' acceptance of technology is influenced by their perceptions about the usefulness of the technology (perceived usefulness) and their perceptions about its ease of use (perceived ease of use). In other words, teachers may accept technology only if they believe the use of that technology will help improve their practices. Ease of use implies that despite believing in the usefulness of technology, teachers may resist using it if they believe it is complicated to use. The Unified Theory of Acceptance and Use of Technology (UTAUT) model (Venkatesh, 2011), the revised version of the TAM Model, adds social influence as another factor influencing end-users' acceptance of technology. Social influence implies that teachers may accept to use technology if they believe important others expect them to use it (Oshlyansky, Cairns, & Thimbleby, 2007). To this, Hennessy, Harrison, and Wamakote, (2010) add that teachers may use technology in the classroom if the latter is policy mandated. Hence, Hennessy et al., (2010) caution that familiarity with the national policy on the use of ICT as well as supportive school policies are a prerequisite for effective integration of technology in the classroom.

While ease of use is one of the important factors for teachers to accept and use technology (Venkatesh, 2011), the Apple Classroom of Tomorrow (ACOT) (Dwyer, 1995) demonstrated that it takes appropriate training, sufficient time and sufficient resources for teachers to become self-efficacious in the use of technology in the classroom. It involves a five stages continuum process: Entry, adoption, adaptation, appropriation and invention. At the entry level, technology has just entered the school environment and the individual teacher's personal career. Most teachers are timid of technology and shy away from it unless there are incentives or its use is mandatory. This stage is also characterised by teachers' frustration because of the challenges relating to the management of the technology. At the adoption stage, teachers struggle to accommodate the technology into existing classroom practices. The use of technology in this stage is predominantly mere drill and practice and conventional practices remain unchanged despite the availability of technology in the physical classroom environment. At the adaptation level, teachers start to gain confidence in the use of technology, and because of this confidence, traditional practices begin to change. The use of technology for drill and practice is replaced by the use of technology for mathematical problem solving. At the appropriation stage, the use of technology in the teachers' teaching is spontaneous. Teachers use technology with ease without making significant mental effort. At this stage, technology becomes an integral part of the teaching and learning practice. The invention stage, which is the highest level, involves the use of technology for knowledge creation.

It can be said from the above that, although the introduction of tablet technology in mathematics classrooms in township schools in South Africa represents a change to the classroom practices, this change needs to be first accepted and used by teachers to impact classroom practices. The section above showed that acceptance and use of technology in the classroom does not come easy. The section that follows explores the intrinsic features of tablets that may improve teaching and learning of mathematics, if accepted and used effectively by teachers.

2.4 Intrinsic features of tablets to support the development of mathematics concepts

A tablet is "a device with a touchscreen interface, screen size ranging from 5 to 12 inches, colour display, Wi-Fi and/or 3G internet connectivity, and advanced operating system such as Apple iOS, Google Android, Windows7 and BlackBerry" (Perrin, 2012). Tablet technology such as the iPad has been termed 'revolutionary' and 'game changer' because of how people can access information, communicate and learn with it (Bort, 2013). The tablet also appears to be a digital device able to bring various digital educational tools together into one place to support teaching and learning of any kind. A systematic review of teaching and learning with tablets (L. Zhang & Nouri, 2018) revealed that the tablet concurrently affords augmented and virtual learning, feedback and assessment, individualised learning, inquiry based learning, mobile learning, documentation and communication and peer learning. Hence, due to these benefits many schools are adopting tablet technology in the effort to transform classroom practices.

Churchill, Fox, and King (2012) grouped the tools available on tablets into seven categories, namely, productivity tools, teaching tools, notes tools, communication tools, drives, blogging, and content access tools. The review of the literature (Carr, 2012) also indicates that tablet technology has the potential for new and fast delivery and communication of mathematical knowledge, symbol and graphical manipulation and may offer the opportunity to create an interactive learning environment for learners to collaboratively construct mathematical knowledge.

With regard to classroom teaching and learning, the literature (Goodwin, 2012) reveals that tablet technology allows access to instructive applications for mathematics drill and practice, manipulative applications for guided mathematics discovery, and productive applications that allow learners to create their own content and digital artefacts. All these applications are meant to support learners’ deeper understanding of mathematics.

Goodwin (2012) also identified five more affordances of tablet technology beneficial to the teaching and learning of mathematics:

1. Multiple senses applications: Tablet devices have specialised applications in which the auditory, visual, and tactile senses are combined (Goodwin, 2012). Flevares and Perry (2001), Martin (2000) and Sinclair & and Pimm (2015) argued that combining multiple senses can lead to better teaching and improved understanding of mathematical concepts.

2. Mathematics gamification applications: Tablet devices embody some mathematics gamification applications that can be used to enhance teaching and learning of mathematics (Goodwin, 2012). Sætre (2013) argued in his study that the use of Dragon Box, an algebra game for tablets, motivated and enhanced learners’ learning of algebra.

3. Connectivity applications: Wirelessly connected tablets give teachers and learners access to multiple sources of information they need to understand mathematical concepts. They are able to be part of mathematics community of practice. Furthermore, connected tablets allow the teacher to provide the learner with timely feedback (Goodwin, 2012).

4. Interactivity and multiple representations of concepts: tablet technology supports teaching and learning of abstract concepts through interactive teaching and learning materials and multiple representations that allow making connections within and between concepts (Goodwin, 2012).

The literature suggests that tablet technology marshal other educational technologies due to its ability to embed all forms of instructional media to support teaching and learning (Bort, 2013). They are powerful in terms internet connectivity and mobility (Galligan, Loch, McDonald, & Taylor, 2010; Goodwin, 2012; Pitchford, 2015; Sætre, 2013). They give access to a plethora of educational applications that are able to develop numeracy and literacy skills for learners of all age groups (Hubber et al., 2016; Pitchford, 2015; Sætre, 2013). In addition, the majority of these educational applications are designed to allow for a differentiated learning experience and assessment (El-Saghir, 2012), thus, giving learners some degree of control over their learning. This could be the reason why integrating tablet technology has been a major trend in mathematics classrooms around the world and in South Africa in particular.

2.5 Related work

The use of tablet technology in mathematics teaching sparked the interest of many scholars. Hilton (2018) investigated the impact of teaching and learning mathematics with tablets on learners' attitudes and engagement in one urban primary school in Australia, using both qualitative and quantitative research methods over a two-year period. The findings from his study shed light on the potential of educational applications to improve teaching and learning of mathematics. In his study, learners aged between two and six years who used educational applications both in their homes and at school to learn mathematics changed their attitudes toward mathematics. Their engagement in mathematics lessons also increased significantly. The different levels of activities that the educational applications provided made mathematics lessons more personalised and added fun to the learning process. Personalised learning was a big advantage to gifted learners. Rather than moving at the learning pace of their peers in the classroom, they made use of the instant feedback the applications provided to progress to their zone of proximal development (ZPD).

The traditional classroom makes implementing differentiated teaching and learning difficult. It requires that different learners move approximately at the same learning pace in the classroom while the teacher tells the learners what to do in the lesson. However, when learning is personalised, learners can move at their own pace. The role of the teacher changes from being the sage on the stage to that of the guide on the side. This new role allows the teacher to provide each learner with personalised support (de Hond, 2018). In Hilton's (2018) study, the infusion of educational applications in mathematics teaching and learning changed the traditional classroom dynamics. Learners in mathematics classrooms developed at different paces, and applications provided learners with personalised learning support in the form of instant feedback. This meant that the teacher could spend more time supporting learners who required support. Teacher participants in Hilton's study received training on the use of tablets in mathematics curriculum. The training took place before the study and during the study. This is mainly because training equipped teachers with the knowledge of how to plan and deliver differentiated mathematics lessons that use tablets. In addition, each teacher had his own tablet device, which meant that teachers could prepare thoroughly when at home. Hence, it was not a challenge for them to facilitate differentiated mathematics lessons.

Papadakis, Kalogiannakis, and Zaranis (2018) also evaluated the effectiveness of desktop computers and tablet intervention on learners' learning of numbers in the early grades in Greece for a period of two years. More than 365 learners from 21 randomly selected classrooms participated in the study. The findings of the study showed that learners who used technology (either desktop computers or tablet computers) had a greater understanding of number sense than learners who were in the control group. Interestingly in this study, learners who used tablets outperformed learners who used desktop computers. This was because tablets provided more affordances than computers did. They afforded multiple modalities, instant feedback, and more interactivity. In addition, learners had great interest in tablet devices than they did in personal computers. This interest motivated them to spend long hours engaged in mathematical educational applications. These findings corroborated the study on the effect of tablet applications on mathematics learning for Grade 1, 4 and 6 learners in Greece (Fokides, 2018). The later also found that learners who used tablets mathematics games outperformed their counterparts in the control group.

Moyer-Packenham et al., (2016) conducted a mixed methods study in which interviews, post-tests, wall and screen capture videos, pre- and post-assessment, and time stamping were used to capture the data on the impact of virtual manipulatives on learners' construction of mathematical knowledge. In his study, the mathematics performance of 100 learners, aged between three and eight years, who engaged with six different mathematical manipulative applications improved significantly. In addition, learners who used manipulatives applications solved mathematical problems faster than their counterparts did in the traditional mathematics classrooms. The study concluded that, “children’s interactions with externalized representations, through the use of virtual manipulatives touchscreen applications, are an embodied process, and as such, are not a precursor to mathematical thought—they are mathematical thought” (Moyer-Packenham et al., 2016, p. 46). With this assertion, Moyer-Packenham et al.(2015) emphasised that virtual mathematical manipulatives are able to tie learners’ mathematical actions and thoughts together to the extent that you cannot separate the body and the mind. They are also able to speed up new mathematical thoughts and ideas. This concurs with Moyer, Salkind, and Bolyard (2008) who also asserted that virtual manipulatives that can be manipulated give the learner a concrete experience while at the same time providing a visual, symbolic and verbal representation of mathematical ideas and thoughts.

Near home, as Hubber et al., (2016a) and Pitchford (2015) indicate, the Malawian Government implemented tablet technology intervention in 68 primary schools in the effort to address the lack of teaching and learning resources, and the persistent low attainment in mathematics. The intervention consisted of learning centres where learners gathered to learn with tablets and a variety of learner-centred mathematics applications delivered through iPad tablets. The applications provided a series of curriculum aligned mathematics activities for learners to work on their own pace through the support of a virtual tutor speaking in Chichewa, which is the official language of Malawi. Learners practiced the activities as often as they wanted to master mathematics concepts (Pitchford, 2015). A Randomized Control Trial (RCT) (Hubber et al., 2016a) that was conducted with 283 primary school learners from standards 1–3 found that learners who used tablets for mathematics learning improved their conceptual mathematics knowledge by 4% and by 18 % on curriculum knowledge. The study found that tablet technology could be a potential pedagogical way to improve early mathematics attainment in schools in Malawi.

The use of tablet technology for teaching and learning mathematics is still limited in South Africa. Masonta, Ramoroka, and Lysko (2015)'s study that explored the use of TV White Spaces and tablets in five rural secondary schools in Limpopo Province, South Africa, found that the majority of mathematics teachers and learners did not have access to tablet devices. The schools had few tablets devices that were used by few selected teachers and learners from higher grades. The majority of mathematics teachers and learners relied on the information from textbooks. A Snapshot survey of ICT integration in South Africa (Padayachee, 2017) also found the lack of access to tablets by learners to be the major challenge affecting the integration of technology in mathematics curriculum. This shows that the national effort to improve teaching and learning of mathematics through the use of tablet technology may not be achieved due to the lack of access to this technology in some schools.

The studies above suggest that tablet technology is a promising instructional innovation to improve learning of mathematics. However, there are growing concerns about the negative impact that touch technology may have on cognitive development of young learners. Bauerlein (2008) maintained that new digital technology is the reason for the documented educational deficit of young Americans. In his view, although the new technology is providing young Americans with greater access to knowledge, information, and enrichment than any previous generation, the same "technology has contracted their horizons to themselves, it has become their means of sealing themselves off from those very things" (p. 235). He further said that because of mobile technology, digital age young Americans cannot read and write; they could not do simple calculations or write grammatically correct prose. They do not read for pleasure, and the time that should be used for schoolwork is spent on social media. Young Americans are doing fragmented, partial, and superficial screen reading, which allows for unsustainable scanning, skimming, jumping, skipping, clicking away, and clicking through. Consequently, their minds are conditioned against quiet, concreted study, against imagination unassisted by the visual, and against linear and sequential analysis of texts.

Similarly, (Richtel, 2010) argued that digital mobile technologies are the biggest distractors and time-wasters the world has ever known. The devices give learners the ability to do Facebook, YouTube, texting, and listening simultaneously. This takes their focus from the schoolwork and puts their brain at risk of losing the capacity to sustain attention. “Their brains are rewarded not for staying on task but for jumping to the next thing. The worry is we’re raising a generation of kids in front of screens whose brains are going to be wired differently” (Richtel, 2010, p. 10).

There are also several challenges in most schools that integrated tablet technology. These relate to application selection and technical support (Alberta Education, 2012), learners’ distraction, and lack of relevant curriculum aligned applications (Chou, Block, & Jesness, 2012). Harmon (2012) asserted that application selection is a process of trial and error. New educational applications are released each year; hence, teachers find it a daunting task to keep pace with the ever-changing landscape of educational applications. The ability to adjust the content to meet the needs of individual learners while promoting the vertical construction of the curriculum knowledge is also a serious challenge as many educational applications come with the content and activities that have a fixed sequence and pace.

In a study to explore the pedagogical use of tablet technology in the teaching and learning of Grade 10 life sciences in two schools in Johannesburg, South Africa, Rafiki (2015) found that learners got off track while looking up information on a website. Learners were using the devices to play games, take pictures or as a mirror during lessons. They also used their devices to search the web for social content and sport sites instead of using them for the prescribed task. Therefore, teachers were compelled to continuously monitor the learners so that they did not get off track.

In conclusion, in as much tablets may have enhanced features to support the development of mathematics knowledge and skills, the use of this technology in the classroom needs to be carefully planned and monitored.

2.6 Research gaps

Research on the pedagogical use of tablet technology in mathematics teaching in rural and townships schools in South Africa is scarce. In addition, most studies on the integration of tablet technology in mathematics teaching are from the West and focussed on the impact of tablet educational applications on learners' attitudes towards mathematics or the impact of tablet educational applications on learners' performance in mathematics (see for example, El-Saghir, 2012; Galligan et al., 2010; Herodotou, 2018; Papadakis et al., 2018; Sætre, 2013). These studies overlooked the opinions of teachers on the pedagogical value of tablet technology in the teaching of the subject. As I perused the literature, I also identified a gap concerning the use of the conversational framework (Laurillard, 2002) in exploring the value of tablet technology in teaching and learning mathematics. Yet the framework provides useful theoretical tools to analyse the pedagogical value of educational media. It draws from instructionism, social learning, constructionism, and collaborative learning theories underpinning modern learning and progressive pedagogy(Laurillard, 2009). It distinguishes itself from other theories like the Technology Acceptance Model (Davis, 1989), the Theory of Affordances (Conole & Dyke, 2004; Gibson, 2014; Greeno, 1994), and the Technological Pedagogical Content Knowledge (Koehler, Mishra, & Cain, 2013) that are commonly used in Educational technology by mapping the affordances of technology to learning experiences. Another gap identified is that very few studies have used the qualitative methods for data collection and analysis. Most studies in this area used quantitative methods, which cannot provide thick descriptions of the phenomenon under investigation in the current study. This study has successfully bridged the gaps identified by using the qualitative research approach with exploratory case study design (Yin, 2015), and the conceptual analytical framework developed from the Laurillard's (2002) conversational framework. It has also drawn on contemporary learning theories to explore township mathematics teachers' experience of using tablet technology in their teaching.

2.7 The Conceptual Framework

Qualitative studies like this one use the conceptual framework to identify important concepts that are relevant to the study and to explain how these concepts relate to one another (Green, 2013). A conceptual framework is different from a theoretical framework although some novice researchers use these two concepts interchangeably (Rocco & Plakhotnik, 2009, p. 121). Ideally, a theoretical framework is used to investigate an existing theory while a conceptual framework does not begin with a theory. It is rather a process of theorising from scientific investigatory work (Rocco & Plakhotnik, 2009, p. 126). This means that a conceptual framework is used to explore an area that is under study and for which there is no existing theory. It is made of a network of linked concepts collected from the relevant theoretical and empirical work to situate the study into the existing body of knowledge (Jabareen, 2009). Each concept within a conceptual framework is picked cautiously based on the ontological or epistemological role it plays in the framework (Jabareen, 2009, p. 51). Both conceptual and theoretical frameworks help to (a) build a foundation; (b) demonstrate how a study advances knowledge; (c) conceptualize the study; (d) assess research design and instrumentation; and (e) provide a reference point for interpretation of findings(Rocco & Plakhotnik, 2009, p. 122).The present study explored the pedagogical value of tablet technology in teaching mathematics in township schools, an area which is understudied and for which there is no existing theory. Hence the conceptual framework used was deemed appropriate to ground the study into knowledge bases relevant to the research problem and the research questions. In developing the conceptual framework of the present study, I used different theoretical works that include constructivism (Piaget, 1964a), social constructivism(Vygotsky, 1978), the conversational framework(Laurillard, 2002) and meaningful learning (Saarelainen & Ruokamo, 2007) to flesh out ten concepts: knowledge construction, interactive media, adaptive media, productive media, communicative media, reflection, feedback, discursive learning, experiential learning,and meaningful learning. These concepts informed the themes that guided the presentation and the discussion of the study findings.

2.7.1 Constructivism and Social Constructivism

There are two prominent theories in mathematics education, constructivism and social constructivism (Cobb, 1994). Constructivism derives from Piaget who argued that children construct their reality of the world by acting on the objects in their environment (Duckworth, 1964). Piaget was of the view that reality is constructed from experience rather than acquired (Piaget, 1964). The following is how he explained it.

> To understand the development of knowledge, we must start with an idea which seems central to me-the idea of an operation. Knowledge is not a copy of reality.

> To know an object, to know an event, is not simply to look at it and make a mental copy or image of it. To know an object is to act on it. To know is to modify, to transform the object, and to understand the process of this transformation, and as a consequence to understand the way the object is constructed. An operation is thus the essence of knowledge; it is an interiorized action which modifies the object of knowledge. (Piaget, 1964b, p. 176)

In view of the above, what people know is subjective to their interaction with the environment, their background and their prior knowledge (Ertmer & Newby, 2013). In teaching and learning, constructivism shifts the instruction from the teacher to the learner. Rather than having the teacher, transmitting the knowledge to passive learners, the teacher is compelled to create an environment in which learners actively construct their knowledge through their interaction with the phenomenon, in this case educational materials. Steffe and Kieren (1994) take this further by stating that:

> It is not the adult's interventions per se that influence children's constructions but the children's experience of these interventions as interpreted in terms of their own conceptual structures…the teacher cannot cause the child to have experience qua experience. (Steffe & Kieren, 1994, p. 719)

It is clear from the above that the learning of mathematics is not the direct result of the teacher's teaching but of what the learner does with the content. The role of the teacher is therefore to construct an environment conducive to knowledge construction and to provide opportunities for children's engagement with mathematical activities (Steffe & Kieren, 1994). Ertmer and Newby (1993) asserted that this can be achieved by using active pedagogical approaches such as experimenting, modelling, coaching, classroom discussion, debates, and providing learners with authentic tasks situated in a real world context.

Social constructivism concurs with constructivism on the active involvement of the learner in the teaching and learning process. However, it distinguishes itself from constructivism by its focus on the cultural and social character of learning. Vygotsky (1978), regarded as the father of social constructivism, asserted that knowledge is a product of social interactions mediated by tools in the cultural environment. He asserted that learning starts with participation in a socially organised activity and is then internalised when the individual is alone.

> Any function in the child's cultural development appears twice, or in two planes. First it appears on the social plane, and then on the psychological plane. First it appears between people as an inter-psychological category, and then within the child as an intra-psychological category. This is equally true with regard to voluntary attention, logical memory, the formation of concepts, and the development of volition. (Vygotsky, 1978, p. 163)

In view of the above, the learning of mathematics is both a social and an individual activity. The interaction with other people, especially more knowledgeable people, is crucial for the social knowledge construction of mathematical knowledge. The more knowledgeable person assumes the mediational role of helping the learner make sense of mathematics. Mediation involves the use of cultural tools and signs including language, various systems of counting, diagrams, algebraic symbol systems, and writings to facilitate the understanding of concepts. Through mediation, the more knowledgeable other is expected to identifying the gap in the learner's knowledge in order to build proper scaffolding for learning. Mediation and scaffolding occur in the ZPD which represents the gap between what children can do on their own and what they cannot do without the assistance of an adult (a more knowledgeable other).

As in the above, mediation entails pushing children beyond the boundaries of their thinking, as opposed to Piaget's (1965) notion of genetic structures that ties learning to physiological and mental development. In Piaget's view, a child must have achieved a certain physiological and psychological stage to be able to learn some mathematics processes. Mediation, however, entails that children can learn and do mathematics that is beyond their developmental level with the assistance of a more knowledgeable person and with proper mediational tools.

Ernest (1998) asserted that social construction provides the basics for a better vision of teaching and learning of mathematics:

1. It recognises that both social and individual processes have central and essential roles to play in mathematics education.

2. It capitalises on the active construction of mathematical knowledge through experience and interaction with the social world.
3. It recognises the crucial role of the teacher in mediating the construction of mathematical knowledge, particularly in correcting learners' errors and misconceptions and ensuring the learning of accepted school mathematics, both written and spoken.

According to Venter and (Barnes & Venter, 2008), in the social constructivist teaching and learning environment, the teacher is not the authority who owns objective mathematical knowledge and facts to be transmitted to a passive learner. Instead, learning mathematics becomes a process in which both the teacher and the learner become co-constructors of mathematical knowledge. Teachers facilitate the learning process by using real context rather than presenting mathematics as a ready-made system with general applicability. Kim (2001) argued that in a social constructivist teaching environment, mathematics is learned through reciprocal teaching, peer collaboration, cognitive apprenticeship, problem based teaching and other methods that involves interaction with other people.

In conclusion, this study favours a social constructivist perspective because it builds on the general premises of constructivism and adds to them the social and cultural contexts influencing learning. Based on the premises of social constructivism it can be argued that:

1. The learning of mathematics is an active process of constructing rather than merely acquiring mathematical knowledge and facts. Therefore, the teacher has to use active pedagogical approaches that encourage learners' mathematical actions.
2. Mathematical knowledge is socially and individually constructed. Therefore, the teacher needs to provide occasions for interactive mathematical discourse and opportunities for individual and collaborative mathematics tasks.
3. Cultural and psychological tools and signs are used to mediate the construction of mathematical knowledge. This includes technological and non-technological tools

that can add value to the teaching and learning of mathematical concepts; however, this study will focus on cultural tools provided by tablet technology.

2.7.2 Conversational framework

Although social constructivism provides this study with an understanding of how learners come to learn mathematics, it does not directly address how teachers ought to design technology enhanced social educational environments. Laurillard (2002) provided a practical conversational framework that can help to bridge this gap.

In Laurillard's (2002) conversational framework, teaching is an "iterative dialogue between the teacher and the learner focussed on a topic goal" (p. 77). The dialogue occurs at two intertwined levels: The discursive and the experiential levels. At the discursive level, the focus is on articulating and discussing concepts, ideas, theories and forms of representations. The teacher leads the discursive level toward learners' understanding of theoretical descriptions. At the experiential level, the focus is on providing the learner with the opportunity to act, to experiment and to practice the theoretical knowledge learned at the discursive level. The experiential level is learner self-directed or peer-directed. A complete learning experience (conversation) must have discursive, adaptive, interactive and reflective events that are mediated by technological and non-technological media tools.

2.7.2.1 Events of an instructional conversation

A) Discursive

The teacher describes the topic, ideas and concepts to be learned and while doing so gives learners opportunities to ask questions and express their own ideas. The discussion progresses with learners and the teacher engaging in the process of challenging their understanding. The teacher provides the feedback, and the learner continually uses it to reach an understanding of the topic.

B) Adaptive

Based on the teacher's interaction with learners at the discursive level, the teacher adapts the learning environment and preferably adjusts the task to meet the learners' needs.

Then the learners use the teacher's feedback to adjust their actions for better understanding of the concepts.

C) Interactive

This is an experiential aspect of the conversation. The teacher provides an appropriate learning environment for learners to practice and transform their conceptual understanding of what was discussed. The teacher provides the learners with a task or an activity to act on and to receive the feedback on their actions.

D) Reflective

The teacher and the learners reflect on the learning process in relation to the achievement of the topic goal. The teacher might change the topic, adapt the task or change the topic goal after reflecting on the conversation process. The reflection process is an opportunity for both the teacher and the learner to fine-tune their skills and knowledge as they learn what worked and what did not work.

It is clear from the above that the instructional conversation is a cyclic and an active process involving actions at the discursive and experiential (interactive) events, followed by feedback (reflection) and revision (adaptation). My view is that reflection and adaptation occur as imbedded in the discursive and the experiential tasks. As teachers engage learners in the instructional conversation, they might find some drawbacks in their teaching and may quickly change their teaching methods to meet learners' needs. The changes at the discursive event might also force them to adapt the experiential task they had planned and vice versa. Learners too, while pondering on the inputs from the participants in the instructional conversation, might reflect on and adapt the way they do and think about mathematics. The instructional conversation events can be represented as follows:

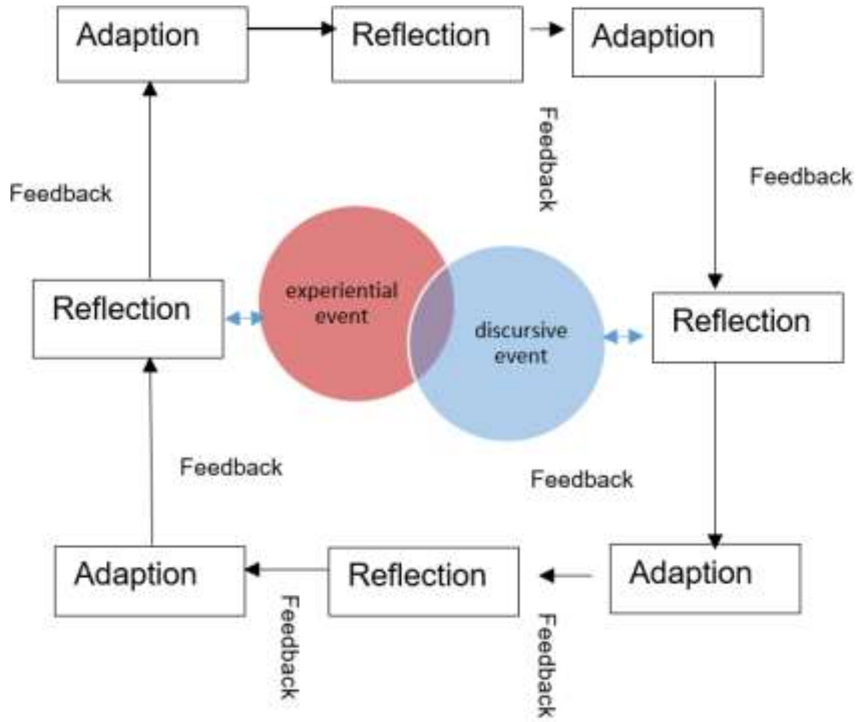


Figure 2 Instructional events

In Figure 2, the two main events of the instructional conversation are the discursive event and the experiential event; the two events are intertwined. That means, what happens at the discursive event affects the experiential event and vice versa. The discursive event is aimed at helping learners to construct a theoretical understanding of mathematical concepts through discussion while the experiential event seeks to provide learners with opportunities to practice the theoretical knowledge through direct engagement with the knowledge. Both events are amplified and enriched by the feedback from the teacher and peers. Ongoing feedback leads to ongoing reflection on practices, and adaptation of practices. In mathematics teaching in particular, as Sidhu & Srinivasan (2018) argued, instant feedback supports better understanding and long-term retention of mathematical knowledge by learners. Feedback also leads to meaningful learning(Hakkarainen, Paavola, Kangas, & Seitamaa-Hakkarainen, 2013).

Many researchers (Haroutunian-Gordon & Tartakoff, 1996; Schoenfeld & Kilpatrick, 2008; Setati, 2001; Temple & Doerr, 2012) agree that mathematics should be taught and learned through conversation. Teaching mathematics through conversation helps to develop the ability to speak and think mathematically and the ability to talk about mathematics. In addition, during the instructional conversation, the teacher is able to see the difficulties learners encounter, either in talking about mathematics or in talking mathematically, and can thein provide appropriate scaffolding (Pratiwi, Herman, & Jupri, 2018).

Sfard, Nesher, Streefland, Cobb, and Mason (1998) made a distinction between talking mathematically and talking about mathematics. Talking mathematically means to have the ability to convey mathematical meanings using mathematics symbolism but when talking about mathematics the learner uses the natural language to express mathematical knowledge and ideas. When they talk about mathematics, learners tend to use the everyday language. It is therefore recommended that during the discourse process the teacher support the development of specialised mathematical language. In addition, talking about mathematics is a necessary skill but the ultimate goal is to push learners to the level where they can think and talk mathematically. Talking mathematically enables them to participate in the communities of mathematicians and to apply mathematics to everyday life. One of the aims of the CAPS for mathematics is to “develop the correct use of the language of mathematics” (DoBE, 2011, p. 6). This aim implies that citizens who are unable to think and communicate mathematically may find themselves cut off from participation in the life of the country and in the global community in general.

The literature promises that the ability to speak and to think mathematically can be developed if the subject is taught through conversation. Franke, Kazemi, and Battey, (2007) asserted that, “what it means to do and learn mathematics is enacted through the discursive practices that form in the classroom” (p. 230). In the classroom discourse, teachers introduce learners to mathematical concepts, ask more questions and ask for more than recall of the answers. They provide learners with opportunities to express ideas and actions, to present problem solutions, to make conjunctures, to talk about a variety of mathematical representations, to explain their solution process, and to prove why their solution work. This allows teachers to get to know the learners’ mathematical thinking, and then build on it to support the development of mathematics proficiency. Riccomini, Sanders, and Jones (2008) and Pierce and Fontaine (2009) also show that learners who demonstrate language barriers can quickly develop mathematics vocabulary and quickly fill-in gaps in their prior mathematical knowledge if they get opportunities to engage with multimedia mathematics content. This underscores the importance of using tablet media to enrich mathematics discourse.

It is clear that the instructional conversation as classroom mathematics pedagogy brings together constructivism and social constructivism. It underscores the importance of social and individual contexts of learning. The discursive level takes place around a planned activity by the teacher; this is what Vygotsky (1978) called a socially organised activity. At the experimental level, the teacher can provide the learner with a problem based activity to practice what they learned at the discursive level. It can be done in groups, in pairs or individually. This must be followed by a reflection on how well the teaching goals were achieved so that the teacher can provide relevant feedback and if necessary adjust the activity to meet learners' needs.

Based on the general premises of social constructivism and Laurillard's (2002) conversational framework this study argues that:

1. Mathematics lessons need to be grounded in the conversation that involves the discursive and experimental processes.
2. The discursive process involves interactive and iterative mathematical discourse to enhance learners' social construction of mathematics concepts.
3. The experiential process involves both individual and collaborative construction of mathematical knowledge.
4. The experiential process is enriched by the teachers' scaffolding in the form of feedback and this helps improve the mathematics that is taught and learned.
5. Tools mediate both the discursive and experiential activities. Laurillard (2002) grouped mediating tools into five media forms, as discussed below.

2.7.2.2 Media forms

In line with the conversational framework, the instructional conversation needs to be facilitated using different technological and non-technological instructional media.

Laurillard (2002) grouped mediating tools into five media forms namely narrative, interactive, communicative, adaptive and productive.

a) Narrative

These are non-interactive linear presentational media forms that just convey the teacher's descriptions of the topic. Narrative media include text and video materials. They afford learning by providing the learner with a coherent structure of the topic descriptions in which concepts are linked, relationships are established, and cues are used in order to make the description meaningful to the learner. Although narrative representations are fundamental to learners' comprehension, they do not provide learners with the opportunity to express their own ideas or to react to the description they convey. The learner has to take what they offer. They also cannot provide the learner with intrinsic feedback for their actions. To avoid this pitfall, narrative media have to be combined with the teacher's discussion and activities with feedback.

B) Interactive

These linear media are delivered in an open, user-controlled environment by either a disc or a network including hypertext, hypermedia and multimedia resources. It affords learning by providing the learner with the resources to explore, better representational quality, the control over the sequence of the content, control over the type of learning activity and control over input to the content questions. However, just like narrative media, interactive is not enough to ensure that all aspects of the conversation are covered. It can offer a variety of perspectives but there is no re-articulation with regard to learners' performance. Learners cannot interrogate it; they just take what it offers. Hence, it needs to be supported with other media to bridge this gap.

c) Adaptive media

These are computer-based programs embodying some models of the world that change based on the input from the user. The program accepts the input from the learner runs the model and then provides the results. Adaptive media include simulations, virtual environments and tutorial programs. Adaptive media affords learning by providing learners with intrinsic feedback based on their input to a model. Laurillard (2002) asserted that the intrinsic feedback provided by adaptive media is individualised, private and formative. It enables learners to know how close they are to achieving the learning goal. Adaptive media is the only form of media to offer learners the opportunity to express their own ideas and to cover most aspects of the teaching and learning process. However, it is also not discursive. It has to be supported by face-to-face classroom discourse.

d) Communicative media

This supports the discussion by facilitating the exchange between the teacher and the learners and between the learners themselves. It can take a synchronous form if the exchange is happening at the same time or asynchronous if the exchange happens at different time intervals. The exchanges happen by texting, videos, and emailing.

e) Productive media

This allows learners to produce an output from the learning experience. Learners use the productive media to articulate and express what they have learned. In this regard, it can be used to support the reflection phase of the learning experience.

Each media form supports a different learning experience: Narrative media supports apprehension; interactive media supports exploration and investigation; adaptive media supports experimenting and practising; productive media supports articulating and expressing; and communication media supports debating and discussing. All these media forms must be employed for complex learning (Hedberg & Larson, 2009).

In the teaching of mathematics with tablet technology, the conversational framework calls on mathematics teachers to combine the affordances this technology offers to provide learners with the best learning experience that involves narration, interactivity, adaptability, communication and productivity. However, teachers are not bound to use technology media tools only; the conversational framework suggests the use of all possible media capable of enhancing the classroom conversation. In the teaching of mathematics, this may include chalkboard explanations, textbooks and other real objects that teachers might use to enhance their teaching. Whenever possible, a mathematics lesson should include narrative media to provide learners with a structured description of mathematical theories and interactive media to enhance the understanding of mathematical concepts and most importantly to bridge the learning gap not covered by narrative media. The lesson must also include some simulations to provide the learner with the opportunity to solve authentic mathematical problems and to receive intrinsic feedback upon completion. Authentic mathematical problems are complex and ill-defined and embedded in real-life context. They are formulated in such a way that the learner cannot solve them without consulting different information sources and experts in mathematics (Herrington, Herrington, Mantei, Olney, & Ferry, 2009). Authentic learning tasks have the potential to develop learners' higher-order thinking skills (Lombardi, 2007), because upon completion learners are required to present their solutions and reflections to the entire class in order to receive constructive feedback (Herrington & Oliver, 2000). Obviously, the feedback received allows learners to polish their reflections. This makes authentic learning different from traditional teaching where the teacher provides learners with the information and then learners are tempted to memorise that information without understanding it.

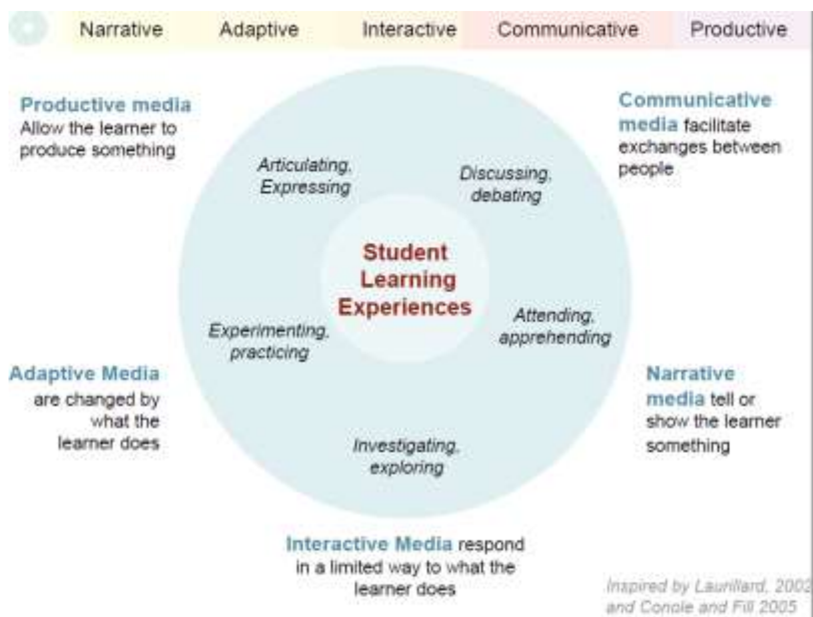


Figure 3 Media forms (Hedberg & Larson, 2009)

Figure 3 illustrates the media forms and the learning experiences accruing from their use. It indicates that there are five categories of media that teachers and learners might use in the instructional conversation. These are narrative, adaptive, interactive, communicative and productive media. A combination of these media in a lesson is desirable because no single media form is sufficient to cover the teaching and learning experience fully. Narrative media seem to cover the lower cognitive processes of knowing and understanding, while productive media seem to cover higher cognitive levels of producing and generating knowledge. This suggests that interchanging media in the instructional conversation may be informed by the complexity of cognitive processes, which are the focus of the lesson. Infusing the media forms in the model of instruction events developed in Figure 1 leads to the model that follows.

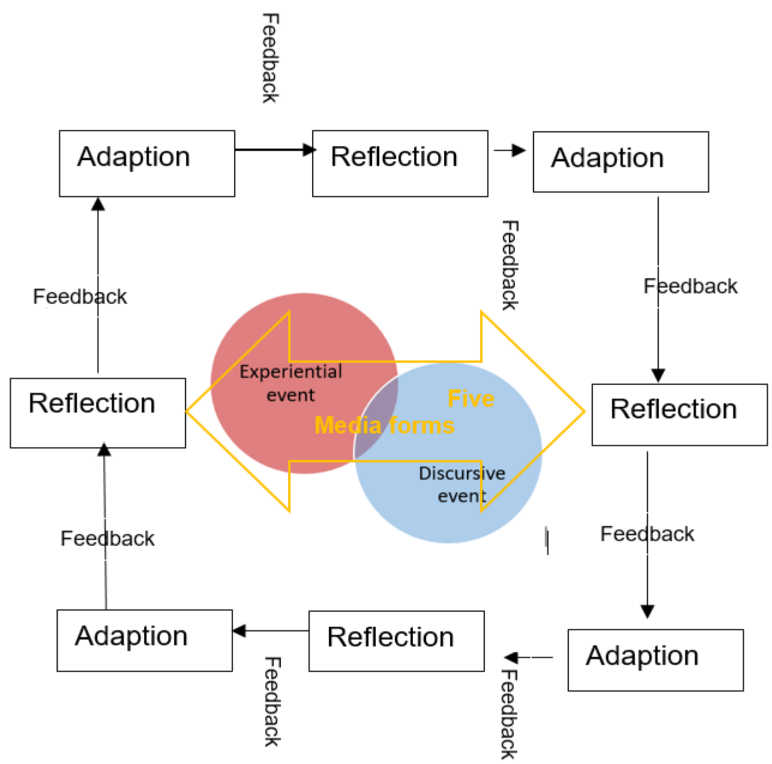


Figure 4 Instructional conversational event mediated by media

Figure 4 represents the instructional events discussed earlier with the media (representing the five media forms) at the centre. The model shows that media mediate all instructional events.

The model in Figure 3 suggested that all forms of media must be present and employed in the instructional conversation to provide learners with a full learning experience. The model placed emphasis on what learners do with media. It is, however, silent on what teachers do in the lesson to ensure that the use of media provides learners with maximum learning experiences. This study focusses on the pedagogical value of tablet technology and focusses strongly on how teachers use it to improve the teaching and learning of mathematics. With this in mind, the study also adopts the theory of meaningful learning that provides minimum control features to be used as a benchmark to evaluate whether the teacher's designed instructional conversation derived maximum learning benefits (meaningful learning). The model in Figure 3 is important as it will provide the study with the language to describe tablet technology educational applications, but the pedagogical value of tablet technology will be the possibilities this technology provides to teachers to teach for meaningful learning in the discursive and experiential instructional events.

2.7.3 Meaningful Learning Theory

Meaningful learning stems from Ausubel' s (1968) subsumption theory. In that theory, meaningful learning means that learners are able to actively integrate the new information and structures into the existing one (Novak & Cañas, 2008). Meaningful learning has been mentioned in academic literature for as long as didactics has been a subject for the study (Gadelshina, Vemury, & Attar, 2018). The literature indicates that meaningful learning results in many learning gains but the most significant ones are knowledge retention and knowledge transfer. Knowledge retention occurs when learners are able to remember the information at a later stage in life. Knowledge transfer, on the other hand, occurs when learners are able to apply knowledge to new situations and can use the knowledge acquired to solve problems (Mayer, 2002). Knowledge transfer, which is the goal, can only occur if teachers implement meaningful learning strategies. In meaningful learning environments, learners are able to discuss the information, to interpret it, to relate it to existing knowledge, and to use it to solve problems (Gadelshina et al., 2018). This means that there is a big difference between rote learning and meaningful learning. With rote learning, learners can memorise the information and recall it, but they cannot use that information when faced with a problem to solve. They cannot apply that information to new situations (Mayer, 2002).

Three conditions are necessary for meaningful learning to occur:

1. The material to be learned needs to be clear and carefully presented using language and examples relatable to the learners' prior knowledge.
2. The learners must have the relevant prior knowledge.
3. The learners must choose to learn meaningfully (Novak & Cañas, 2008)

While the first and the second conditions are closely related and centred on prior knowledge, the third condition relates to learners' autonomy in the instructional conversation as opposed to autocratic traditional teaching. Autonomy in the learning process is also an attribute of constructivism and social constructivism and an important element of the conversational framework. In view of these conditions, Clarke and Roche (2018) argued that to make mathematics lessons meaningful, teachers must capitalise on learners' needs and interests and situate mathematic tasks in real world contexts, provide more hands-on activities, develop learners' ability to think and engage, and allow learners to draw from different perspectives.

Literature presents many ways of characterising meaningful learning (Kärki et al., 2018; Saarelainen & Ruokamo, 2007; Vahtivuori, Ruokamo, Tella, & Tuovinen, 2002) but this study chooses to adopt the attributes in Saarelainen et al. (2007). This choice is because Saarelainen et al. (2007) provided an exhaustive list that integrates all the attributes from the other authors mentioned. Saarelainen et al. (2007) maintain that the teaching aimed at meaningful learning should be active, self-directed, constructive, individual, collaborative, conversational, contextual, emotionally involving, goal oriented, reflective, abstract, and multiple perspectives oriented. While it is almost impossible to have all these features in one teaching, Saarelainen et al. (2007) maintained that meaningful learning should not be seen as a process in which all 12 features must be present at all times and that these features are intertwined and overlapping. In line with Vahtivuori et al. (2002), Gadelshina et al. (2018), Kärki et al. (2018), and Saarelainen et al. (2007) meaningful learning attributes can be explained as follows:

Constructive: This means that the teacher's designed instructional conversation makes it easy for learners to assimilate new knowledge into the existing one (Saarelainen et al., 2007; Kärki et al., 2018). One can say that this attribute is based on the view of constructivism that learners are active constructors of their own knowledge as opposed to the behaviourism assumption that learners are like blank slates to be filled with the information (Berryman, 1991). The infusion of tablet technology media resources in mathematics teaching may provide learners with an interactive learning environment that is conducive for mathematical knowledge construction (Kiger, Herro, & Prunty, 2012).

Active and self-directed: This means the teacher encourages learners to take responsibility for their own learning. Teachers and learners become partners in the teaching and learning process, negotiating meanings as opposed to the traditional approach where learners are passive receivers of the information from the teacher and where the teacher acts as the sage on the stage. In active learning, learners are free to share ideas, ask questions and seek answers (Saarelainen et al., 2007; Kärki et al., 2018; Gadelshina et al., 2018). It is commonly known that learners in active learning classrooms score greater learning gains than their counterparts in traditional classrooms (Patrizia, Murdaca, & Penna, 2018; Walker et al., 2018). Active learning can be achieved through collaborative methods that give learners the opportunity to interact and work together toward a common goal (Walker et al., 2018; Eickholt, 2018) and through problem based learning (Eickholt, 2018). There seems to be an agreement in the literature that effective use of tablets in primary school mathematics promotes learners' active engagement in mathematics lessons(Hilton, 2018; Kay & Lauricella, 2018; Schuetz, Biancarosa, & Goode, 2018).

Collaborative: The teacher provides the learners with opportunities to construct knowledge collaboratively. Learning becomes a joint and social activity. In such teaching and learning environments, there is a sense of shared expertise and ongoing conversation on the content (Saarelainen et al., 2007; Gadelshina et al., 2018).

Conversational and interactive: The teacher's designed lesson is a dialogical process in which ideas are shared and discussed. The learners' input in the discussion is not only encouraged but also valued. The teacher acts as a discourse guide (Saarelainen et al., 2007).

Contextual and situational: When designing learning activities, the teacher takes into account the learning context and the environment in which the learning takes place. This makes the teacher's teaching involve authentic real world problems (Saarelainen et al., 2007).

Guided: Although learners are encouraged to take responsibility for their own learning, teachers do not withdraw the support and feedback to scaffold learning and to lead learners toward learning goals (Saarelainen et al., 2007; Kärki et al., 2018).

Individual: Individualised learning, also known in the literature as personalised learning, points to the teacher's teaching that considers the learner's learning style, interests, personality, and prior knowledge as important factors influencing how the learner constructs the knowledge (Bourkoukou, El Bachari, & El Adnani, 2016; Bourkoukou et al., 2016). Generally, it is costly and difficult to provide a personalised learning experience in a traditional classroom (Andersen, 2011; Patrizia et al., 2018). However recent studies (Andersen, 2011; Huang, Chiu, Liu, & Chen, 2011; Patrizia et al., 2018) indicated that the new technology, especially tablet technology, offers greater opportunities to achieve personalised learning. The properties that are intrinsic to tablet technology that make personalised learning possible include flexibility, accessibility, interactivity, multimedia-enriched content, note taking tools, bookmarking and repeated exposure to information and information processing (Huang et al., 2012, Patrizia et al., 2018). The interactivity features in particular allow the learner to select the content to engage with and to sequence it in order to learn at their own pace (Laurillard, 2002).

Reflective: The lesson design encourages learners to examine how well or how bad they have learned by explaining, criticising and justifying ideas and thoughts. Reflection is aimed at fostering self-assessment, which helps learners to realise their weaknesses, strengths, and potential (Gadelshina et al., 2018). Reflection is not imposed on learners but is encouraged through collaborative interactions between the teacher and learners and through carefully designed learning tasks/activities (Kostiainen et al., 2018). Reflection is an important aspect of learning because it helps to make the learning experience more meaningful and allows learners to digest what they learn (Laurillard, 2007). According to Loughran (2002, p. 35), "experience alone does not lead to learning; reflection on experience is essential". This means, having learners engaging with educational mathematics apps alone does not lead to learning but rather the reflection on what they learned from that engagement. Teachers too must reflect on their own teaching by examining their thoughts before the teaching, during the teaching and after the teaching, to uncover the difficulties learners encountered (Artzt, Armour-Thomas, Curcio, & Gurl, 2015).

Abstract: This implies learning at higher level or construction of new ideas at the abstract level (Saarelainen et al., 2007). For this to occur, as Piaget indicated, the teacher needs to support learners' learning with concrete and semi-concrete materials (Ojose, 2008). Piaget argued that learning is tailored to development (Piaget, 1964). He was of the view that individuals undergo a developmental transformation ranging from sensorimotor, preoperational, concrete, operational, and formal operational. The formal operation, which is the highest developmental stage, is referred to as abstraction. It is at this stage that, according to Piaget (1965), learners have reached the cognitive maturity and can learn abstractly. Formal learning normally starts at 11–12 years. While Piaget believed, the learner must have reached a certain developmental level to learn certain materials (Duckworth, 1964), for Vygotsky (1978), learning precedes development. Vygotsky argued that learners could learn things above their developmental level with proper mediation. In other words, a learner under the age of 11 can learn mathematical concepts at the abstract level if the teacher uses appropriate mediational tools.

Emotionally involving: This means that the lesson design includes materials and activities that ignite learners' interest, fun and motivation to learn (Saarelainen et al., 2007). Participants in the lesson share their learning experiences and feelings (Kostiainen et al., 2018). Motivation and interest are said to have a strong influence on learners' achievement in mathematics(Pinxten, Marsh, De Fraine, Van Den Noortgate, & Van Damme, 2014). Papadakis et al. (2018) indicated that learners demonstrate intrinsic motivation and interest in the learning of a subject when the instructional conversation employs active learning strategies. Many studies (Attard & Curry, 2012; Calder & Murphy, 2018; Fokides, 2018; Hilton, 2018) also found that the motivation and interest to learn are even greater when active learning is embedded in tablets interactive resources.

Multiple perspectives: The lesson seeks to make learners aware of different perspectives. Transferability is often promoted through discussions of the content in the instructional conversation (Saarelainen et al., 2007).

Goal oriented: Learners work toward achieving a specific learning goal. They set their own expectations for active learning (Kostiainen et al., 2018).

Based on different theories explored in this chapter, the conceptual framework depicted in Figure 5 is schematised.

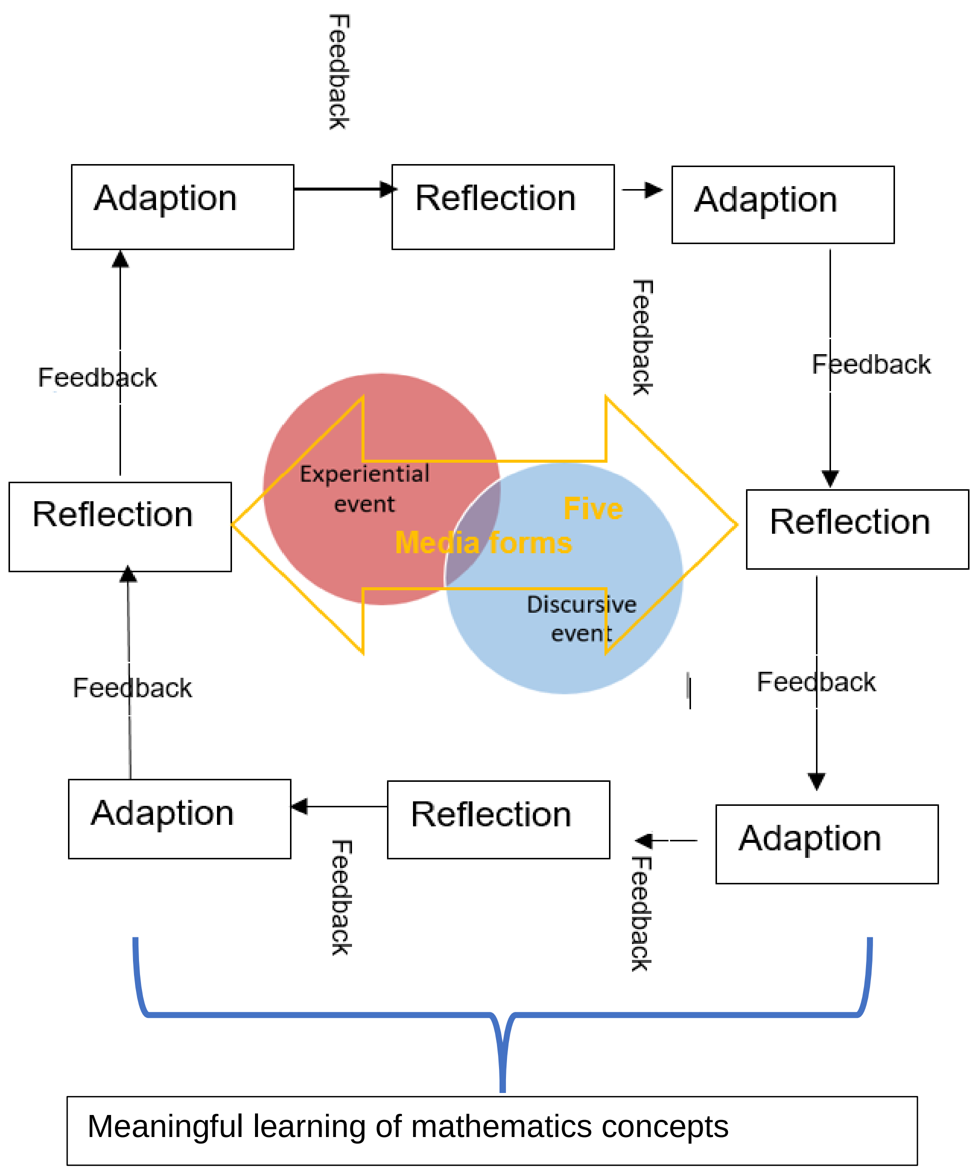


Figure 5 Diagrammatical representation of the conceptual framework

The conceptual framework above has seven major constructs which are: the **discursive event** and the **experiential event** (two events are intertwined), mediated by **five media forms**, **feedback, reflection, and adaptation**. These constructs are used in the present study to mean the following.

1. **Five media forms:** These are narrative media, interactive media, communicative media, adaptive media and productive media which should be used to mediate the understanding of mathematics concepts. Their meaning was provided in Section 2.7.2.2.

2. **The discursive event**: includes iterative and interactive activities by the teacher and the learners aimed at describing and explaining mathematical concepts and ideas. The teacher leads the discussion toward the understanding of the topic description. This should take a narrative form.

3. **The experiential event**: includes opportunities provided by teachers for learners to practice the mathematical theories that have been taught at the discursive level. This can be done either in groups, in pairs (social construction) or individually. At the experiential level, learners get some autonomy and work independently under the guidance of the teacher. What happens at the discursive event affects the experiential event and vice-versa.

4. **The feedback**: the participants in the instructional events must receive ongoing constructive feedback on their mathematics actions. This feedback may come from the teacher or from the peers. The feedback can also come from the adaptive media when the student engages with the mathematics activities these media provide.

5. **Reflection:** the feedback is meant to allow learners to know whether they are in the right path to achieving the learning goals. It must allow them to identify the gaps in their learning and to take appropriate actions. The same applies to teachers too. It should allow teachers to know whether the teaching strategies and the instructional media they are using are helping learners to achieve learning goals. It should give them an idea of appropriate actions to take thereof.

6. **Adaptation:** Reflection on goals must lead to adaption of mathematics actions and the conceptual understanding by the learner. It should also lead the adaptation of the teaching strategies and teaching media on the part of the teacher. The teacher can adapt the discussion based on the feedback received at the experiential level. The teacher can also adjust the experiential level based on the feedback received at the discursive level. The Feedback-Reflection- Adaptation cycle, supported by media is important to meaningful learning of mathematics concepts.

7. **Meaningful learning**: the features above should aim to provide learners with meaningful learning experiences. Meaningful learning is goal oriented, constructive, active and self-directed, collaborative, conversational and interactive, guided, individual, abstract, emotionally involving (focussing on learners' interest), and multiple perspectives. The literature reviewed indicated that not all these meaningful learning features must be present for the teaching to lead to meaningful learning. In the context of this study, meaningful learning is said to happen when the discursive and experiential events are goal oriented and link to one another, when learners are involved in the instructional events individually and/or collaboratively, when ongoing feedback is provided, and when the instructional conversation uses a variety of media to provide learners with multiple perspectives to link mathematics concepts, when the experiential task involves higher order learning (abstract learning) as opposed to drill and practice, and when the participants reflect and adapt their actions as they participate in instructional mathematics conversation.

2.8 Chapter Summary

This chapter explored the literature relating to the use of technology in mathematics with a special focus on tablet technology. It started with a critical analysis of the important value placed no mathematics subject, and this allowed explaining why there has been an increasing interest in the use of tablet technology in mathematics teaching.

The chapter highlighted the features that are intrinsic to tablet technology to promote the development of mathematics knowledge and skills. While doing so, the chapter explored the challenges relating to the use tablets in mathematics teaching.

The chapter explored existing studies relating to the use of tablet technology in mathematics teaching. This helped to identify the research gaps the current study attempted to cover. The review of the related work showed that simply providing teachers with tablet technology may not translate into its effective use in the classroom, unless teachers believe in the potential of technology to improve teaching and learning and have the relevant knowledge of how to use it in their teaching.

The chapter explored different learning theories underpinning the use of tablet technology in mathematics teaching and learning. These include constructivism, social constructivism and meaningful learning theories. It also explored the conversational framework that gives guidelines on how tablet technology should be used in mathematics lesson to achieve instructional goals. The analysis of these theories and frameworks allowed developing a conceptual framework for this study. The next chapter provides a detailed account of the research methodology, the research paradigm and the research design that were followed to collect the data that closed the research gaps identified in this chapter.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This study sought to explore the pedagogical value of tablet technology in the teaching of sixth grade mathematics in South African township schools. The study was guided by the following three research questions:

1. What are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics?
2. How are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics translated into pedagogical actions in the actual teaching of sixth grade mathematics?
3. What challenges impact teachers' use of tablet technology in the teaching of sixth grade mathematics?

This chapter outlines the research methodology that guided this study. To do so, it starts with a description of the research paradigm, the research design, and the informants. It proceeds to explain the data collection procedures and instruments that were employed, data analysis and interpretation procedures followed, and issues of trustworthiness and ethical consideration the researcher took into account during the study.

3.2 Research Paradigm

The positivism research paradigm and interpretive research paradigm are often used in educational research (Aliyu, Bello, Kasim, & Martin, 2014; McMillan & Schumacher, 2014). On the one hand, positivism uses the discourse of the existence of a single stable reality (ontology) and the use of scientific methods such as hypothesis testing and controlled trials as the only epistemological processes accepted to objectively generate knowledge about reality(Aliyu et al., 2014; Kaboub, 2008). It links to quantitative research methods in which data collected are often numerical and analysed statistically, and this is done in an effort to minimise researchers' bias. It assumes that if different researchers in different corners of the world and at different points in time worked on the same experiment with the same statistical analysis, the results would always be the same (McMillan & Schumacher, 2014). Interpretivism, on the other hand, uses the discourse of multiple socially constructed realities to speak about the research process(O'donoghue, 2007). It suggests that individuals actively construct their own realities of the world, individually and collaboratively, through participation in socially organised activities and situations (McMillan & Schumacher, 2014). It links to qualitative research in which, to study the social realities, researchers are compelled to immerse themselves in the lives of the research participants and in the natural settings where such realities are constructed (O'Donoghue, 2007). The data collected are predominantly narrative descriptions of social realities and researchers use their professional judgements and perspectives to give the data meaning (McMillan & Schumacher, 2014). This means different researchers studying the same natural phenomenon in its natural setting can come up with different interpretations based on the theoretical frameworks they use as lenses to view the phenomenon, the academic disciplines they are coming from (education, sociology, anthropology etc.) and their own background (O'Donoghue, 2007). This explains the complexities and the richness of research in the interpretive terrain. Interpretive researchers have a number of rules and protocols, such as the use of research questions, the use of a theory or conceptual framework, in-depth exploration of the social phenomenon, and triangulation procedures, to follow to ensure that the quality and the rigour of their research process are not distorted (McMillan & Schumacher, 2014).

A research paradigm should be chosen based on its appropriateness and its effectiveness in relation to the hypothesis or the research questions the research seeks to answer (McMillan & Schumacher, 2014). Some studies may land themselves in the positivist terrain while others may land in the interpretive terrain. You would not for example use the positivist paradigm to study the lived experience of teachers in a multilingual classroom. In carrying out that research, you might need to follow teachers in the classroom setting and directly observe what they do , to share the struggles and challenges they encounter, and then arrive at a fuller understanding of what it is like for them to teach in that environment.

In view of the aforementioned, this study sought to understand the value of tablet technology from the perspectives of teachers, the classroom practices when they teach with tablet technology, and how they interpret the e-Education policy in their teaching. The information that was required to fulfil this research ambition was embodied in the feelings, experiences, practices and beliefs of teachers, and it could only be accessed through immersion in their lives. In addition, teaching with tablet technology is a social practice involving the interaction between the knower (the teacher) and the less knowledgeable (the learner), and this makes the interpretive paradigm the best fit for this study because it allows for direct exploration of the social practice in the classroom setting. I spent four weeks interacting with the informants in the classroom settings in order to develop my own understanding of their experience of teaching with tablet technology. Prolonged interactions with the informants in the classrooms helped to build some level of mutual trust, which then encouraged them to open up and to share their perspectives about the value of tablet technology in their teaching and the perspectives behind the practices they enacted in the actual teaching.

3.3 Research Design

In Chapter 1 it was made clear that the use of tablet technology in township schools in South Africa is very new and under-researched. Therefore, this study was an exploratory and discovery oriented research that examined the use of tablet technology in township schools. This research also had the opportunity to help participants better understand their practices and to develop a model for optimising the benefits of tablet technology in their schools. Therefore, I used the case study design (Yin, 2014a) to develop a holistic understanding of the use of tablet technology and its pedagogical value in township schools. The case study design was chosen because of its potential to provide the researcher with an opportunity to do an in-depth study of the phenomenon under investigation within its context (McMillan & Schumacher, 2014). The case study design was also chosen in a pragmatic effort to capture large amounts of data with a small number of informants, and the opportunity it offered to use multiple data collection methods, thereby making the triangulation of data possible (Yin, 2016). There are usually only a few informants in a case study to allow in-depth investigation (McMillan & Schumacher, 2014). Employing the case study design allowed me to document narrative descriptions in the informants' own voices. It also allowed me to examine their perceptions and the classroom practices they enacted in order to give the reader a holistic understanding of what the use of tablet technology is like in the studied schools and to judge whether there are compelling benefits to using tablet technology in mathematics teaching.

The study chose to focus on sixth grade mathematics because of ongoing public concerns about the quality of teaching mathematics at this grade level. In this regard, the study sought to know if the use of tablet technology offers the promise to improve teaching and learning of mathematics at sixth grade level. There are many township schools in the country that are currently using tablet technology, but this study singled out two township schools (School A and School B) in Gauteng. These were selected based on their unique characteristics. They are located in Gauteng where there are more likely to be teachers with the relevant pedagogical content knowledge. It was important for the study to have teachers who did not have knowledge gaps in the content and pedagogy. Teachers from both schools had received training on how to use tablet technology in the classroom through in-service teacher development programs. In other words, the study assumed that the teaching staff in both schools had the relevant technological knowledge to teach with tablet technology, which was going to make them feel confident when visited in the classroom. Schools A and B were also among the first township schools in the country to start using tablet technology in the classroom. Both schools started using tablet technology in 2011, so it could be assumed that they were more experienced in the use of tablet technology in classroom instruction compared to other township schools that have recently integrated tablets as part of the Gauteng paperless classroom project. In addition, there were testimonies in the media that both schools were doing well with technology, and both schools had appeared in the media and claimed that the use of tablet technology had improved teaching and learning, including teaching and learning of numeracy and literacy. All these characteristics were parameters that set the two schools apart and allowed me to see them as bounded systems of special interest and deserving to be studied in their own right.

3.4 Informant Selection

As explained above, the informants in a case study are very few to allow in-depth investigation (McMillan & Schumacher, 2014). In this regard, the current study had five informants who were selected intentionally and purposively (Creswell, 2012; McMillan & Schumacher, 2014). Four were female and one male. Jabulani and Sandra were ICT coordinators and heads of division. In South Africa, ICT coordinators are expected to promote the use of technology in the curriculum to model the effective use of technology in the classroom and to provide technical support to teachers (Tondeur, Van Braak, & Valcke, 2007). Jabulani and Sandra were selected for the study because of their positions with the belief that they would be exemplary in the use tablet technology in schools and able to share with ease the lived experiences of using tablet technology in their teaching. In addition, because they were the ICT coordinators, they would be able to provide a fuller picture of the use of tablet technology in their schools. Sandra won the iTeacher award, which is awarded by iSchool Africa to teachers who demonstrate innovative use of tablet technology in classroom teaching. She was selected to participate in this study in order to share her innovative use of tablet technology, and opportunities and struggles she encounter as she strives to use this technology innovatively in her classroom. Before the study started, I learned through informal channels that learners' performance in mathematics in Samantha's, Sabina's and Seraphina's classes improved steadily after they started using tablet technology in their teaching. Therefore, it was in the best interest of the study to involve them in order to hear from them how the use of tablet technology has contributed to better teaching and learning of sixth grade mathematics. The informants' teaching experience varied between 10 and 30 years. They all had been teaching with tablet technology for the past six years.

3.5 Data Collection Instruments

Case study research uses multiple data sources for the extensive collection of evidence in order to gain a deeper understanding of the phenomenon under investigation (McMillan & Schumacher, 2014). This study used classroom observations, interviews and documentary review to collect data. These instruments were nested in the interpretive paradigm and aligned with the qualitative case study design (McMillan & Schumacher, 2014). Having adopted the interpretive paradigm meant that it was important for this study to explore the phenomenon of teaching with tablet technology from teachers who have lived it, and most importantly, to hear their views of how they experienced this phenomenon. The interview was considered the most appropriate tool to do this as it allowed capturing teachers' voices through one-on-one conversations. It was also important to examine how teachers' perceptions were translated into pedagogical actions in actual teaching. Non-participant observation was considered the most appropriate data collection tool to cover this aspect, because it allowed for direct exploration of the phenomenon of teaching mathematics with tablet technology in the actual teaching. In situations where teachers' perceptions did not align with the practices they enacted in the actual lessons, teachers were asked to provide reasons for these differences. It was also important to examine the actual teaching against other important documents in the classroom such as learners' work completed on tablets and the teachers' lesson plan. This occurred through document analysis. The data generated from these sources helped me to arrive at a holistic understanding of the pedagogical value of tablet technology in the studied schools and the disparities between policy and practice. The data collection tools are further explained in the sections below.

3.5.1 Interviews

Interviews were the most used to capture teachers' perspectives about the use of tablet technology in their teaching. The interviews preceded classroom observations in an effort to allow examining how teachers' perceptions were enacted in the actual lessons. The interview with each informant lasted one hour. The interview schedule consisted of 24 question items. These were developed from the research questions. They were designed to capture information on the background of the teachers, their experience of teaching mathematics prior to the introduction of tablet technology in their schools and their experience of teaching mathematics after the introduction of technology in their schools. It also captured the pedagogical shifts that followed the use of technology in their teaching, the availability of professional development programs on the use of technology, the teachers' understanding of the ICT policies and how they translate them into pedagogical actions in their teaching, the challenges they encounter, etc. Teachers were encouraged to suggest the date, the venue and the time that were convenient for them to be interviewed. This was done in order to avoid any disruptions to their teaching timetable. All teachers chose to have the interview after school hours. During the interview, I listened carefully as teachers narrated their lived experiences; I asked probing questions to encourage teachers to provide in-depth information. I also carefully watched the teachers' body language while they talked, as this became an additional source of information to confirm or contradict the information that the informants shared. With permission from the teachers, the interviews were audiotaped so that no information would be lost while trying to write down the information they shared.

3.5.2 Non-participant observation

Observation as a data collection method allows the researcher to collect live data from natural settings (Cohen & Morrison, 2011). In other words, through observation the researcher has first-hand experience of the phenomenon. In this study, teacher participants were visited in the classroom for four consecutive weeks to observe how they taught with tablet technology. The purpose of the observation was to understand what teachers really do when they teach with tablet technology and to distil from observed practice the value tablet technology adds to teaching and learning of sixth grade mathematical concepts. My role was that of a nonparticipant observer. That means, I did not participate in any classroom activity or offer suggestions about how to teach with tablet technology. That type of observation allowed me to capture the classroom events as they happened. I believe that if I acted as a participant observer, I might have affected how teachers used tablets in their teaching and influenced the credibility of the study findings.

The observations took place in two phases. The first phase consisted of observations of informal lessons. Informal observations were requested by teacher participants in order to familiarise the learners with the researcher. This also helped to minimise the 'halo effect' that suggests that having a visitor in the classroom may trigger tensions and anxiety in the classroom causing the participants in the classroom to behave differently (Patton, 1999). The halo effect also suggests that when participants are aware that they are being observed, they may fake their behaviours to exhibit the behaviours they think the researcher wants (Patton, 1999). Four full days were spent in each classroom in order to get to know one another, and this made it unnecessary for the participants to fake their behaviours. Research participants requested that the informal lessons not be recorded or used for the purpose of this study. Their request was respected.

The second phase consisted of the observation of formal lessons. This took place when teachers felt they were ready to be observed formally. Five formal lessons in total were observed, one in School A (there was only one participant in School A) and four in School B, where there were four participants. With permission from the participants, all formal lesson observations were videotaped in order to make the classroom experience visible and to capture teachers' actions as they taught with tablet technology. The camera was placed at the back of the classroom so that it did not disrupt the learners. Videotaping allowed capturing nonverbal cues such as gestures, facial expressions, body movements, eye contact, and tone of voice. Bunglowala and Bunglowala (2015) asserted that 93% of human communication is nonverbal. Hence, there was a risk of losing a great deal of information if lessons were not videotaped. In addition, videotaping helped to ensure a thorough and rigorous data analysis as the video could be replayed several times, stopping where necessary to understand what was happening in the classroom.

3.5.3 Document Analysis

Document analysis is "a systematic procedure for reviewing or evaluating documents both printed and electronic (computer-based and Internet-transmitted) material" (Bowen, 2009, p. 27) in order to get more insights into the phenomenon being studied (O'Donoghue, 2007). This study reviewed the work learners completed with tablets during the classroom observations, and then compared it with the practices teachers enacted in the classroom and with self-reported views about the value of tablet technology in their teaching. Lessons plans were also collected from teachers and analysed. Two teachers only had lesson plans; Jabulani and Sandra. The data from these lesson plans were used sparingly for triangulation purpose.

3.5.4 Data Analysis and Interpretation

Data analysis is a process of “ taking the data apart” (Creswell, 2012, p. 10) and placing it in order to discern meanings and patterns. During the process of analysing data, the researcher breaks the data into bits to see how concepts interconnect, and this allows the researcher to classify, describe, interpret, explain, and understand the phenomenon or the event the data refers to. Data analysis is a crucial process as it compels researchers to go beyond their first impressions of the data in order to try and give the data meaning (Dey, 2003; Stake, 1995; Yin, 2014b).

In this study, the process of data analysis started concurrently with data collection. A descriptive coding (Bowen, 2009) using the analytical conceptual framework presented in Chapter Two was used when taking field notes in order to make meaning of the classroom observations and the teachers’ interviews. This helped to stay focussed. It also helped in generating codes that were used once the data collection process was completed. The paragraphs that follow describe how data obtained from each data collection method were analysed.

Each individual interview was transcribed a few hours after the interview. While transcribing, the New Comment tool under the Review tab in MS word was used to log all the codes and meaningful insights that were emerging. After transcription, all interview responses were organised according to the interview questions they related to. Then, organised responses were examined thoroughly, new codes and insights were generated and added to the ones that emerged when transcribing. The conceptual framework was used to sieve the codes and to tease out those that referred to the constructs of the conceptual framework. These constructs informed the major themes the study used to represent the pedagogical value of tablet technology. The conceptual framework reduced the pedagogical value of tablet technology in sixth grade mathematics to meaningful learning experiences learners are provided with when this technology is used in the classroom to mediate teaching and learning. A considerable number of quotes representing the voices of teachers were selected from the transcripts and used in the data presentation chapter to give the reader a sense of how the participants perceive the value of tablet technology in their teaching.

Recorded videos of the instructional events were also transcribed. After transcription, a thematic analysis followed in order to generate codes that represented the approaches teachers used in their lessons and the value tablet technology added to teachers' teaching. The codes generated were then organised based on concepts from the conceptual framework; the discursive and the experimental events in particular, which were identified as the two major teaching events of the instructional conversation. The same process was followed to analyse the notes that were taken during lesson observations.

The work learners completed on tablets was compared and contrasted with the findings from the interviews and classroom observations. The analysis of the documents involved skimming, reading and interpretation (Bowen, 2009).

3.6 Trustworthiness

An important point to remember about qualitative research is that it expects researchers to use their subjective interpretation of the phenomenon investigated. This often raises the issue of trustworthiness and this is seen as a drawback by positivist researchers. In this study, a number of protocols (Forchuk & Roberts, 1993; Guba, 1981; Shenton, 2004; Yin, 2014) were used to minimise the level of subjectivity and to ensure that the research findings are trustworthy. These are explained below.

The selection of the research sites and the informants was purposeful to comply with the investigated phenomenon of the use of tablet technology in sixth grade mathematics in townships schools. This ensured that the study was located in a data-rich context.

Participation was voluntary in order to have only those teachers who were willing to provide the information freely. Participants were encouraged to be frank at the beginning and were guaranteed of the anonymity of the data they provided.

I familiarised myself with the research participants before the actual data collection process. This allowed me to gain their trust and acceptance, and it encouraged them to act confidently and speak openly during data collection. The teachers negotiated an agreement before the actual data collection that the school would receive the final product of the study. This served as a token of their participation in the study. It was a sign that the participants wanted to learn from the findings of the study and a guarantee that they would not hesitate to disclose the information that was going to help to improve the use of tablet technology in the school.

All lessons were video recorded and this allowed for thorough and rigorous data analysis. The video was played several times to gain more insight. The data were also collected using multiple data collection methods that included interviews, lesson observations and document analysis to ensure the trustworthiness of the findings through data triangulation.

The interview transcripts were sent to the participants for verification of content. The participants were requested to rewrite, clarify and make notes on the transcripts if further clarification was needed. This helped to strengthen data accuracy. The input from other PhD students, my PhD supervisor and different experts I met at conferences where I presented papers assisted to refine my interpretations of the phenomenon.

3.7 Ethical Consideration

The study involved the use of human beings; hence, ethical protocols were followed to protect the rights and welfare of the participants. As Miles, Huberman, and Saldana (2014) stated:

> We cannot focus only on the quality of the knowledge we are producing, as if its truth were all that counts. We must also consider the potential 'wrongness'" of our actions as qualitative researchers in relation to the people whose lives we are studying, to our colleagues, and to those who sponsor our work. All research must be guided by the classic principle of humane conduct: First, do no harm. (Miles, Huberman, & Saldana, 2014, p. 56)

In view of the above, permission to conduct the study was sought from the Gauteng Department of Education and the school administration. The University of the Witwatersrand also issued the research ethics clearance before I went to schools to collect data. The university ethics committee ensured that my research would not infringe the rights of the participants.

The research participants were guaranteed that they would not be harmed or disadvantaged in any way by participating in the study or by opting to withdraw from participation at any stage during the course of the study.

All participants were informed at the beginning of the data collection process of the purpose of the study. Participation in the study was voluntary. Research participants were informed of their right to withdraw from the study at any time. They were given consent forms to confirm or decline their participation in this study. Sixth grade learners do not have the majority age; therefore, they needed their parents' consent. The consent forms were sent to their parents to grant or decline permission to observe their children in the classroom. Learners whose parents did not allow their children to be observed sat in unobserved rows in the classroom.

Confidentiality and anonymity were ensured by using pseudonyms instead of participants' real names in my research writing. In addition, whenever it was necessary to embed pictures in the research report to illuminate the findings, the faces of the participants were blurred or cut off.

In order to minimise inconveniencing participants, interviews were conducted at times, dates and venues preferred by the participants. Permission to record the interviews and to video record the instructional events was sought. Videotapes were kept in a safe place so that they were not accessible to any other person. After completion of the project, raw data went to the supervisor and will be destroyed within 3–5 years of completing the study. The final report was submitted to the University of The Witwatersrand, the Faculty of Humanities and will only be used for academic purposes.

3.8 Chapter Summary

In this chapter I provided a detailed account of the research methodology that guided the collection and the analysis and interpretation of the data of the current qualitative study. I provided the justification for the choice of the research paradigm, the research design, methods, data collection instruments and analysis approaches that I considered more appropriate. I also explained how the issues of trustworthiness and ethical considerations were dealt with. The next chapter provides the analysis and interpretation of the data that were collected using the methodology described in this chapter.

CHAPTER FOUR: DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter presents the findings that emerged from the examination of sixth grade mathematics teachers who used various educational applications to teach different topics that included shapes, fractions, and addition and subtraction of ordinal numbers. Data were collected using a variety of tools: Interviews, lesson observations, field notes and review of documents (learners' work completed on tablets). I examined teachers' classroom practices, focussing on events marked by the conversational framework.

This chapter starts with describing the study setting, then the findings resulting from the interviews with teachers. These findings are organised around three major themes that emerged from the analysis of the interview data: Tablet Media and meaningful teaching of mathematics concepts, Tablet media and teacher mediation and Tablet media and teachers' professional growth. Then the findings from the lesson observations are presented. These are organised around the instructional events of an instructional conversation targeted in this study: The discursive mathematics event and the experiential mathematics event. The theme of "The challenges impacting teachers' use of tablets" was used to analyse all the data from interviews and lesson observations that related to the challenges teacher participants are facing as they attempt to teach mathematics meaningfully using tablets. While presenting these findings, each teacher is regarded as a unique case. The data resulting from the analysis of documents will be used sparingly along these themes for triangulation purpose.

4.2 The Study Setting

The study setting consisted of two township schools in Gauteng Province, School A and School B that are using tablets in mathematics teaching. Both schools are serving low-income communities, and because of this, they have been designated as no-fee schools. Like most schools in this category, Schools A and B completely rely on government funding (Sayed & Motala, 2012). Use of tablet technology in both schools started in 2011.

4.2.1 School A

School A is a township school in the Gauteng Province. The majority of learners in the school are from working class families and of African descent. The school has about 800 learners enrolled from Grade R to Grade 7. All the school buildings are permanent structures made of bricks and mortar. The buildings are old as they were inherited from the apartheid regime. Classrooms are overcrowded. The average learner to teacher ratio is about 43:1. Overcrowding is due to an increase in learners' enrolment that has not been accompanied by the supply of additional classroom buildings. Since 2011, the year the school started using tablet technology; learner enrolment has increased by 52%.

Electricity and running water are available in the school. However, the school has no alternative source of power, but power outages do not affect teaching and learning because in most classrooms teachers are still using chalkboards.

The technology infrastructure includes two telephone lines, one in the principal's office and the other at the reception desk. Both lines are currently working satisfactorily. There are two photocopying machines in the school with printing and scanning capability. These are used for the production of examination papers and teaching materials like posters, charts, labels and worksheets. The school used to have Wi-Fi connectivity in the administrative building but it is no longer working as some of the Wi-Fi infrastructure has been removed.

At this school, sixth grade learners have access to tablet technology donated by an anonymous sponsor who identified the school through a nearby high school. The school received five mobile laboratories containing 10 tablet devices each. The devices rotate between classrooms using a booking system. There is a timetable in the administration office indicating the lesson periods and classes that would be using tablets. The sponsor also provided a mobile projector that the school also manages using a booking system.

Tablets came loaded with mathematics and English educational applications. The sponsor targeted improvement in numeracy and literacy of Grade 3 and 6 learners. The applications include, but are not limited to, game-based learning applications, the dictionary and interactive manipulatives. The school has no library, and therefore, tablets, learners' textbooks and the DBE books are the main sources teachers and learners use to access information. At the beginning of the project, the sponsor provided a mobile Wi-Fi rooter that allowed teachers and learners to connect to various educational resources but he repossessed the rooter when his contract terminated in 2015. Since then the school has not been able to provide teachers and learners with internet connectivity.

4.2.2 School B

School B is also a non-fee-paying school in the same township. The distance between School A and School B is approximately one kilometre. Just like School A, School B is serving learners from working class families and of African descent. The school has about 1 200 learners enrolled from Grade R to Grade 7. The school buildings are newly refurbished permanent structures made of bricks and mortar. The classrooms are overcrowded due to increased enrolment. The average learner to teacher ratio is about 43:1. The overcrowding is also due to the increase in enrolment that was not accompanied by the supply of additional physical infrastructure. The research participants indicated that the school has the capacity to cater for 500 learners but currently has 1 200 learners.

The school's technological infrastructure includes two telephone lines, one at the reception and another one in the principal's office. There is a Gauteng Online Computer Laboratory but it is no longer functioning. There are four printers in the print room that used for the production of exam papers and teaching materials like posters, charts and labels. There is no Internet in the school.

In the classroom, teachers and learners have access to tablets that the school received from the same sponsor who donated to School A. The school received five suitcases, consisting of 10 tablet devices each. The devices are managed using a booking system. The devices came loaded with teaching materials aimed at enhancing teaching and learning of English and mathematics. They also came with a projector that rotates between classrooms together with the tablets. The sponsor provided Wi-Fi connectivity at the inception of the project but he took the rooter when his contract with the school expired in 2015. Since then the school has not been able to revitalise the internet connectivity. The school does not have a library.

In conclusion, Schools A and B have almost similar conditions.

4.3 Findings from Interviews

Close reading of the interview transcripts revealed three major themes that best represent teachers' perceptions of the pedagogical value of tablet technology in the teaching of Grade 6 mathematics in the studied schools:

1. Tablet Media and Meaningful Teaching of mathematics concepts
2. Tablet Media and Teacher Mediation
3. Tablet Media and Teachers' professional growth

These themes are discussed below:

4.3.1 Tablet Media and Meaningful Teaching of mathematics concepts

Tablet Media and Meaningful Teaching of mathematics concepts theme refers to teachers' perceptions of the value of tablets to provide access to various forms of media including narrative media, interactive media, adaptive media, and productive media and the use of these forms of media to teach for meaningful learning. That is the teaching that involves presenting mathematics concepts using multiple presentational materials and examples relatable to the learners' world of experience. It is also the teaching that capitalise on learners' experience in instructional mathematics events. Under this theme we will discuss how the use of adaptive media has affected learners' attitude towards mathematics and how it has increased their engagement in mathematics discourse. Before engaging in deep discussion of the analysis of these themes it is worth giving the reader an overview of the e-resources teachers and learners had on their tablets at the time of the school visit. This will allow the reader to easily follow the presentation in this chapter as we further analyse teachers' perceptions of the value of tablet technology using the concepts from the conceptual framework of the study.

4.3.1.1 e-Resources loaded on tablets

A close look at tablet devices the teachers and learners were using showed that the devices were loaded with digital mathematics content that embedded the text, pictures, audio, hyperlinks and videos in the form of simulations and games, thus, allowing teachers to teach mathematics concepts using multiple representations. The devices had productivity applications such as Chalk application that learners used to create their own knowledge and to express their understanding of mathematics concepts. Educational mathematics games were also used to enhance the understanding of concepts and to engage learners with the content.

a) Chalk application

Chalk application was a productivity application that was used in School A to teach fractions and in School B to teach shapes. It allowed learners in School A to create their own fraction models to demonstrate higher-level understanding of the concepts taught. Figure 6 is an example of the fraction model a learner in School A constructed using the Chalk application. In School B, learners used it to draw shapes and to annotate them in order to explain their properties. A close look at this application showed that it has an intuitive interface that allowed learners to turn the tablet into a chalkboard for them to write, sketch or draw. It also allowed learners to pick colours and to use them in their presentations. Although it was not used in any of the lessons, the Chalk application also has a feature that allows the user to add voices, text, audio, video, images and graphics from other files.

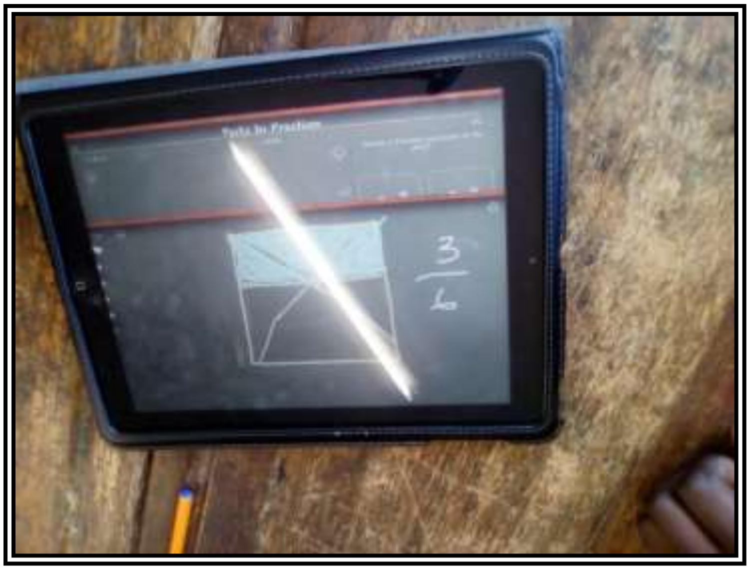


Figure 6 Learners constructed their own fractions models using the Chalk application

b) Fun Math

Fun Math was an interactive game-based learning application that, according to the teachers, allowed learners to develop their numeracy skills while having fun. A thorough examination of this application showed that it covered quite a number of mathematical topics including fractions, addition, subtraction, division, multiplication and geometry. Just like Math Bingo, Fun Math has different difficulty levels to match the learner's skill and knowledge. During the Fun Math activity in both schools, learners were presented with questions and different possible answers to choose from. They were required to work out answers before choosing the right answers from the many possible answers provided. During the activity, the application provided learners feedback when choosing the answer and then asked learners to shake the device to continue to the next question. Unless the learner shook the device, a new question was not given. This is probably was what made the game fun for learners, especially those inclined to kinaesthetic learning. Arguably, the game enhanced learners' understanding of concepts through practice, fun and prompt feedback. Because of the fun, learners learned the content without realising it.

c) Bubble Pop Math Challenge

In the Bubble Pop Math educational game, learners competed to solve mathematical challenges by bursting bubbles that showed the correct answers before they smashed into the pond. The game had eight levels that became more difficult as the learner moved from the lower to the higher level. The games included activities on number recognition, multiplication, division, and fractions. Teachers believed that if learners worked with these applications and interacted with their peers in the classroom, they developed a deep understanding of mathematical concepts and ideas. Bubble Math allowed learners to practice mathematics skills while having fun. Arguably, it trained them to solve mathematical problems in a very short time. They had less than two minutes to choose the right answer otherwise the bubble representing the right answer smashed into the pond.

The educational applications discussed above were used in all the observed lessons to achieve different teaching and learning goals. In Sandra's class, learners started with a Math Bingo game on addition and subtraction; learners used the Fun Math application if they did not have Math Bingo on their tablets. Sandra believed learners' minds were awakened because they started with something they liked. The lesson ended with a Bingo game on geometry to practice the topic of shapes and figures she had just taught. In other classes, Bubble Pop Math and Fun Math games were played at the end of the lesson to practice the topic of fractions.

In all the classrooms, there were interactive discussions among learners while the games were being played. There was also much competition between groups of learners as every group strived to win the game in a very short time. The games provided hints in case the learner had tried several times but still got the answer wrong. The games also provided prompt feedback: If the answer was correct, learners received a popup message reading, "That's correct", and if the answer was wrong, they received a popup message reading "incorrect". This feedback was significant because it provided learners with opportunities to evaluate their own progress without waiting for the teacher to mark their work. This was especially important in big classes where it was difficult for the teacher to attend to each individual learner. Each group created a profile that allowed them to save their work, to start from where they stopped last time, and for the teacher to check each group's progress.

Learners' scores on the educational games were quite good. They ranged between 65% and 100%. However, it would be an illusion to take the performance on educational games as an indication of how well learners learned or understood the concepts. There were no opportunities for learners to describe qualitatively what they learned from the educational games and how it affected their understanding. The discursive aspect could possibly have revealed the level of learners' understanding and the learning gaps. Many learners were observed guessing answers instead of working them out. It could therefore be that they were acquainted with drilling those activities to the extent that they could just choose answers without necessarily understanding computational algorithms involved or without being able to apply them correctly.

Figure 7 is an example of activities learners were engaged in. They received instant feedback every time they selected an answer. Figure 8 shows the kind of feedback learners received.

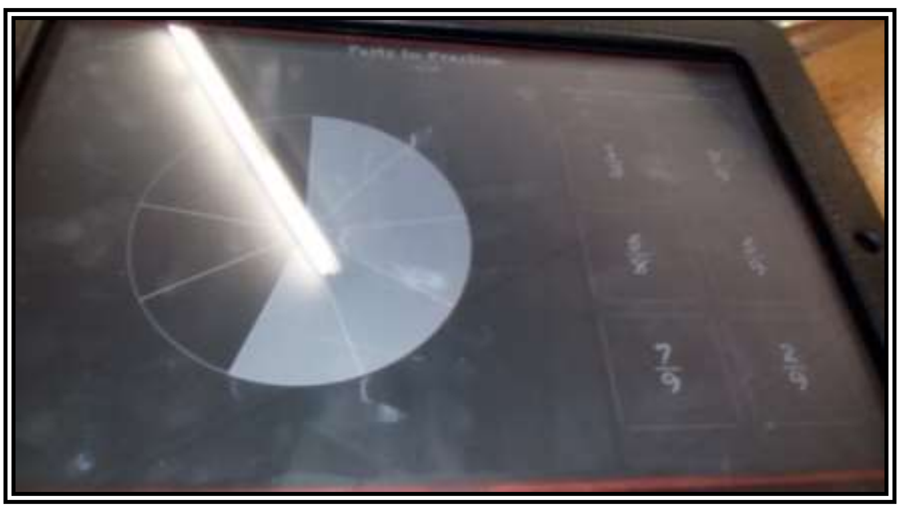


Figure 7 Example of a multiple choice activity on Fractions

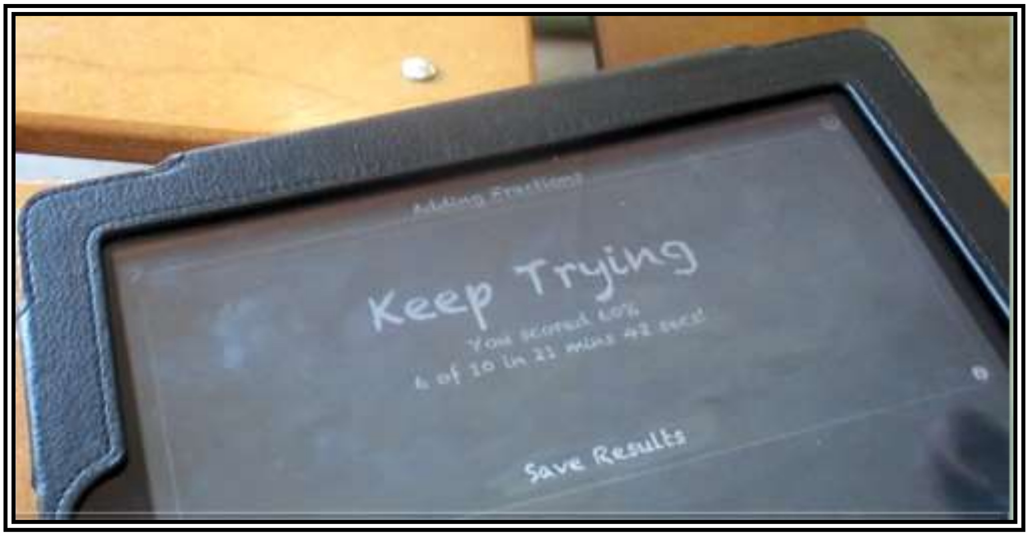


Figure 8 Learners received prompt feedback

The section that follows presents teachers' perceptions of how the applications above and other e-resources available on the school tablets have turned the teaching of mathematics around, promoting a shift from abstract teaching to meaningful teaching of mathematics concepts. While presenting the data on teachers' perceptions, tablet media will be categorised using the concepts from the conceptual framework of the current study. Learning experiences they are believed to support will also be provided. Four sub-themes will be used in this regard: narrative and interactive media, adaptive media, and productive and communicative media.

4.3.1.2 Narrative and Interactive media

The research participants had considerable teaching experience ranging from 10 to 30 between them. Their experience is shown in Figure 8.

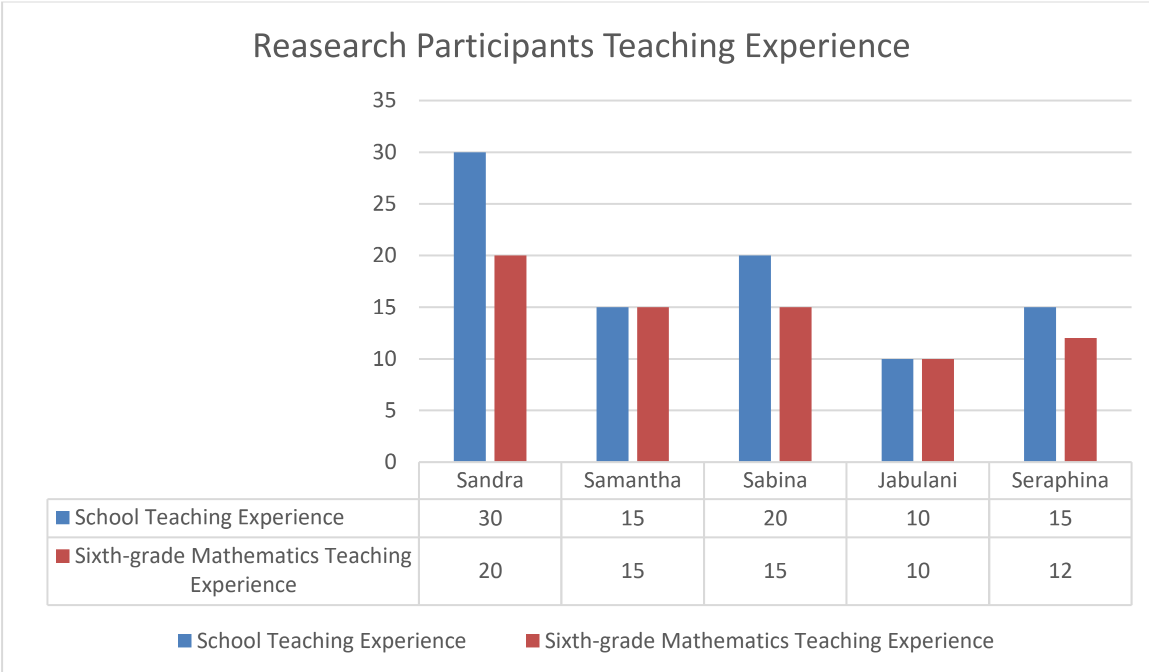


Figure 9 Participants’ teaching experience

As shown in Figure 9, Sandra was the most experienced teacher with 30 years in the teaching profession and 20 years teaching sixth grade mathematics. Jabulani was the least experienced with 10 years in the teaching profession. He has only taught sixth grade mathematics since he became a teacher.

All the teachers had at least a university degree and were qualified mathematics teachers. Therefore, it can be said that they had the relevant subject content knowledge. Reflecting on their past teaching experience, teacher participants stated that it had been difficult to teach mathematics concepts in ways that were meaningful to their learners’ needs. This was due to the lack of media to facilitate learners’ understanding of abstract mathematical concepts. They admitted that they had taught the subject in an abstract manner and that this had resulted in very limited learner engagement in the classroom mathematical discourse. Learners found it very difficult to understand concepts taught in an abstract manner.

> It was not all the time that I would have teaching aids. It was difficult to teach learners in abstract manner. Of course, there are things that are around you that

> you can use but sometimes it gets difficult if you are teaching abstract concepts like time and time zones. You only see them in books. It is just abstract. –Sandra

> I have been teaching mathematics using all methods [meaning, traditional methods] and it has been very boring for learners. –Jabulani

The comments above give insight into pedagogical difficulties teachers faced when they did not have the resources to teach abstract concepts like time and time zones in ways that were meaningful to their learners. They had the relevant subject knowledge but the lack of resources made it difficult for them to support their learners' learning. Both schools are in the quintile 1 category of South African schools' quantile system. This means they serve the poorest learners and cannot charge them school fees. The teachers said that this placed a financial burden on their schools and as a result, their schools could not provide them with the resources they needed to teach the subject effectively. The teachers claimed that the introduction of tablets in their teaching environments meant they are now able to use tablet multimedia content to visualise abstract concepts. They see the visual representation of concepts as a fundamental condition for meaningful understanding of mathematics concepts by learners.

> Tablets allow meeting my learners' learning styles; they teach them with pictures, audio and videos. This was not possible before. –Sandra

> What I like about tablets is that they teach our learners with interactive pictures and videos, so learning becomes simpler. –Jabulani

The comments above suggest that the use of multimedia allows for multiple representations of mathematics concepts to meet the full range of learners' learning needs. Teaching media like graphics, audios and videos are the category of narrative media which normally allow describing the content in a structured manner. They support apprehension and attending. An added advantage of narrative media embedded in tablet educational applications is that they are also interactive. They provided learners control over the choice and the order of the material to explore. They also provided hypertext for additional information on the content. This offered alternative perspectives from which learners could explore abstract mathematics concepts. They supported investigating and exploring mathematics concepts. The use of these interactive media to support the construction of mathematics concepts was confirmed during lesson observations in Seraphina and Sabina's classes. In their classrooms learners used interactive visual models the devices provided to make sense of fraction concepts. For the fraction model in Figure 10, for example, learners first counted the equal parts the model had been divided into for them to know what the denominator was, and then they counted the parts highlighted in a different colour to know what the numerator was. This appeared to enrich the learning experience they had gained with the physical manipulatives the teacher had used to introduce the topic. In Samantha's class, learners used tablets to produce their own visual models to demonstrate their understanding of fraction concepts (see Figure 11). In Sandra's class, as seen in Figure 12, learners also used productivity applications to produce visual graphics to explain the properties of the rectangle. This suggested that there was meaningful learning of mathematics concepts because learners could relate the teacher's explanations to the models they had on their devices and the physical objects they were familiar with in their everyday experience.

Figure 10 Example of visual fraction models learners used to make sense of fractions

Figure 11 Learners produced own fractions models

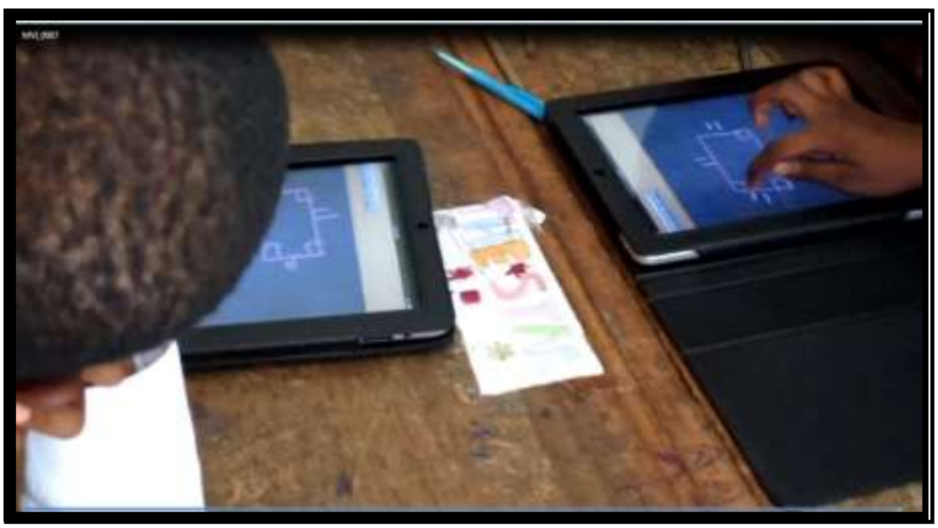


Figure 12 Learners produced visuals to explain the properties of the rectangle

4.3.1.3 Adaptive media

Teachers appreciated that the use of tablet media arouses learners' interest in mathematics lessons and increases their participation in mathematics discourse.

> When I am teaching with tablets, learners become holistically involved. They are the ones giving me the information. –Seraphina

> Now when you bring the technology [tablets], whether you use it as a chalkboard for them to multiply, as long as they are doing that, children start being very excited and they just want to participate. –Sabina

> Now when I bring the technology, as long as it integrates what I am teaching, firstly it arouses their interest, even the ones that you think are slow they take part in the lesson discussion. –Sandra

In the above comments teachers indicated that their learners are now interested in mathematics discourse because of the use of tablet multimedia content. This could mean that use of various forms of media has made mathematics lessons more interesting to them and improved their attitude toward it. The interest learners have developed for the subject is clearly explained in the comments below.

> Now, when I come with a suitcase full of tablets, learners become attentive. They love my lesson. They will follow my lesson. They will even follow me after the lesson and say, ‘Teacher when are you are coming back?’ The lesson can go on without stopping. –Seraphina

> Now, when I bring the technology learners are very much excited. They love my lesson. –Jabulani

The comments above also show the interest in the subject generated in learners by merely bringing the technology into the classroom. They suggest that learners appear to have positive reactions when tablets are used in the subject. Sandra ascertained that since the introduction of tablets in her classroom, she no longer has learners who dislike mathematics. During the formal lesson observations in her class, learners were even willing to go beyond the minimum lesson duration. She had a double period lesson of 120 minutes, and the lesson went on longer than usual. She used about 10 minutes of the learners’ break time, and despite this, the learners were still energetic and interested from the beginning to the end of the lesson.

It is not clear from the comments above whether it is one form of tablet media or a combination of different forms of media that affects learners’ interest and attitudes towards mathematics. However, during lesson observations learners showed a lot of interest in mathematics discourse and engaged productively in mathematics conversation when teachers gave them opportunities to use educational games like Math Bingo and Fun Math. Educational games are in the category of adaptive media that engage learners with the learning content on their own pace. The Math Bingo game that was used in most classes allowed learners to personalise their learning by giving them options to create their own profiles and to select the game options for addition, subtraction, multiplication or division and also the level of difficulty (see Figure 13). The learning was to some extent tailored to learners' interest. While playing, as depicted in Figure 14, learners were receiving reinforcements for every question answered correctly. The reinforcements were in the form of acclamation and animated animal images, which were displayed on the bingo grid every time the correct answer was selected. Learners also got a bingo upon winning the game (see Figure 15). Hence learners tried several times to get all the questions right. Below the bingo grid was a status bar that indicated the amount of time the learner has spent on the task, the questions the learner had answered correctly and the questions learner had answered wrong. This would not have been possible in a traditional classroom where the teacher has to mark work by learners for them to know how well they have performed. Teachers just intervened by checking the questions most learners struggled with in order to provide proper scaffolding. The teacher's support consisted of writing on the chalkboard all the questions the majority of learners answered incorrectly and then demonstrating how to correct them. Because of the interest that learners showed when educational games were played, Sandra mentioned that all her lessons start with learners playing an interactive educational game. She believes "learners learn better when the lesson starts with something they enjoy doing. It sharpens their minds".

Figure 13 Learners could personalise the Math Bingo game

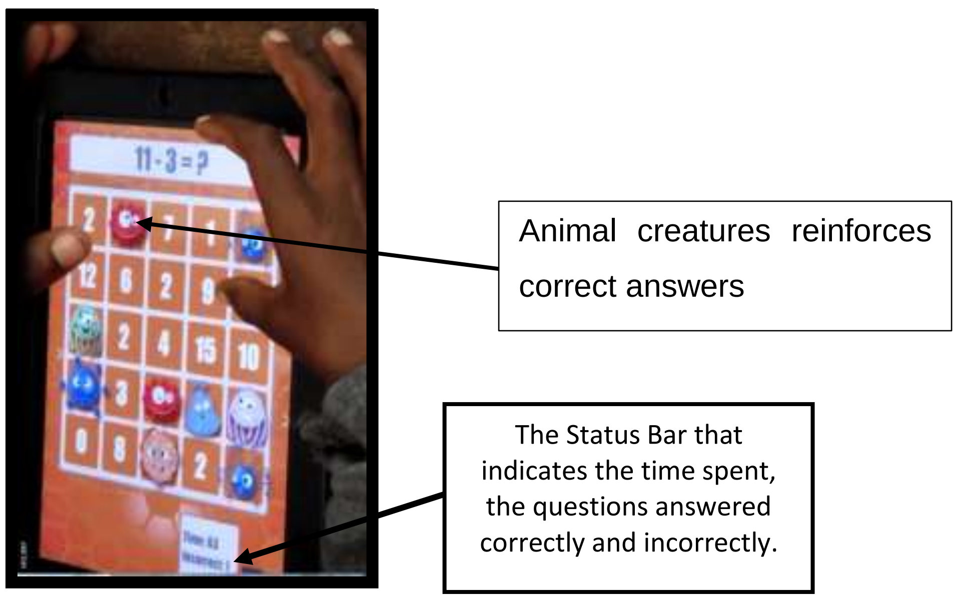


Figure 14 Learners received reinforcements for the correct answers

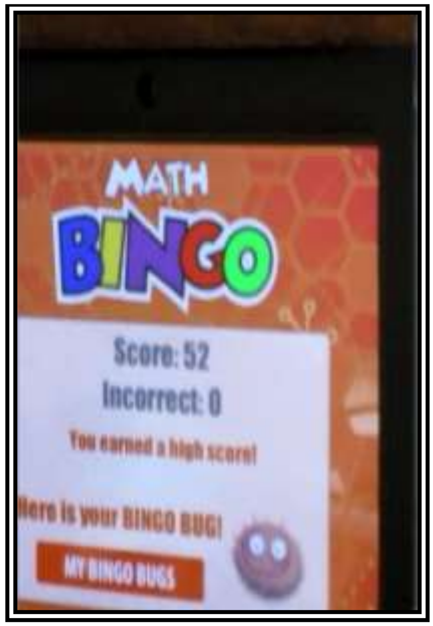


Figure 15 winning the game was rewarded with a Bingo

Teachers opined that use of adaptive media like Math Bingo did not only increase learner engagement in mathematics discourse but also increased their engagement with mathematics tasks. Teachers affirmed that learners use adaptive media to revise the content taught in the class and to practice mathematics activities during their own time. This means that learners are spending more time practicing mathematics tasks. This is particularly important in mathematics where practice enhances mastery of concepts. More practice is likely to enable them to get higher scores on mathematics educational games in particular and in math in general. To them being able to answer all the questions in the game correctly is a sign of being a bright learner; therefore, most learners in both schools are likely to develop a positive attitude toward math. Because of this, Sandra in School A said her learners have study groups in which they use tablets after school hours to practice mathematics. However, these study groups did not take place during the data collection period probably because of the initiation rite, known as Ulwaluko that Grade 6 boys were to attend. On the first day of the school visit, the community leader came to ask the school principal to release learners on time for the boys to attend the Ulwaluko event. In School B, sixth and seventh grade learners practice mathematics for an hour every day after school hours. Just like in School A, after school study groups did not take place during school visits due to the Ulwaluko event. Teacher Seraphina, who is also the school’s deputy principal, said the time learners spent practicing mathematics has resulted in a significant improvement in the school’s annual results in mathematics. Their learners’ scores in the Annual National Assessment improved for three consecutive years after the introduction of tablets in the school. It would be hard to say whether this improvement occurred because of using adaptive applications to practice mathematics or because of the extended time spent practising mathematics. However, it has been clear that the use of tablets adaptive applications motivates learners to practice mathematics.

Research participants boastfully expressed the view that the improvement in learners’ performance in mathematics following the use of adaptive media, has affected the school reputation and public image positively. They indicated that previously the surrounding community despised the quality of their teaching. This was due to ongoing underachievement in mathematics both schools experienced prior to the introduction of tablets. Currently, parents are coming in numbers to seek admission for their children. They want their children to be taught using tablets.

> We are no longer a township school. We are a school that every parent wants his child to come to. –Sandra—School A.

> Every parent wants his child to come to our school to learn with tablet. –Sabina—School B.

It looks like the community believes the use of tablets will translate into long-lasting pedagogical changes that will benefit the learners. Hopefully, this will materialise but it cannot be guaranteed given the complexities associated with teaching and learning.

Teacher participants also mentioned that learners’ enrolment has increased significantly leaving their schools with no option but to turn some learners away. The enrolment increased by 52% in School A and 46% in School B since they started using tablets. On one hand the increased enrolment is to be celebrated but on the other hand it has affected the use of tablets in sixth grade mathematics negatively. Currently in all the sixth grade mathematics classrooms, teachers have more learners and too few devices. Learners have to be grouped to share the devices. Regular use of tablets for group tasks leaves sixth grade mathematics teachers with no clear picture of how each individual learner would perform in the absence of the support from peers.

Another example the research participants gave to highlight how the use of adaptive media has turned the teaching of mathematics around is the improvement in the attendance turnout. Previously, the teachers said, it was difficult to get learners to come to school. However, since they started using adaptive media, learners no longer need to be persuaded to come to school. They are attending regularly in numbers with the expectation that their mathematics lessons will integrate tablets. It was mentioned that the attendance improved by 46% in School A and 50% in School B.

> The tablet project has increased our learners' attendance by 46%. –Sandra—School A.

> If ever something is interesting to learners, then they give in. I can assure you that our attendance has increased by 50%. –Jabulani—School B.

Improved attendance means a lot to sixth grade mathematics teachers. They teach their lessons in the same sequence they have planned. They no longer have to teach the same topic repeatedly to give absentees the opportunity to catch up. However, if adaptive media are the driving factor for learners to attend regularly, then teacher participants have a very important task, which is to keep these resources updated and interesting. If these resources become uninteresting, then the motivation to attend school regularly will possibly decline.

It was noted during lesson observations that all classrooms had small group seating arrangements with learners working in groups of four to five. It was revealed during the interviews that teachers intentionally chose this arrangement to provide opportunities for peer-directed learning and sharing. Through their experience of teaching mathematics, teachers mentioned that they have realised that gains in understanding mathematics are higher when learners are given opportunities to use adaptive mathematics applications for social learning. Learners benefit from the intrinsic feedback the adaptive game provides and the feedback from the peers. Therefore, they have been providing learners with many opportunities to use adaptive educational games for small group peer-directed teaching to allow higher performing learners to assist their peers who might be grappling with understanding the concepts taught. The comments below indicate that teachers appreciated the benefits of peer teaching.

> Collaborative game based learning should be done more often. Sometimes there are learners who are inactive in the class, you see them sitting very quietly, but when they are working together as a group, you find that these are the ones driving the group. Teamwork is very beautiful. –Sandra

> Tablets allow learners to learn from each other. As you move around the classroom as learners are going through game based applications and doing the activities that you ask them to do, even those ones that you think are shy take part. They are able to see what is going on. In that way, teaching and learning become an active process. –Sabina

> Sometimes you fail to push a point to the learners, and then you say to them, ‘Now do it in groups’. When they are doing it together as a group, it becomes easier. It is like when things that you do know when you grow up and your friend say, ‘Oh, let us try this together’. It becomes more and more meaningful. –Seraphina

The easy mobility of the tablet made the sharing of mathematics ideas and information possible as learners could move from one row to another with the device in their hands. Teachers were visiting them in their small groups to check the progress and the problems encountered, if any.

While most teachers appreciated the use of adaptive applications for small group teaching, especially opportunities it provides to engage weak and introverted learners with the content, Jabulani contested persuasively that if not controlled, the use of adaptive applications for group work can in fact work against weak learners’ mathematics cognitive development. He mentioned that whenever he gave learners opportunities to use them in small groups, higher performing learners tended to do all the activities without involving their peers in the process of working out the answers or in the problem-solving process. However, this is not unique to instances when learners use adaptive applications; it is common in all forms of group work, irrespective of whether technology is used. Jabulani had to keep on monitoring learners in their groups to ensure that each learner got a chance to participate in the group activity. He preferred a one-to-one (1:1) tablet integration model in which each learner has his or her own device to use in the classroom. He believed this allows to identify and to attend to each individual learner’s needs.

Teachers were using adaptive applications as an incentive to motivate their learners to work hard and to improve their performance in mathematics. Teachers were doing this in two ways: They were using adaptive media as a task contingent reward and as a performance contingent reward.

As a task contingent reward, learners who were ahead were given opportunities to engage freely with adaptive media as a reward for their effort.

> If I have learners who are outstanding or who are done with the work, they can use educational games instead of having them just sitting and doing nothing. It is like an incentive that I am giving them. They get more interested and work even harder. –Sandra

The use of adaptive applications as a performance contingent reward relates to opportunities to be taught with educational games as a reward for demonstrating an outstanding performance or a desired behaviour in the classroom.

> Our learners' discipline also improved because they know if they behave well they are going to get an incentive of being taught using tablets. –Jabulani

> Learners try to cooperate with me whenever I tell them that I will take the tablets away if they do something wrong. –Seraphina

It was seen in Jabulani's class that whenever learners were given opportunities to use educational games to reward the good work, learners were free to play any mathematics game of their choice. Jabulani intervened only when learners requested his support or to check that they were not distracted by other applications. This freedom is probably the motivating factor that inspired learners to work hard.

Teachers appreciated the value of adaptive media to model the teaching of concepts that were previously difficult. They shared that adaptive applications came with built-in mathematics models which change depending on the learners' input. They provide clues and tips for learners to achieve learning goals. Teachers opined that they assist with the teaching of Fractions and Long Division.

> Here in Gauteng, we are having a challenge with the teaching of fractions … learners are having problems finding the common denominator. They will not know if they do not know their multiplication table. –Samantha

> Long division method is a problem for our learners and in other schools as well. As we meet with other educators, they actually voice out that their learners have problems with long division method and multiplication. –Seraphina

Samantha's comment suggests that learners lack the prerequisite knowledge to build on. Fortunately enough, as Jabulani and Sabina indicated, modelling applications are helping to cover the learning gaps and to teach complex mathematical concepts to all learners.

> But the tablet teaches this [long division] in a simple way. It just tells you where to go, it tells you that you can add; now you are subtracting; now you are multiplying; now you are dividing. Therefore, this is how I also learned how to teach division. ─Jabulani

> Tablets tell them what they have to do; they flicker where they have to go. Therefore, it makes it simpler for me to really teach this division concept. –Sabina

Although learners lacked the prerequisite knowledge, the comments above reveal that teachers did not have the relevant pedagogical content knowledge to mediate learners' understanding of difficult concepts. In their comments, Sabina and Jabulani admitted that they learned how to teach division from game-based modelling applications. They appreciated that modelling applications teach their learners through systematic computational arithmetic procedures and thus made it easy for them to master these concepts. They also appreciated the value of providing learners with instant feedback to scaffold learning.

Another pedagogical value which was celebrated by teacher participants, was the ability of modelling applications to situate the teaching of difficult topics into simulation activities and the way these activities are sequenced from low to high-level knowledge. In some applications, such as Fraction Application, the next activity level could not unlock unless learners had mastered the previous level. It was noted that modelling applications have sections for learners to first explore important terms before they can start engaging with practical activities. It is possible that going through important concepts provided them with basic knowledge to understand computational procedures involved in the practical activities. An example of a fractions application in Figure 16 shows that the application provided learners with the ‘Understanding Fractions’ section to learn key concepts and the ‘Working with Fractions’ section to compute fractions. The ‘Understanding Fractions’ section was used by Jabulani to explain the numerator, denominator, proper fraction and improper fraction terms. He read the definitions of these terms from his tablet then asked learners to repeat after him. Then he used charts and drawings on the chalkboard to visualise these concepts and to help learners to understand them easily.

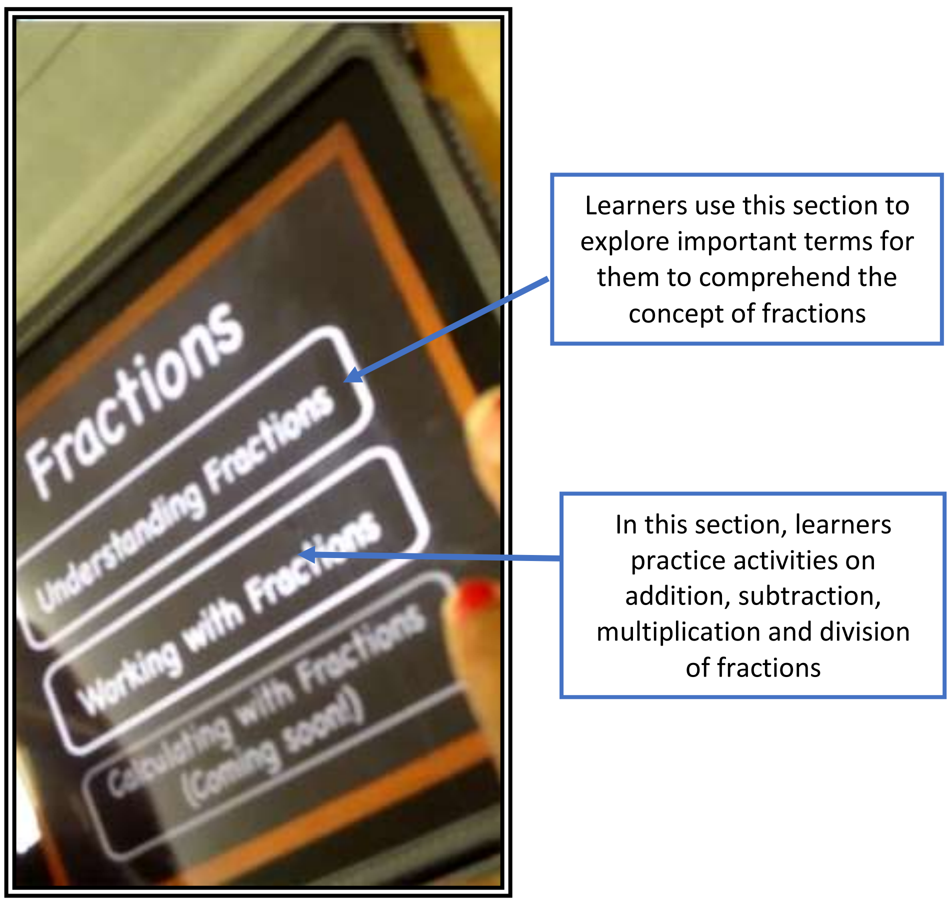


Figure 16 Understanding of Fractions section allowed learning important concepts before engaging with fractions operations

Although teachers claimed adaptive applications taught them how to simplify the teaching of complex and difficult concepts, the lesson observed in Jabulani's class demonstrated that he still does not break down the teaching of difficult mathematics topics like fractions into small sub-topics that can be easily understood by learners. In his lesson on fractions, learners were being introduced to the topic for the first time. His lesson plan indicated that learners were to describe and compare common fractions in diagram form. However, in the same lesson Jabulani touched on complex operations of how to divide and simplify fractions. Simplifying fractions requires learners to have mastered the multiplication and division operations. It was introduced when learners had not even mastered the simple skills of how to add and subtract fractions of common denominators. The challenges learners faced in understanding difficult concepts was not necessarily due to the lack of the prerequisite knowledge but also to the sequence in which the content was presented. Figure 17 below is a picture of Jabulani's chalkboard when he was introducing fractions to learners: Jabulani introduced the concepts of numerator and denominator, and in the same lesson, he touched on addition and simplification of fractions.

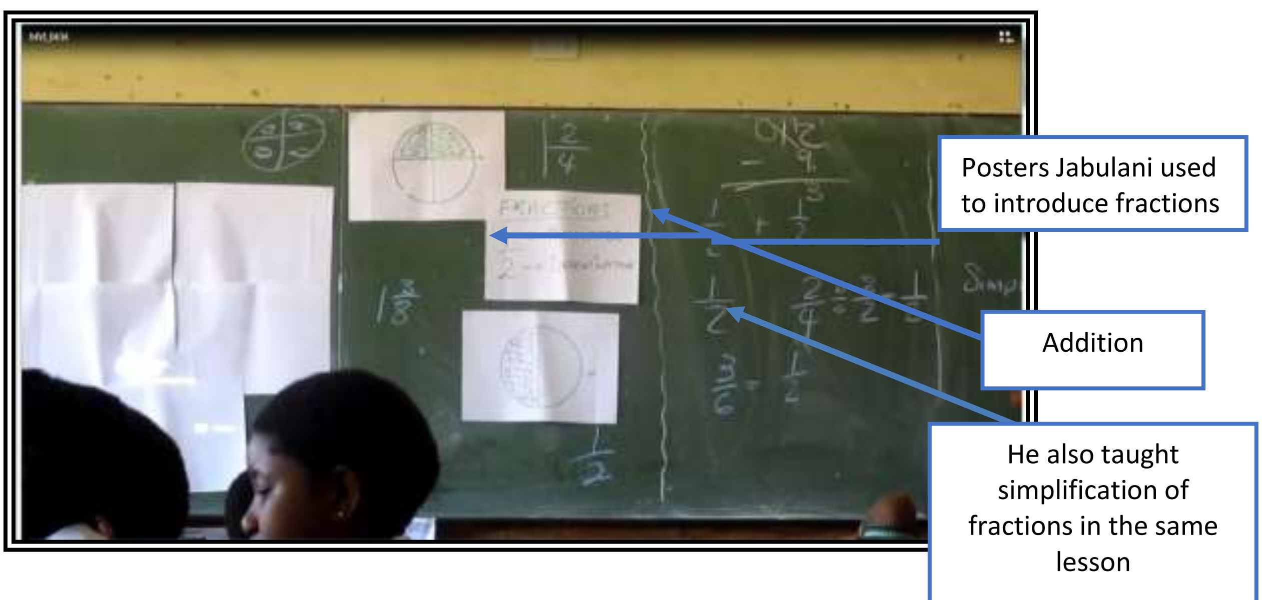


Figure 17 Jabulani's chalkboard while introducing fractions

4.3.1.4 Productive and Communicative Media

Teachers mentioned that tablets proved their pedagogical value by providing opportunities to design paradigmatic activities that promote connections between spoken and written mathematics descriptions. Sabina showed an activity in which she asked learners to use productivity tools to produce visual models to express their understanding of fractions. In that activity she read fractions, e.g. three quarter, half, and three over eight, then learners used tablets to produce visual models that best represented the fractions she read them. Sandra also explained that in her geometry lesson she asked her learners to use productive tools to produce and annotate the properties of shapes like parallelogram, pentagon, hexagonal and triangles. This was confirmed through observations in her class. Learners used the Chalk application to draw rectangle, pentagon and triangle shapes. They also annotated them to explain their properties. While drawing shapes could be done using pencil and papers, tablets provided an added advantage to use different colours and to modify the geometric shapes several times to meet the requirements. Tablets also provided opportunities to produce interactive three dimensional shapes. This could not have been possible with pencil and paper.

Teachers also mentioned that they are now providing learners with cognitive real life challenging tasks for which they use educational applications to complete the tasks and communicate their ideas. Chalk was the most mentioned application used by learners in this regard. It was observed that upon completion, teachers gave learners opportunities to connect their tablets to the projector in order to present their work to the entire class. In respect of this, the chalk application allowed the tablet to be turned into a communicative media to share mathematics solutions. Many learners were excited to have their work presented to the entire class. This seemed to be an incentive for them. It would have been time consuming and costly to have learners share their work with the entire class in a traditional classroom because it would have required providing each learner with the copy of the work. In this regard, the use of tablets in sixth grade mathematics has an added advantage of being convenient while increasing learners' productivity during lessons.

The use productive media to solve real life mathematics challenges was clearly visible in Sandra's lesson on fractions. She taught the topic using a combination of strategies including the tablet multimedia resources, real objects in the classroom and chalkboard explanations. After introducing the concept of fractions, she gave learners fractions word problems, asked them to solve the problems and then present their answers using graphical representations. The following were some of the problems learners were engaged in:

1. If I had a farm and divided it equally among my four children; three boys and one daughter; what is the fraction of the farm that will be allocated my boys?
2. If Tom has already eaten 2 of his 8 pieces of pizza, what is the fraction of the pizza that is left?

Learners interacted with one another in their groups to solve these problems. Different groups used different graphical symbolic representations to present their answers. Every learner in the group tried to answer, and then the entire group agreed on the right answer and the graphical representation to be used to present it. Groups that finished first were given the opportunity to connect their tablets to the projector and to present their answers to the entire class. The rest of the class asked questions relating to the methods used and the choice of graphical representations. Sabina intervened here and there to refine and clarify the responses to the questions that were asked by learners. Code switching was used if the teacher noted that learners were struggling to understand her explanations in English. Teacher Sabina was of the view that engaging learners in such activities gave her the opportunity to listen intently to her learners' ideas, see the expressions of their mathematical reasoning and enables her to provide them with appropriate feedback. She also stated that this approach encourages learners to spend ample time on mathematics tasks, as "they want to show others what they are capable of doing". This extended mathematics practice coupled with instant feedback is possibly helping learners to develop mathematical proficiency and to have a positive attitude toward mathematics. Learners are now able to practice mathematics activities on their own and move at their own pace. This is unlikely to occur in a traditional classroom where all learners learn at roughly the same pace at the same time.

Teachers were happy that the Chalk application allows using tablets to work answers out, to record them and to present them, thus helping to save on papers. Although the thrust of the study was the value of tablet technology in the teaching and learning of mathematics, there were subsidiary benefits like the development of other skills such as the mastery of ICT skills, which are worth mentioning because they developed as a result of using tablets in mathematics teaching and learning. Developing those skills was also in line with the e-Education policy which says that, while integrating ICT in the subject they teach, teachers must also help learners to develop the 21st century skills. The 21st century skills include among others ICT literacy, problem solving, social skills and leadership. However, these skills will not be dealt with at length, as the core of the study is to unpack the difference tablet technology brings to the teaching and learning of math concepts.

4.3.1.5 Subsidiary benefits

This sub-theme refers to the skills of ICT literacy and leadership skills learners are developing through the use of tablets in mathematics teaching and learning.

Teacher participants indicated that they are incorporating basic ICT skills in mathematics lessons so that their learners are able to use tablets effectively in mathematics and are ready for life in the 21st technological world.

> We want them to know how to use tablets in mathematics lessons. We want them to know how to create tables, how to use the keyboard, and where on the device to go if they want to use the calculator. We also want them to develop the basic ICT skills for them to have a better future. Surely they will need these skills at colleges and in their future careers. –Sabina

> We cannot divorce from technology, technology is everywhere. I make sure that I teach basic ICT skills that the learner will use even when he goes out of school. –Seraphina

> I teach them basic skills so that in the future when they go to colleges, the computer will not be the white elephant in the room. They will be able to say, ‘In our school we were doing this and this with our mathematics teacher’. Then they will teach others. –Jabulani

In the above, the ability to use ICT is regarded as a critical skill learners need to have in order to be effective in tablet -integrated mathematics lessons and to lead a meaningful life in the digital world. Teachers opined that they embed ICT skills in the mathematics curriculum activities in a way that learners develop them unknowingly. Samantha explained how she familiarised learners with graphing tools:

> I just ask them to draw shapes and allow them to take turns. This allows learners who are not sure or who would not otherwise know the skill to learn from others. – Samantha

Sabina on the other hand demonstrates the skill to her learners and then sets up a mathematics activity that integrates the ICT skill she has taught.

> I take them through the steps and after that, I allow them to do it on their own through mathematics activity. This gives them the opportunity to explore. I allow them to be independent. I keep on assisting them in their groups. –Sabina

During lesson observations, teachers started their lessons by asking learners questions relating to how to switch on the devices, how to locate the keyboard, how to find the information on the device, and how to navigate from one application to another. Learners applied these skills under the guidance of their teachers. This was in line with the e-Education policy which encourages teachers to incorporate ICT skills in the curriculum they teach. In view of the e-Education policy, ICT integration in the curriculum starts with teachers and learners exploring what they can do with it. Obviously that cannot happen unless they develop the technology literacy first.

> Enriching the learning environment through the use of ICTs is a continuum; it is a process that takes learners and teachers through learning about ICTs (exploring what can be done with ICTs), and learning through the use of ICTs (using ICTs to support new ways of teaching and learning), supporting and enriching each other at the same time (DoE, 2004, p, 19).

Although teacher participants are committed to help learners develop ICT skills using tablets, they also expressed concerns that regular use of the devices might cause learners to forget handwriting skills. Although this might be possible in smart paperless schools, I saw no reason for this concern in the studied schools as in both schools there are too few tablets and educational applications to use on a regular basis. Thus far, in the studied schools, tablets were only used in English and mathematics. Handwriting was still dominant.

Teachers expressed that the use of tablets in mathematics teaching brought about opportunities to develop learners' technological self-efficacy. In Sandra's class, the distribution and the collection of the devices in the classroom was managed by alternating teams of learners. During the research visit in her classroom, a team of learners brought in the devices from the office, took them out of their cases and distributed them between learners. Figure 18 depicts the team of learners that on that day were responsible for the collection and the distribution of tablet devices. They gave Sandra one tablet to use and helped her to connect it to the projector. In Figure 19, the learner is providing Sandra with technical support to connect her tablet to the projector. After the lesson, the same team collected the devices from their peers, counted them to check if all devices were returned. They carefully put them in their cases, and then took the locked cases to the office together with a return form Sandra had just signed.

Figure 18 Learners distributing tablet devices

Figure 19 Learners connecting the teacher's tablet to the projector

Sandra opined that giving learners the responsibility of handling the devices develops their technological self-efficacy so that if in the future learners are given the technology to use, they will be able to manoeuvre it with confidence.

> If in the future they are given the technology; here is the computer, here is the tablet, and the use of technology will be natural. –Sandra

Teacher participants also indicated that while using tablets for group tasks, learners are likely to develop social skills and complex communication skills of mathematics ideas. They learn to respect the input from their peers and to tolerate differences. While engaged in the group tasks learners see how their peers approach mathematical problems to devise solutions, and this can help to improve own mathematical problem-solving skills.

4.3.1.6 Section Summary

This section discussed how tablets are providing teachers with various forms of media including narrative, interactive, adaptive, productive and communicative media, to teach mathematics in meaningful way. The use of these media has turned the teaching of mathematics around, promoting a shift from abstract teaching to meaningful teaching of mathematics concepts. Much value was placed on adaptive media in the form of educational games as they allow for personalise learning, and have affected learners' attitudes towards mathematics positively. They are also helping with the teaching of concepts that were previously difficult to teach and learn. Productive media like the Chalk application has also caught the attention of the participants. It provides tools to produce mathematics artefacts, allows the tablet to be turned into a chalkboard to work answers out, to record them and to present them. The section revealed that while seeking to develop learners' mathematics knowledge and skills using tablets, teachers also develop learners' ICT skills, complex communication, and problem-solving skills as a by-product of using tablets in mathematics lessons. The ICT skills such as the ability to search information on the tablet, the ability to document and to present work using the tablet have the dual role of allowing the effective use of tablets in mathematics lessons and preparing learners for the future.

4.3.2 Tablet Media and Teacher Mediation

This theme looks at the instructional roles teachers in the studied schools are assuming to ensure that their learners understand the connection and the relevance of what they are learning from the tablets media to the curriculum and their everyday life. It also includes the role teachers are playing to ensure learners learn the right content in the proper sequence from tablets. As it will be explained under this theme, teacher mediation also helps to address the downside of using tablets.

Teachers were observed using a combination of concrete objects, textbooks and tablet resources, and these were intertwined with chalkboard explanations. A conversation with them after the lesson revealed that using various tools and information sources ensures that learners see the connection between the tablet resources, the curriculum and everyday life and that they have a wide range of information to support the development of mathematics proficiency.

> We make sure learners see the relevance of whatever we do in the class. They should see that what they are doing on tablets is similar to what they have in the textbook, except that what they have on tablet is more fun. –Seraphina

> I have to go back to the chalkboard, textbooks to make sure every child can see mathematics in everyday life, and that the knowledge will remain appropriate even if the learner goes out of school. –Samantha

> We use the chalkboard, charts and the textbook as well. That is how we supplement the information to broaden our learners' understanding. –Seraphina

It is clear from the comments above that the teacher's mediation entails helping learners to make the mental connections between the tablet content, the curriculum (CAPS) and their everyday life. The comments also suggest that unless these three components (tablet, CAPS, everyday life) are connected, the use of tablet media is unlikely to support meaningful learning of mathematics by learners.

Sandra mentioned that another important mediational role is to help learners experience tablet mathematics applications in the local language and in their local context. She opined that tablet applications are developed in the west by people who do not understand the South African context. An example she gave is that mathematical problems in educational applications use western names and western cities, and this makes it difficult for her learners to relate these problems to their everyday context. She added that these applications also use American English her learners are not familiar with. Her learners are still struggling to understand and communicate mathematics ideas in South African English. In the Math Bingo game, for example, players are called Bingo Buddies, and therefore, she told learners that buddies are like best friends within the South African context. This helped learners to understand the content of the game from their own world of experience. Without this understanding, the engagement with the game was slowed. In Figure 20 Sandra can been seen using gestures to help learners understand an activity on geometric figures. She tried to explain the same activity in English, which is the official medium of instruction in the school, but learners found it difficult to understand. Therefore, she decided to use gestures and code switching. This shows that without the teacher's mediation, it can be difficult for learners to understand tablet mathematics content.

Figure 20 Sandra's body language while explaining a tablet activity

Jabulani did not seem to agree with his colleagues that the context in which the applications were made can have an impact on how learners conceptualise mathematical knowledge. It does not matter to him whether mathematics content is in American English or South African English.

> Function is function. It is part of the curriculum. Addition is addition; subtraction is subtraction, and all of these are part of the curriculum. It does not matter whether they use the American or the South African English. –Jabulani

Contradicting his view, he used code switching in the classroom to facilitate the understanding of the tablet activities he wanted learners to complete. He also allowed learners to use local languages to share mathematical ideas. This also confirmed the views of his colleagues about the downside of tablets, particularly the language used in tablets applications to present mathematics content. Based on this, it can be argued that learners can develop and share mathematical ideas only if they have a solid grasp of the language the applications use and when these educational applications use context-rich mathematics content. It is easier for a South African township learner to understand mathematical problems embedded in the South African context than when mathematical problems draw from the American context.

There was a common agreement among teachers that tablet activities are not sequenced in accordance with the curriculum they teach.

> Frankly, I can say this is not a government tablet. This is the NGO [Non-Government Organisation] tablet. Therefore, the sponsor put different applications he wanted. Some of them do not even speak to our curriculum. –Sabina

In the above comment, Sabina strongly highlighted the gap between the curriculum and the tablet content. Because of this gap, teachers were using tablets together with textbooks to make sure all curriculum topics were taught and learned. This again highlights the importance of teacher mediation if learners in the studied schools are to benefit from the use of educational mathematics applications.

> Tablets do not have the material that exactly fits the actual content from the Department. Sometimes I have to go and switch to the textbook and photocopies. –Samantha

> Let us say you want to teach shapes, it does not have different types of shapes. It does have information on how to measure the shapes. We use the chalkboard, and we use the charts and the textbook as well. That is how we supplement the information. –Sandra

Clearly, tablet educational applications do not cover the depth and breadth of the CAPS. This means that using only tablet mathematics applications will not help achieving the aims set out in the CAPS curriculum. The mediational role of the teacher is crucial as it helps bridge these gaps. There is a need to tailor the tablet content to the CAPS so that all the curriculum topics are covered and that the tablet digital content speaks to the context and the needs of their learners. This will help learners to gain more from educational applications even in the absence of the teacher.

It was clear from the interviews that teachers do not just make tablet applications available to learners. Instead, they help their learners to select the right applications and content to interact with. This was clear in Samantha's comment that "not everything on the tablet is good for the learner. Use of tablets needs to be guided to ensure that the right material is made available to learners at the right time". From Samantha's point of view, the teacher is the agent of meaningful use of tablets in the classroom. The device can be a valuable educational tool if mediated properly or harmful if its use is left to learners' discretion.

Again, as teachers mentioned, learners do not know the content progression. Therefore, when tablets are used, teacher participants show learners where to start and where to end so that the sequence in which the content is to be taught and learned is not compromised.

> As a teacher, you know what you are targeting. Therefore, you tell learners where you want them to start from and where to stop. Then next time you move to whatever section. –Seraphina

> When you are working with this [application on fraction,] you have to set it. You start with simple fractions so that learners know the basics before they can deal with operations that are more complex. When you see that they understand the principles you can now move on to fractions with different denominators and you keep on reminding them over and over. –Samantha

The comments above highlight the teacher's agency. They suggested that use of tablets in instructional mathematics conversation can be beneficial to meaningful learning of mathematics by learners if the teacher is able to adjust the sequence of the tablet educational content to match the sequence of the CAPS. Otherwise, it can be harmful to the learning of mathematics by learners if the teacher does not ensure that learners interact with the tablet materials in the sequence of the CAPS. This makes the teacher the driver of successful learning with tablets.

The lesson observation in Jabulani' class showed that it was not always possible to get learners interact with the tablet content in the sequence of the CAPS. He asked learners to do a tablet activity starting from level one and to stop at level seven. Learners opted for the levels, which were different from what he had instructed them to do. They started from difficult levels, and even did activities on levels higher than level seven. It could be that the learners had not been paying attention to Jabulani's instructions or were curious about the activities in the levels they opted for. This cautions that teachers should be provided with tools to lock and unlock some sections of the tablet applications so that they can be accessed only when it is the appropriate time. Otherwise, their availability can interfere with the proper construction of mathematical knowledge by learners.

After listening to the concerns of teachers regarding the content gaps between the CAPS and tablets, the study sought to establish why teachers did not choose to have applications that exactly aligned with the curriculum they teach. The responses to this question showed that teachers were relegated to spectators when the tablet project started in their schools. They were not consulted about the applications that would be relevant to the curriculum they teach. The sponsor just came with pre-loaded tablets and then a few teachers were selected to attend the training.

> The information that we have is the information that was given to us. So we still check our DBE books, textbooks ... but we need more applications such as how to calculate the square, applications like number line, how to change the percentage into decimal fractions. We need all those things. –Samantha

> There are many applications we do not have. Therefore, you have to go back to the chalkboard and textbook. You cannot use the same application repeatedly, it gets boring and you do not know what to do anymore. We need more applications but the school does not have a budget for that. –Sabina

> There is lack of specific applications for different topics; we just use what we have to be innovative. If you can come and create them for us, we will appreciate. – Sandra

It was clear from interacting with the teacher participants that they wanted to be regarded as valuable partners in any technological initiative seeking to transform teaching and learning of mathematics in their classrooms. They positioned themselves as being the most knowledgeable of the classroom environment and responsible for any change that happens in the classroom; therefore, failure to involve them resulted in having educational apps that did not entirely address their classroom needs.

This section revealed that the teacher is more important than tablet technology itself. The section first suggested that the educational applications teachers in the studied schools were using were designed and developed for overseas learners. Therefore, teachers were playing a mediational role to adapt the tablet resources to the curriculum requirements and the needs of township learners, and to ensure that tablet resources were used in the sequence and pace the South African curriculum prescribed. The section highlighted that learners cannot benefit from the mere use of tablets in the absence of their teacher's mediation.

4.3.3 Tablet Media and Teachers' Professional Growth

This theme looks at the use of tablets to expand teachers' knowledge and skills in the pedagogical use of tablets in instructional mathematics conversation.

All the teacher participants were 35 years old and older. Because of the newness of technology in the South African teaching environments, these teachers did not learn and were not taught with technology at school and college. However, with technology currently being present in their teaching environments, they were compelled to develop the knowledge and skills of how to make use of it to improve teaching and learning.

The teacher participants indicated that they had participated in in-service professional development programs on the use technology in the classroom. The first training they attended was provided by the Gauteng Department of Education and focussed on basic computer applications. This took place just before the launch of the Gauteng Online in 2001. Two of the participants, Jabulani and Sandra, were also coordinating the use of the Gauteng Online computer laboratories in their schools but for reasons still unknown to them the Gauteng Online computer laboratories are no longer functional. The most recent training they attended was organised by the tablet sponsor. It aimed to prepare them to use tablets in their classrooms. The training adopted the 'train the trainer' approach, and five teachers from each school were invited to participate and they were required to go back and train their colleagues.

Teachers in School B expressed how ill prepared they felt to use tablets in the mathematics classroom despite the training they attended. They raised concerns that the training focussed on how to open a tablet and how to navigate to different applications without modelling how to incorporate tablets into mathematics teaching and learning experiences. The training did not model how to design mathematics assessment tasks that integrate tablet applications or how to use tablet applications to develop their own mathematics content. Although teachers are currently doing the best they can to meet their learners' needs, they do not feel comfortable enough to use tablets to teach some of the curriculum topics like long division. They also mentioned that they are not using many educational applications like Yolaroo Fractions and Yolaroo Exponents and Numbers, which are loaded on the devices, because they do not know how to use them in ways that would improve their learners' mathematical learning.

> They did not teach us in context, like you must teach learners like this. As educators, we are trying to design lessons and to check if the applications meet our learners' needs. You can see we are 25 teachers in the school but not all of us can be able to teach leaners with tablets. –Sabina

> They taught us how to open the tablet and where to find the instructions. Therefore, you as a teacher must be able to find out how you can use it to teach learners. This is not always easy. –Jabulani

It is clear that the teachers are not satisfied with the training on the use of tablets they received. They would like to participate in training programs on how to teach lessons that combine tablets with mathematical concepts but such opportunities are not available. They see the potential of tablets to support teaching and learning but they lack the knowledge of how to fully exploit the technology in order to maximise delivery of the curriculum to the best advantage of learners.

The classroom observations in School B showed that even the four mathematics teachers that are attempting to use the devices in the classroom are still lacking basic technical skills of how to connect the tablet to the data projector. One teacher moved between classes to help with the data projection leaving learners in his classroom unattended. Although regarded in the school as a tech-savvy, the same teacher did not know how to change the data projector's settings for full screen display. This shows the need to support teachers in School B to develop the technological knowledge so that they can confidently use technology in the classrooms.

While in School B teachers felt ill prepared to use tablets in the classroom, Sandra in School A felt comfortable enough to creatively use tablets in her classroom. She mentioned that it was easy for her to learn how to use tablets in mathematics because she was familiar with using it in the English subject and in her everyday life outside school. In addition, she belongs to a community of English teachers that come together to collaboratively design and develop tablet -integrated lessons and find solutions to problems they face as they teach with tablets. She mentioned that being in that community improved her teaching.

> When we come together I would take my lesson and present it, somebody else would also present his/her lesson. Therefore, we are like sharing the information about our successful experiences and challenges. Because I love it, I do take new things other people present and use them in my classroom. –Sandra

During lesson observation, Sandra was very comfortable using the tablet in the classroom. She spontaneously interchanged the use of the tablet with other approaches including use of manipulatives, and this enriched learners' learning experience of the topic of shapes she was teaching. This, together with the comment above show that peers can be valuable social capital to draw on in order to learn pedagogical technological skills.

Sandra indicated that regular use of tablets helped her to develop innovative ways of using the devices to invigorate her teaching. She claimed that she is now able to use the AppMachine, which is an application on her tablet, to combine different applications to then build her own application that best fits the lesson she is teaching. If that is the case, then regular use of tablets helped her to move from the entry level to the creation level where she no longer relies on readily available resources but can develop her own.

The above shows that teacher participants are at different stages in the use of tablets. Sandra seems to be at the advanced stage while others are either at the entry or adoption stages. However, all the participants indicated that there have been some improvements in the way they use tablets in mathematics teaching. They shared that they have spent time exploring the applications, and by doing so, they gained new insights on how to use them in their lessons. They learned through trial and error. Three teachers who have their own tablets used them to learn from the internet how other teachers around the world use the devices in mathematics teaching to benefit learners' learning. Teacher Sabina shared that she learned from a teachers' channel on YouTube how to add notes on tablet media to highlight important information learners should know. Teacher Samantha also got inspired by a teacher who shared her experience of using tablet to take videos of learners while solving mathematics problems and the impact it has on learners' learning. When that happens, as Samantha learned, learners go an extra mile. They practice mathematics several times before the video can be recorded. This is to ensure that they do not make mistakes and to avoid being embarrassed when the video goes viral. It also gives learners a sense of owning their learning. Although Samantha cannot share her learners' videos online due to the lack of internet connectivity, her learners enjoy playing them over and over. "It is entertaining and while doing so they are learning", she mentioned. They also like moving around the classroom to watch those of their peers. Samantha believes that sharing their screens helps learners to learn from their peers.

Teacher participants who have bought their own tablets shared that having their own devices helped them to know what other educational mathematics applications they can use to enrich their teaching. Unfortunately, they cannot install them on the school tablets because of lack of connectivity and the budget to purchase the applications. Teachers gave an example of the Slice fraction application, which according to Sandra, is more interactive, engaging and more differentiated that the Fraction application they currently have.

Clearly, teaching with tablets in the studied schools is largely self-taught. The tablets are playing a significant role in allowing teachers to sharpen their skills through exploration and discovery, but the main limitation is the lack of own tablets by some teachers and the lack of internet connectivity in their schools. It has been clear from Sandra's experience that prior experience with technology and use of technology in other subjects and in everyday life has a positive impact on the teachers' use of technology in the mathematics lessons. She was comfortable using the devices in her teaching of mathematics because she had been using it for non-teaching purpose and in other subjects. The findings in this section suggest that teachers' professional development in the use of tablet in the classroom should not only provide technical skills but also model how the devices should be used in the teaching and learning of the curriculum.

4.4 Findings from Lesson Observations

While the previous section focussed on the pedagogical value of tablet technology from the teachers' views (self-reported data), this section makes explicit the pedagogical value of the tablet as enacted in the teachers' practices. The section responds to the second research question: How are teachers' perceptions about the value of tablet technology translated into pedagogical actions in the actual teaching of sixth grade mathematics? The section draws from five mathematics lessons observed in Schools A and B. Teachers' lessons will be presented first, then analysed using two themes: The discursive mathematics event and the experiential mathematics event. The themes are informed by the instructional events marked by the conceptual framework.

4.4.1 Sandra's Lesson on Shapes

Sandra was the most experienced of teacher participants. She has been in the teaching profession for 30 years. She has also been teaching sixth grade mathematics for 20 years. She indicated during the interview that the use of tablets in her teaching allows her to make mathematics lessons come alive and be meaningful to learners. She also believed the use of tablets is helping to make mathematics lessons learner-centred. This section will report on two period lessons that were observed in her class in School B. Here follows a description of the lesson.

Before the start of the lesson, a group of learners came in with four boxes of tablets from the administrative building, a mobile screen and a data projector. They distributed the devices between 42 learners seated in small groups of four–five learners. Sandra also took one tablet for her to use. One learner helped her to connect it to the data projector. When everything was set up, Sandra started addressing her learners.

> **Sandra**: I want you to start with a mental activity. Please put other things away.

Then she guided learners in the process of finding the mathematics applications on their devices that she wanted them to use. This helped to save time and avoid difficulties learners might encounter when trying to find the applications on their own.

> **Sandra**: I want you to go to the math application. Remember when we go to the math application and we type 'math' from our keyboard. How do we get our keyboard?
>
> **Class**: From the left bottom corner.

Sandra: Go there and type math. All the applications that have mathematics will appear. Then choose Math Bingo.

Learners followed Sandra's instructions and were all able to retrieve the list of mathematics applications on their devices. However, not all tablets had Math Bingo. Some tablets had Math Bingo, others Fun Maths and others Pop Maths; others did not have any of the three applications, so they were put aside. Learners who did not find any of the three applications on their devices joined other groups.

Sandra: We have different applications: Some of us have Math Bingo, others Pop Maths or Fun Math. If you have Math Bingo there, if you do not have it, quickly go to Fun Maths. If you do not have Fun Maths, you must use Pop Maths. If you do not have any of them then leave your tablet there and go to the person next to you.

The game had different levels and learners were asked to start with the lowest level. Learners took turns within their groups to do activities so that everyone in the group could be involved. While learners' excitement was high as they played, they did not seem to pay attention to the necessary computational processes involved in working out answers. They were rushing to complete the game; therefore, many were just guessing answers. After seven minutes, Sandra asked everyone to stop. She checked the scores, and then asked the class to give a round of applause to the group that had managed to get to the highest activity level. After the mental activity, Sandra introduced the new lesson. She used a series of questions to progressively draw learners into the new lesson.

Sandra: Today we are going to look at things around us. Are we all looking?

Class: Yes

Sandra: There are objects around us that have shapes. Can you see them? What shapes can you see there on the walls and outside?

A learner: Flat shape.

A learner: Triangle.

Sandra: Who wants to show me a triangular shape in this classroom?

A learner stood up and showed a window frame. However, that was not a triangle.

Sandra: Is it a triangle that one?

Class: No!

Sandra: Is there any triangle there, Grade 6? (Pointing at the window)

Class: Yes!

Sandra quickly moved to the window. She counted the sides and the corners of the window frame. She explained that the frame had four corners with right angles therefore it is not a triangle but a rectangle.

Sandra: There is a right angle here. What else do we have? Therefore, we have a rectangle in that shape. What other objects in the classroom have the shape of a rectangle?

Class: Chalkboard.

She asked learners questions to elicit the properties of a rectangle from them.

Sandra: How do we know the chalkboard has the shape of a rectangle?

A learner: It has width and length.

Sandra: Which one is the width there?

A learner stood up to show it but she got it wrong.

Sandra: Is that the width?

The learner who got it wrong was asked to remain standing so that she could be corrected. Another learner stood up and went to the front to show the width of the chalkboard. This one got it right. Sandra asked a follow-up question for the learner to justify his answer and to clarify his thinking and reasoning.

Sandra: Good. Why do we say it is a width?

A learner: It is short.

Sandra: What do we call the other sides? These ones are widths. [Touching the two widths] What do we call other sides?

A learner: We call them lengths.

Sandra: Do we agree class? Why do we say these are lengths?

A learner: Because they are big.

Sandra: What is the right word? Do we say big?

A learner: Because they are longer.

Sandra: There is a special name: How do we call objects that have a width and a length?

A Learner: Two-dimensional shapes.

Sandra: Two-dimensional shapes! [She repeated] Give him a round of applause! [She asked the class]

Using the same questioning strategy, Sandra asked a series of questions to encourage learners to explain the difference between two-dimensional and three-dimensional shapes.

Sandra: Is it the same as a 3D?

Class: No! Two-dimensional shapes are flat.

Some learners: Two-dimensional shapes are flat.

Sandra proceeded to ask what other objects in the class were not flat. Learners made examples of the box, the table legs, and the classroom.

Sandra: Tell me which objects in the class are not flat ThoKozo?

ThoKozo: The box of tablets.

Sandra: Very good, ThoKozo. What else?

A learner: The table.

Sandra: What else?

A learner: The legs of the chair and the table.

Sandra: What else?

A Learner: The classroom.

Sandra: Give him a round of applause.

Learners were then asked to go on their tablets and to find the Chalk application. Sandra reminded them how to get to the Chalk application. She also reminded them how to use the Chalk application to draw, to sketch, to put colours and to erase. She then asked all learners to use their fingers to draw rectangles. After a couple of minutes she checked their progress.

Sandra: Are we done? Who is done?

Most learners raised their hands.

Sandra: Well done!

Sandra then used learners' work to expand their knowledge on the properties of a rectangle, especially the relationship between the width and the length.

Sandra: What else can you tell us about the rectangle? I want us to come up with some characteristics. When I am standing in front of you, you can say: Teacher Sandra is short; Teacher Sandra is not too fat; and Teacher Sandra is wearing a green and white dress … I want us to describe that figure.

Lindiwe what do you see in that figure?

Lindiwe: It has long lines and short lines.

Sandra: Do we agree Grade 6?

Class: Yes!

Sandra: Let us now talk about the relationship between the short line and the long line. I want you to mark the long line and the short line; one mark on top, one mark on the other side. Look at those two lines. How are they seating? This line is on this side and the other one is on the other side. What can you tell me about their relationship?

Sabelo: They are parallel.

Sandra: Give him a round of applause! Teacher Sandra was not expecting that.

Sandra: What can you tell me about these other ones?

A learner: They are adjacent.

Sandra: Is that true? Adjacent is next to. Are these adjacent?

Kabelo: They are equal.

Sandra: Very good. Give him a round of applause! They are equal. What can you tell me about these two lines? One is sitting here another one is sitting there.

Nonto: They are opposite.

Sandra: Very good. They are opposite and equal. They are also parallel. We say they are opposite, parallel and equal. Parallel means they cannot meet. They cannot join. Go to the shorter sides, the widths. Look at the widths again: What can you say about them? Are they equal?

A learner: They are the same.

Sandra: Good. What else can we say about the two lines?

A learner: They are equal

Sandra: Any other input?

A learner: They are two-dimensional.

Sandra: Can we say they are two-dimensional Grade 6? Remember we say a shape is two-dimensional. Can we also say a line is two-dimensional?

Class: No!

After she realised that the learners had a clear understanding of the properties of the rectangle, she concluded with a general remark about the properties of the rectangle.

Sandra: Now these are the characteristics of a rectangle. It has the length and the width. The lengths are equal and parallel to each other. The widths are also equal and parallel to each other.

Sandra then drew a rectangle on her tablet. She used it to assess learners' understanding of the properties of the rectangle she had just taught.

Sandra: How many corners do we have there?

Kabelo: 4

Look at the corners of this house. There are four corners. What is the name of the angle that you see there in the corner? Look at the window. What do we say about this angle?

Rodrigue: Right angle

Sandra: Good.

Sandra: Almost like what you have there. Now let me check. What did we say about this line and this one? Are they equal or not equal?

Sinhle: Equal

Sandra finally drew a square, and then asked questions to see if learners will be able to differentiate the rectangle from other shapes and to apply the knowledge of the rectangle to a different context.

Sandra: Give me the name of this shape first. Is it still the same as a rectangle?

Class: No?

Sandra: So what is its name? What shape is that?

Tracey: Square.

Sandra: Agree Grade 6?

Let us go back to what we did. What can you tell me about these lines? What can you say about the sides of a square?

Sharika: They are all equal.

Sandra: They are all equal.

Class: They are all equal.

Sandra: What is the other name of a shape that has four sides?

Nkosikhona: It is a quadrilateral.

Sandra: Very good. What is a quadrilateral? What does ‘quad’ mean?

Nonkoliso: Quad means 4.

The lesson ended with a final practical task in which learners were asked to draw and to describe the properties of the square and the pentagon.

> **Sandra**: Draw me a square: one must do one side, another one the other side. Mark the lines that are equal. Also, do the angles.

Learners completed the task and the first three groups presented their work to their entire class, and then it was break time.

4.4.1.1 The analysis of Sandra's lesson

Sandra's lesson on shapes can be divided into two pedagogical events: The discursive mathematics event and the experiential mathematics event.

a) The discursive mathematics event

The discursive event refers to all teaching and learning activities that were intended to develop learners' conceptual understanding of shapes. It includes mathematics dialogue that occurred, exchange of ideas, and the question and answer process that ran throughout the lesson. In the discursive teaching event Sandra and her learners compared and contrasted different shapes. Sandra mediated the discussion by means of systematic questions and narrative media in the form of concrete objects in the classroom. Practical tablet activities were also used here and there in the discursive event to give learners a practical experience of the concepts that were being discussed. The questioning approach seemed to enrich the iterative mathematics discussion as it elicited learners to share ideas and thoughts and to receive feedback on them. Questions like "How do we know the chalkboard has the shape of a rectangle?" reflective learning as it challenged learners to not only find examples but to produce evidence to support their answers. Through questioning, Sandra was also able to access her learners' thinking and to refine their mathematical language whenever it was necessary. For example, when she asked the learner why she referred to one side of the chalkboard as length, the learner said it was because the side she referred to was the longest side. Sandra refined the learner's mathematical language by emphasising that the side is called 'length' because it is longer, not bigger. In some instances, she had to restructure the questions to orient their thinking, thus promoting adaptive learning. Comments like "There is a special name. How do we call objects that have got a width and a length?" served to inform learners that the conversation was moving toward two-dimensional shapes and that it was no longer about the rectangle.

The classroom discussion included knowledge negotiation between Sandra and her learners and ongoing feedback to promote reflective and adaptive learning. In some instances, learners were asked to confirm whether answers from their peers were correct. If the answers were wrong, then learners provided right answers to correct their peers. Good effort was recognised and reinforced with comments such as "Well done", "Good", and "Well done, I never expected that". A round of applause followed such comments. Reinforcing good performance resulted in many learners raising their hands to answer the questions so that they too can be acknowledged.

Learners' participation and contribution to the mathematical discourse depended on Sandra's pedagogical ability to incite them. Learners were not fluent in the medium of instruction but Sandra's questioning, probing, and reinforcement strategies inspired them to actively participate in the discussion. She maintained their participation by adapting her teaching approach to meet their needs. She interchangeably used tablets interactive media embedded in educational games, narrative media like concrete objects, and visual representations, depending on the learning need that had arisen.

The use of tablet adaptive media added value to the discursive event. At the beginning of the discussion, Sandra used Math Bingo, Fun Math and Pop Math games to provide learners with a stimulating environment in which they practised mathematics skills that were previously taught on their own. Upon completing the game, learners were relaxed, excited, and then Sandra took this opportunity to pull their attention into the new lesson.

The use of tablets adaptive media also allowed her to explain important mathematics terms that were important to the understanding of the topic. This was done by going through the 'Important Terms' section of the applications. The section covered 'Important Terms' for geometric shapes and patterns.

The use of tablets in the discursive event allowed Sandra to intertwine the narrative discussion with experiential activities and to shift the discussion from lower to higher cognitive level. After explaining geometric shapes using narrative media such as concrete objects in the classroom, Sandra asked learners to construct different geometric shapes in using the Chalk application [see Figure 21]. Sandra elaborated on learners' constructed geometric shapes to teach their properties. The Chalk application as a productive media did not only allow her to provide an experiential task but also to move learners from the concrete representations to the semi-concrete representation. In the absence of the tablet this shift from concrete example to semi-concrete would not have happened.

Figure 21 during the discursive event, learners got opportunities for practical tasks

In the Chalk application learners used symbols: 'W' for the width, 'L' for the length, and the sign '||' for parallel sides to annotate the rectangular figures they had produced (semi-concrete representation). In this regard, the use of tablets also allowed moving from the semi-concrete to abstract. Sandra elaborated on learners' annotated figures to enrich the discussion and to take it the higher level. Mathematics discussion that followed promoted reflective and adaptive learning as learners used the ideas that were shared to modify their initial shapes.

Sandra challenged the learners to give the properties of the rectangle:

> What else can you tell us about the rectangle? I want us to come up with some characteristics. When I am standing in front of you, you can say: Teacher Sandra is short; Teacher Sandra is not too fat; and Teacher Sandra is wearing a green and white dress … I want us to describe the figures on your screens.

In the above, Sandra challenged learners to determine how the width (W) and length (L) sides related to one another. Having the narrative figures on their screens as shown in Figure 22, made the inductive analysis easy and comprehensive. Learners always referred to the figures to discover the relationships between the sides. They discovered that W and L sides were adjacent, W and W, and L and L sides were parallel, opposite and equal. It was after the inductive analysis that Sandra gave learners a general remark about the properties of the rectangle.

Figure 22 Learners annotating geometric figures

Having the shapes on the tablets screens also allowed Sandra to explain geometric relationships between sides and angles. Firstly, she asked learners to mark the sides that were parallel with '||' signs. After marking them, learners discovered that W and W sides, and L and L sides were equal and opposite. Sandra elaborated on parallel and adjacent, which were terms learners had not picked up. She showed learners that L1, W1, and L2 and W2 sides were next to each other and formed right angles. She told them that the term 'adjacent' is used to describe the sides that meet to form an angle. She also extended W1 and W2 sides, and then L1 and L2 sides to show learners that W1 and W2, and L1 and L2 cannot meet. She told learners that the term parallel is used to describe straight lines that cannot meet.

In short, the discursive mathematics teaching event in Sandra's lesson on shapes was an iterative dialogue between Sandra and her learners aimed at developing conceptual understanding of shapes. This iterative dialogue, through questioning, feedback and reflection did not only allow describing the topic but also helped to develop appropriate mathematics language. The use of tablet media enriched the discursive mathematics teaching event by providing productive media in the form of the Chalk application. The later was used to enrich mathematics discussion with small experiential tasks. The shapes produced using the productive media allowed for abstract learning. Tablets also provided adaptive media, in the form of educational games that was used at the start of the lesson to capture learners' attention and to prepare them for the new lesson.

b) The experiential mathematics event

This event refers to opportunities learners got to experience the knowledge of shapes on their own. It represents the major experiential task Sandra provided at the end of the lesson for learners to practice the knowledge from the discursive teaching event. The experiential teaching event was different from the discursive teaching event in that it used tablet media only to engage directly with the knowledge constructed at the discursive event. In the experiential event learners used the Chalk application to produce their own shapes, to annotate them and to share their products with the rest of the class. This is elaborated on in the paragraphs that follow.

The Chalk application as a productive tool made the experiential task easy. Learners used it to produce square and pentagon figures. They also annotated the properties of the figures using the different colouring tools the application provided. The finished geometric shapes learners produced in the Chalk application assured Sandra that learners had a deep understanding of the topic.

The Chalk application was also used as a communicative tool. The two groups that finished first connected their devices to the projector, and this allowed them to communicate and share their work with the entire class. The presentation of their work resulted in a meaningful qualitative discussion. During the presentation, Sandra asked learners questions to explain the properties of the figures they had produced and to differentiate them from the rectangular figures they had explored in the discursive event. Sandra also took learners' presentations as an opportunity to emphasise that a square has all the properties of a rectangle but a rectangle cannot be a square because it does not have four equal sides.

The use of the Chalk application also promoted peer teaching. Learners cooperated in their small group to take turns to draw the shapes. The application provided tools to erase in case learners needed to correct the mistakes of their peers. Sandra moved between rows to ensure every learner had a chance to participate in creating the shapes.

In brief, Sandra's lesson on shapes complied with the conceptual framework of the study and aligned with her perceptions about the value of tablet technology in sixth grade mathematics teaching. Her lesson had both the discursive and experiential events of an instructional conversation mediated by tablet and non-tablet media. While leading the instructional conversation, she used different approaches including questioning, probing, reinforcing and a combination of tablet and traditional media to ensure that learners participated in mathematics discourse, received feedback and adapted their initial mathematics understanding. She shared during the interview that her lessons are no longer abstract. Here she wanted to highlight the value of tablet media to make abstract concepts visual. She also mentioned that, the use of tablets, educational games in particular, is helping to capture learners' interest and to engage them meaningfully in instructional mathematics conversation. Indeed, during lesson observation Sandra used tablet media, the chalk application in particular, for multiple representation of the knowledge of shapes. Learners were actively involved throughout the lesson. The lesson started with adaptive game activities, which allowed learners to recall prior mathematical knowledge while having fun. The game environment provided instant feedback and this allowed for instant reflection and progress, thus promoting reflective and adaptive learning. She maintained learners' active participation in mathematical conversation through questioning, probing, knowledge negotiation, and reinforcing comments. This did not only allow them to construct a conceptual understanding of shapes, but also to learn special mathematics language learners must use when they converse about shapes.

Sandra believed that without her mediation the learners have trouble understanding the tablet's mathematics content. She mentioned that although tablet's educational mathematics applications afford interactivity and audio-visual experiences, they do not cover the breadth and depth of the curriculum topics. This helps us to understand why in the discursive event Sandra combined the use of tablets media with the use of concrete objects and chalkboard explanations to bridge the gaps. Doing so helped to make the knowledge of shapes contextual and accessible to learners while providing multiple perspectives from which they could construct a mathematical understanding.

Sandra also appreciated the value of tablets to engage learners in collaborative learning activities. She regarded collaborative learning as a social capital teachers should rely on to promote peer teaching. Hence, it is not surprising that in her classroom learners completed all tablet activities in groups. Peer teaching was prevalent in the experiential task that required learners to draw shapes and to annotate the properties. This resulted in a rich mathematical discussion among group members. It should be remembered that all the learning theories that framed the conceptual framework of the present study encourage collaborative learning due to its ability to promote the iterative discussion process for conceptual development.

4.4.2 Jabulani's Lessons on Fractions, and Addition & Subtraction of Ordinal Numbers

Jabulani had 10 years' experience in the teaching profession and 10 years in teaching sixth grade mathematics. During the interview, he mentioned that the use of tablets media allows him to engage learners in instructional mathematics conversation and affords him the opportunity to differentiate learning to accommodate learners' learning styles. However, this was not visible in his actual lesson. His teaching used the 'chalk and talk' narrative media. He did not use tablet media in the discursive event to help with conceptual understanding of fractions. Tablets were only used at the end of the lesson for summative purpose.

As Chapter 2 indicated, teachers are likely to use technology in their teaching if they believe that using technology will help to improve their teaching and when they are able to use technology with ease. There were indicators that Jabulani did not have the relevant technological skills to use the tablet with ease. He spent about 15 minutes trying to set up tablets for learners while he could rather have guided the learners in this process in less time. He also had difficulties using the zooming function on the projector to increase the surface area to project on. The tablet he had connected to the projector was never used during the lesson. The following description of his lesson will reveal how his perceptions about the value of tablets to support teaching were enacted in his actual teaching.

4.4.2.1 Jabulani's first lesson on fractions

There were about 52 learners in Jabulani's Grade 6 mathematics class and they were seated in small groups of four–five learners. Each group had at least one tablet to use. To begin the lesson, Jabulani informed learners that tablets would be used to learn the topic of fractions.

> **Jabulani**: We are going to use tablets to do fractions. Afterwards we are going to write a classroom test. Look on the side there is a paper that I gave you for you to write corrections. You are going to work as a group. You must listen to me attentively. You must also remember what I tell you.

Jabulani then asked questions to recall learners' prior knowledge of fractions.

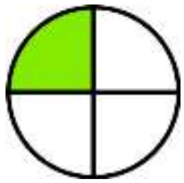
> **Jabulani**: Who can tell me what a fraction is? What do you know about fractions?
>
> **A learner**: A fraction is a number which has a numerator and a denominator.

Jabulani repeated the learner's answer, and the whole class repeated after him. He then moved between groups to get learners to the tablet application he wanted them to use. This took about 15 minutes. Learners were making noise while waiting for the teacher to tell them what to do. It would have helped to keep learners calm if Jabulani had guided them to find the application themselves instead of him doing it for the entire class.

After taking learners to the right application, Jabulani connected his own tablet to the projector. This seemed to be a daunting task. There was no screen to project on. Therefore, Jabulani projected on A4 white papers he had pasted on the chalkboard. He tried to set the projector to full screen projection but he failed: The surface projected on was less than 1m^2. Then Jabulani read from his tablet the definition of a fraction and the whole class repeated after him.

> **Jabulani**: A fraction is a number that has got a numerator and a denominator.
>
> **Class** (repeating after him): A fraction is a number that has got a numerator and a denominator.

He then moved to the chalkboard. He used posters he had pasted on the chalkboard to explain what a numerator and denominator are. The posters had shaded areas similar to the illustrations below and Jabulani was writing his explanation on the side.



Jabulani (explaining while writing on the black board): In this diagram, the fraction of the shaded part is $^1/_4$. The top number is a numerator; the number on the bottom is a denominator. That is why $^1/_4$ is called a fraction.

Then he drew different circles on the chalkboard and divided them into different portions. He also shaded some portions in colours. He then proceeded with questions for learners to understand the difference between a numerator and a denominator.

Jabulani: How many parts are shaded?

A learner: 3

Jabulani wrote the number 3 on the side and placed a fraction separator next to it.

Jabulani: How many parts are there in total?

A learner: 8

Jabulani then wrote the number 8 after the fraction separator. Then he told learners that the fraction represented by the shaded portions was $^3/_8$.

Jabulani followed the same procedures for the drawings that remained.

Jabulani: How many parts are shaded?

A learner: 3

Jabulani wrote the number 3 on the side and put a fraction separator next to it.

Jabulani: How many parts are there in total?

A learner: 4

Jabulani then wrote the number 4 after the fraction separator.

Jabulani: So, what fraction is this?

Class: 3 over 4.

Jabulani moved on to the next drawing.

Jabulani: How many parts are shaded?

A learner: 2

Jabulani wrote the number 2 on the side and placed a fraction separator next to the number.

Jabulani: How many parts are there in total?

A learner: 4

Jabulani then wrote the number 4 after the fraction separator.

Jabulani: So, what fraction is this?

Class: 2 over 4.

Learners were then asked to use the tablet fraction application to complete the assessment task. The fraction application presented them with fraction models, and they had to choose from many options which fraction was represented by the shaded parts in the model. Leaners took turns in their groups to complete the activity. The activity took about 30 minutes. Jabulani walked around to provide assistance. After 30 minutes he asked the learners to put their tablets on the side. He then checked their scores. The scores ranged between 60% and 100%. He asked the class to clap hands for groups that scored 100%.

Some questions in the activity required the learners to have knowledge of equivalent fractions and knowledge of how to simplify fractions. Therefore, most learners failed to get the correct answers to those questions. Jabulani picked it up when he was checking their scores. Therefore, he quickly jumped to the chalkboard to show them how to simplify.

Jabulani: Listen to me now: You have to simplify the fraction to make it simple.

He wrote $^{1}/_{2} + ^{2}/_{4}$ on the chalkboard, and then addressed learners.

Jabulani: When you simplify you divide $\frac{2}{4}$ by $\frac{2}{2}$.

The moment Jabulani started to simplify, learners started looking confused. Then he wrote $\frac{3}{6}$ on the chalkboard.

Jabulani: How many times does 3 go into 3?

A learner: 1 time.

Jabulani: How many times 3 goes into 6?

A learner: 2 times

Jabulani: So $\frac{3}{6}$ equals $\frac{1}{2}$.

The lesson ended there but the learners still looked confused.

4.4.2.2 The analysis of Jabulani's first lesson on fractions

Jabulani's lessons will be analysed using the same analytical tool used to analyse Sandra's lesson.

a) The discursive mathematics event

Jabulani had enough mediational tools to engage learners and to help them develop fractions concept and skills, including tablet fractions application, posters, and fractions diagrams that he had sketched on the chalkboard. Learners also had papers for mathematics work. However, he did not use these tools to create a productive mathematics discourse in which learners were encouraged to share ideas.

Firstly, when the lesson started Jabulani firmly called learners to listen to him intently and to remember what he tells them. This was necessary to maintain order and to keep learners focussed. However, Jabulani should have explained to learners the importance of his instructions and expectations for them. He should also have invited them to interact, engage and contribute to the classroom mathematical discourse. Failure to do so resulted in learners simply listening quietly instead of sharing their ideas and reasoning openly. No learner attempted to ask a question, to add or to challenge Jabulani's description of the topic. It appeared that Jabulani does not tolerate mistakes, and therefore, learners were afraid of being rebuked for wrong answers.

Secondly, throughout the discussion Jabulani did most hands-on activities by himself instead of guiding learners or working with them as partners in the teaching and learning classroom conversation. He spent about 15 minutes of the lesson trying to set up learners' tablets by himself. While he was setting up the devices, the learners got bored and started making noise. This activity took less than five minutes in classrooms where teachers guided the process. In addition, throughout the lesson Jabulani was the only one who asked questions and wrote their answers on the chalkboard. As the lesson progressed, Jabulani stood in front of the classroom pointing to fraction diagrams and posters he had pasted on the chalkboard to show and explain fraction knowledge to the learners.

It is possible that the fraction models Jabulani sketched on the chalkboard helped learners to construct mental representations of fractions. However, the majority of learners were just following and listening passively. By not engaging learners through mathematical discussions, Jabulani missed out on hearing from learners and learning about their mathematical ideas on the fractions topic. He failed to let learners use the Chalk application to draw their own models to demonstrate a deeper understanding of the concepts, to discuss relationships between concepts of numerator and the denominator or to apply the concepts to everyday life. The use of tablets in the discursive event could have given the learners interactive fraction models to help with the interpretation of the fractions concept. Because of these opportunities that were missed, it cannot be guaranteed that the learners gained a deeper understanding of fractions. It can also be difficult to say what and how much learners grasped, as there were no opportunities for them to give narrative accounts of what they had learned. It limited the ability to receive feedback, to reflect on and to adaptive own understanding of fractions.

It should be remembered that the learners in Jabulani's classroom were all black Africans from the surrounding townships. In this milieu, people use indigenous languages for communication and social interactions. So engaging learners through discussion not only could have helped to develop their conceptual and analytical understanding, but it also could have allowed Jabulani to check if learners where using formal mathematics language to express their ideas and to describe their understanding of the fractions. This could also have been an opportunity for him to fine-tune learners' mathematical English vocabulary. There was an instance where he read the definition of a fraction and the whole class repeated it after him. A follow-up question to ask learners to define the fraction concept in their own words or to give examples of fractions should have helped to ensure that learners did not just memorise the definition without understanding it.

Finally, because of the learners' lack of engagement in the discussion, there were no shaping and reshaping of the discussion to meet the learners' learning needs and to prepare them for the experimental task. The discursive event was straightforward with Jabulani leading it in his own direction. A pedagogically sound discursive event should provide opportunities to ask questions, to offer own ideas, receive feedback to improve understanding, and discuss ideas with other learners in the classroom. These features were rare in Jabulani's constructed discursive event.

b) The experiential mathematics event

The use of tablets in the experiential event provided learners with the opportunity to experience fractions through their own engagement with the content and interactions with peers; the opportunity they had not been given in the discursive event. The experiential task was a multiple-choice activity on fractions that presented learners with a fraction numbers and different fraction models for the learner to choose the model that best represented the fraction number. It also had activities on addition and subtraction of fractions. It afforded learners the opportunity to practice and to engage with the topic content without necessarily being limited to the confines of Jabulani's linear presentation.

The experiential task had different levels and used different fraction models, thus accommodating a range of learning preferences. Learners who were passive in the discursive event became very dynamic while doing the experiential task. They moved between rows with tablets in their hands to seek assistance from their peers. This was an indication that Jabulani's teaching approach in the discursive event had denied them this opportunity for social construction of knowledge. It appeared that the decision to allow learners to use tablets in groups was for convenience. There were too few working tablets (about 20 devices) and it was not possible for him to ask learners to complete the task individually. He indicated during the interview that he is not keen on collaborative work. He argued that it makes the classroom environment difficult to control while providing competent learners the opportunity to show off their skills and knowledge at the expense of their peers.

Learners' scores on the tablet activity were good. They ranged from 60% to 100%. It is possible that the way the tablet activity was designed contributed to these scores. It provided instant feedback and opportunities to try again. However, getting a very high score does not guarantee that learners understood the activity and the mathematical processes that were required to complete it. Some learners were observed guessing instead of working answers out. In addition, Jabulani had given them papers to use to work the answers out but most papers were still blank after the activity had been completed. This means that most learners guessed answers. Some learners even got right answers for questions that were beyond their cognitive level and of which they had no prior knowledge. However, they failed to explain the computational procedures they followed to get the right answers when Jabulani asked them to do so. This included questions to simplify equivalent fractions, which was to be covered in a couple of weeks to come. This again confirms that learners simply guessed answers. It also suggests that learners might previously have played the same educational game and were familiar with the right answers. Therefore, there should have been multiple forms of activities for learners to demonstrate their understanding or to experience fractions in many ways. Such activities could include asking learners to formulate own fractions, to represent fractions using different models, to pose fractions problems and to solve them.

When checking learners' scores Jabulani noticed that most learners had failed the questions on simplification of equivalent fractions. He immediately acknowledged that he mistakenly gave learners the task too early in the curriculum. Simplification of fractions was also not part of his lesson plan. The lesson plan indicated that he was to teach learners how to describe and compare common fractions in diagram form. In the Curriculum and Assessment Policy Statement, simplification of equivalent fractions was also to be tackled four weeks later. He therefore acted quickly and jumped to the chalkboard to demonstrate the step learners should have taken to answer questions on simplify of fractions. However, this did not help learners. The majority of learners looked more confused after the teacher's demonstration. Normally learners should master addition, subtraction and multiplication of simple fractions before they can learn how to simplify fractions as this involves complex and multiple operations. The above demonstrates the pedagogical value of adaptive applications to promote reflective and adaptive teaching. Without the power of adaptive applications to record learners' progress, it was going to be difficult to know the mistake he had made by giving learners an activity too early in the curriculum.

In summary, Jabulani's lesson does not reflect a successful instructional mathematics conversation. The discursive event did not provide learners opportunities to offer own ideas, to ask questions and to challenge mathematics ideas of their peers. This means learners had limited opportunities for feedback. Feedback is important as it leads to reflection and adaptation of understanding. The discursive even did not use various forms of media to give learners enough tools to connect ideas. Although the use of tablets in the experiential task provided learners with some level of interactivity and autonomy, it has been clear that the later did not link well to the discursive event. The experiential tasks should aim to deepen the understanding of the knowledge constructed at the discursive event.

4.4.2.3 Jabulani's second lesson on addition and subtraction of ordinal numbers

In the next period, Jabulani changed the topic to addition and subtraction of ordinal numbers. The second lesson followed the first lesson immediately without a break in between.

> **Jabulani**: We are done with fractions. Now we are going to do addition and subtractions. We will use the same tablets.

Then, Jabulani gave learners sheets of papers to use for adding and subtracting. Learners read questions from the tablet application, worked answers out on the paper then clicked to choose the right answer from the many options the tablet provided. As in Figure 23, the activity was too simple for sixth grade level. Jabulani hardly moved between rows to check the progress. There was a lot of noise and this made Jabulani to shout at them.

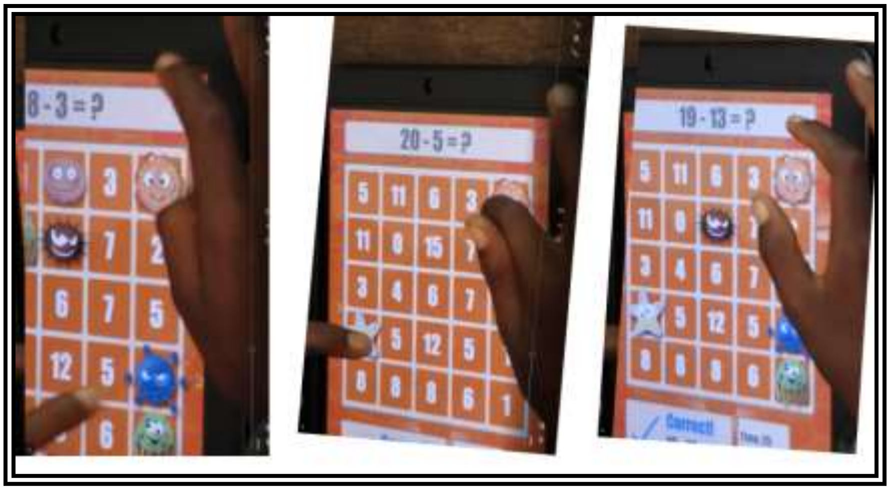


Figure 23 Example of adaptive activities learners engaged with

Figure 22 shows the kind of adaptive activities learners completed with the tablets. These activities were too simple for Grade 6 learners. Jabulani moved to check each group's score and the lowest score was 84%. After he had checked the scores, he went to the chalkboard to explain the method of adding and subtracting. He also highlighted common mistakes learners made. However, learners seemed disinterested and were just making noise. Jabulani stopped for a while waiting for learners to keep quiet and then he rebuked them. It appeared learners were exhausted from having two consecutive and different mathematics lessons.

> **Jabulani**: You must listen to the instructions. When I say 'Please listen' you are supposed to listen. I told you, you are going to start from question 1 to 10 but others went to number 17. Listening is a skill. If you cannot respect now what is going to happen when you get to Grade 9? Some people have got 100%, others 80%. It is still good but you need to improve.
>
> It was break time and the lesson ended.

4.4.2.4 The analysis of Jabulani's second lesson on addition and subtraction of ordinal numbers

a) No discursive mathematics event, no experiential mathematics event

The second lesson on addition and subtraction of ordinal numbers did not reflect the two events of an instructional conversation depicted in the conceptual framework of this study. Jabulani simply asked learners to complete the tablet activity without telling them the objective of doing the activity and what concepts they were to learn as they do the activity. The activity did not even link to the concepts learned in the first lesson. This activity cannot be regarded as a discursive event or an experiential event because the events of an instructional conversation need to always be goal oriented. Both Jabulani and learners looked tired so it seemed he wanted to rest while keeping the learners occupied. The evidence is that he did not also have a lesson plan for this lesson and he immediately sat down after giving learners the activity. He seldom stood up to check their progress. With that in mind, tablets were not used to augment learners' knowledge about the topic but to substitute Jabulani's role. Compared to the previous lesson on fractions, learners were not excited and enthusiastic. It can be argued that lack of motivation and interest were caused by the simplicity of the task and the disjuncture between the task and the previous topic.

In the previous lesson, learners were intrinsically motivated to use tablet but this was not the case in the second lesson. They showed less interest in the activity. This was manifested through the noise they made while completing the task. Failure to adhere to Jabulani's instruction also proved that they were not paying attention. Jabulani had instructed them to start the activity from the lowest difficulty level and to stop at level 7. However, the majority of learners did not start from level 1 or they went beyond level 7. It could be that they only wanted to do an activity that interested them or that they were not listening when the instruction was given. Lack of motivation and interest in the second tablet activity suggests that it is not the tablet per se that motivates learners but the teacher mediation, the purpose of doing the tablet activity and the nature of the tablet activity. It is possible that learners could have focussed fully if Jabulani had linked the task to the knowledge they had previously learned. It is also possible that learners could have shown interest if the tablet activity was a bit more challenging. Clearly, as Figure 23 indicated, the activity was not at their grade level and thus their scores ranged from 84% to 100%. Such scores are not easily obtained in a class of 52 learners and in the teaching and learning setting where learners are still grappling with the English medium of instruction.

Also in the second lesson, the affordance of adaptive applications to keep a record of the learners' progress helped him to identify where most learners fell short in terms of adding and subtracting. Just like in the previous lesson, he quickly reacted by providing explanations to bridge the knowledge gap. A lesson learned from his reactions is that despite the eagerness to quickly rectify the mistake, it could have been appropriate not to do it immediately. He should have considered the learners' attention span as in both cases learners showed signs of being tired. He also should have given himself ample time to prepare thoroughly and then to address the mistake when the learners' minds were fresh.

In brief, Jabulani's second lesson shows gaps between his perceptions about the value of tablets in his teaching and his actual teaching. He claimed he uses tablets for meaningful learning of mathematics concepts but as the above indicated, the devices were used to drill and practice multiple choice mathematics activities, which did not align with the topic goal. His lesson also lacked the events of an instructional conversation that are necessary to support a deeper understanding of mathematics concepts. Lack of the discursive event in the second lesson deterred learners from engaging intelligibly with the tablet activity; they just guessed answers. Jabulani's lessons remind us about the role of the teacher's mediation for a successful mathematics conversation mediated by technology. The use of tablet technology in his lessons did not yield significant learning gains because he did not mediate it well.

4.4.3 Samantha's Lesson on Adding Fractions with a Common Denominator

Samantha is a sixth grade mathematics teacher in School B. At the time we collected the data, Samantha had been in the teaching profession for 15 years, teaching sixth grade mathematics in particular. She believes in the potential of tablets to engage learners in collaborative learning and with mathematics content. In her Grade 6C class there were 45 learners seated in groups of five learners. Each group had a tablet. Many tablets devices were put aside as they were not working.

The lesson started with Samantha announcing the topic of the day and assisting learners to get to the tablet application she wanted them to use to complete the warm-up activity. In Samantha's class, each lesson starts with a mental mathematics activity to wake learners' minds up and to pull their attention into the new lesson.

> **Samantha**: Our topic is adding fractions. We will be adding fractions of common denominators [She wrote the topic on the chalkboard]. However, for the introduction of the lesson we start with a mental mathematics activity. Let us all go to the Chalk application on our tablets. Switch it on. If you come across any problem just call me. Just raise your hand. We slide to unlock. Is it open?
>
> **Class**: Yes, Ma'am.
>
> **Samantha**: Let us look for the chalkboard all of us. Are we all there?
>
> **Class**: Yes.

In addition to the Chalk application, Samantha had papers for learners to use for calculations.

> **Samantha**: You are going to use the papers I am giving you to work answers out. After that, you write down answers on your tablet chalkboard. Do we all understand?
>
> **Class**: Yes, Teacher.
>
> **Samantha**: I will repeat! With this paper, everyone is going to work out answers and after doing that, you write your answers on your tablet.

The questions were written on the chalkboard. Each learner worked answers out on a piece of paper, and then all group members compared their answers to decide on the correct answer. These were then written on the Chalk application.

While learners were still doing the mental activity, Jabulani came in to help connecting Samantha's tablet to the projector. After 15 minutes, learners were asked to stop, and then Samantha assisted with corrections. She called learners one by one to do corrections on the chalkboard. After calculations on the chalkboard, the entire class verified the answers before they were written on the teacher's tablet connected to the projector. Learners referred to the answers projected to mark their own work. This took about 15 minutes. After corrections were made, Samantha checked the scores and asked learners to clap for the group that had scored the highest. She then guided learners to the second tablet application they were to use in the new lesson.

> **Samantha**: Now let us close the Chalk application. Let us type 'adding fractions'. Are we all there?
>
> **Class**: Yes, Teacher.
>
> **Samantha**: Can you see this icon here [showing on the tablet]? It looks like a bar. Let us click on it. Did you go there?
>
> **Class**: Yes, Teacher.
>
> **Samantha**: Remember I told you that we are going to add fractions of common denominator. Do you see that arrow on your tablet?

She waited a moment and then continued to give instructions.

> **Samantha**: Click on it, and then you will see another icon for settings on the top right corner. Let us go to common denominators and click on adding. If you are not there, just raise your hand. You have ten multiple-choice questions to answer. Now you can begin. Answer all 10 questions. Remember, remember, and remember: You work out your corrections first. Remember to compare your answers before you choose from your tablet. It will automatically tell you whether you are correct or wrong; then it will give you the total.

Before doing the task, learners were observed using the 'Important Terms' section to learn or to remind themselves about mathematical concepts they expected to encounter in the game activity. It appeared that learners were familiar with the game. It was not really a challenge for them to complete the task. Some learners even finished the task in less than 10 minutes. It is likely that the teacher had introduced the same activity when she introduced the topic the week before. This was also confirmed by the fact that the teacher did not engage learners in the discussion on how to add fractions. She just gave them a practical activity straight away and the learners appeared comfortable.

While the learners were engaged with the task, Samantha walked around, watching them work and occasionally speaking to them in their groups. After 15 minutes, she asked them to stop. She moved from one group to another checking their scores and congratulating them. She then asked learners the challenges they encountered while doing the task and questions that needed more clarity. All learners seemed to be at ease and no one asked a question. For homework, she asked them to solve fraction problems, which were in their textbooks, and to make representations of those fraction problems using different fraction models. Then the lesson ended.

4.4.3.1 The analysis of Samantha's lesson

Samantha's lesson reflects the experiential mathematics event. Although there were some mathematics discussions when learners engaged with the activity and during whole classroom corrections, this cannot be regarded as a discursive mathematics event. This is because, the discussion that occurred did not aim for the construction of conceptual understanding of concepts but rather to deepen the conceptual understanding learners had constructed in the previous lesson when the topic of Fractions was introduced.

a) The experimental mathematics event

Rather than having one outspoken teacher and 45 passive learners, as in a traditional classroom, Samantha's lesson featured an experiential event in which small groups of learners interacted, discussed, and voiced their opinions to complete the group task. Throughout the lesson learners engaged with the task with the assistance of the teacher. Samantha visited them in their groups to ensure everyone participated and occasionally spoke to them to check if they had encountered any difficulty.

Having learners trying out the task and comparing their answers in their groups fuelled the discussion between group members as each learner had to argue for their answer or to receive explanations on why their answer was not correct. This possibly caused a change in learners' conceptual understanding. It also motivated and encouraged them to take up the challenge to exercise their computing abilities rather than guessing answers without understanding. It was interesting to see how the discussion grew from the group level to the whole class discussion. This happened when individual learners were called up to do corrections on the chalkboard. It is possible that collective corrections by learners and the verification by the whole class helped learners to change their mental schemes, misconceptions, and cognitive conflicts that arose during the group discussion. In one of the groups learners argued as they did not agree on the right answer, but when corrections were made on the chalkboard, the learner whose answer was rejected by the group members was heard saying, “You see! I told you it was the correct answer but you refused”. This is an indication that collective correction on the chalkboard might have helped to settle cognitive conflicts between group members.

The discursive event as we know it did not take place in Samantha’s lesson. Of course, there was some discussion going on when learners completed the group task and during whole class correction but this does not make a discursive event. The discursive event is led by the teacher with the purpose of introducing learners to the concepts and ensuring that learners develop a conceptual understanding of those concepts. One expected the lesson to start with Samantha and her learners engaging with the knowledge of what fractions are, what numerators and denominators are, and the knowledge of how to add common fractions so that learners can comprehend and assimilate related general algorithmic rules. Although Samantha indicated that she had introduced this topic the previous day, the knowledge covered in the previous lesson should have been reviewed before engaging learners in the experiential task. The teacher’s description of concepts in the discursive event is important as it allows learners to learn key concepts, rules and ideas while preparing them for the experiential task. It also allows the teacher to see ideas and the thinking learners bring into the lesson for the purpose of refining or expanding on them.

Tablets were first used in the warm-up activity to record answers. Although this would have been possible with paper, it appeared that Samantha chose tablets to give learners an intrinsic motivation. Learners in most classrooms showed greater interest and concentration when they were using tablets in the lesson. Indeed, during whole class corrections in Samantha’s class learners strived to go to the front to make corrections. It appeared that they were motivated by simply writing the final answer on the teacher’s tablet, which was connected to the projector. In addition to motivating learners, the tablet allowed the teacher to share answers with the whole class, and this enabled learners to mark each other’s work. This also saved the time the teacher would have spent marking learners’ work one by one. To ensure that the learners had been honest when marking their own work, Samantha randomly picked five marked tasks and checked how well they were marked. No dishonesty was found in the way they had been marked. This was an indication that learners have learned the skill of how to act responsibly to enhance their own learning.

Using tablets to record answers provided opportunities for enriched communication and collaborative interactions between group members. In the warm-up activity learners had to vote for the correct answer to be recorded on the tablet. In this regard, learners were also observed explaining to their peers how they worked out their answers and this made it easy for group members to identify the mistakes they made and to learn the correct computations. It can also be said that the motivation to succeed on the tablet activity fuelled learners’ behavioural engagement and collaboration. They collaborated in order to achieve the highest performance. It appeared that to be a classroom culture to clap for learners and groups that perform best on assessment activities, and so each group strived to get this recognition.

The tablet adaptive application generated different types of questions that embedded multimedia resources to scaffold learning. Learners could refer to either the fraction models or fraction problems to answer the questions. The interface also had a resource button where learners got additional information to expand their understanding of the concepts, thus providing learners with narrative descriptions of the topic through the media of text. While learners were choosing answers, immediate feedback was generated. Learners were therefore able to know whether their answers were correct or wrong. In situations of incorrect answers, the tablet provided the learners with hints. The simulation game allowed groups of learners to monitor their own progress without the assistance of the teacher. This could not have been possible in a traditional classroom where learners wait for the teacher to check how well they have performed for them to progress.

Samantha believed in the potential of tablets to arouse learners’ interest in mathematics lessons and to make mathematics lessons an active teaching and learning process.

Indeed, as the above showed, learners were active participants in the lesson in the warm-up activity, the experiential activity and whole class corrections. The warm-up and the experiential activities were self-directed in a way that learners worked on their own and Samantha intervened only to check the progress and to provide some guidance. In the experiential activity in particular, the tablets provided timely feedback, thus allowing learners to timely reflect on their mathematical knowledge.

In the interview, Samantha shared that tablets encouraged group work and allowed learners to learn from their peers. Indeed, during lesson observations, the tablet activities she provided learners required them to work together and to support one another. Each learner in the group had to work answers out individually and then all group members compared and contested their answers prior to selecting the answer on the tablet grid. Weak learners benefited from the explanations from their group members. Mathematical discussions, which happened in the group and during whole classroom corrections, also provided learners with multiple perspectives to construct a meaningful understanding of mathematical concepts and fractions, in particular. One important aspect that lacked in the lesson was the discursive event in which Samantha would have provided her own description of the concepts at the beginning of the lesson.

4.4.4 Sabina’s Lesson on Fractions

Sabina was the second most experienced of the teacher participants. She has been a teacher for the past 20 years with 15 years teaching sixth grade mathematics. She was very positive about the pedagogical value of tablets in her teaching. She believed the tablets have made it possible for her to teach topics that used to be difficult. She appreciates the value of tablet resources to make mathematics lesson more interesting to learners and to provide learners with personalised learning experiences. The following is the report of a lesson on fractions observed in her class.

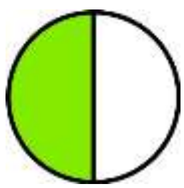
There were 40 learners in Sabina’s Grade 6B. Learners sat in small groups of four each. To start the lesson Sabina posed the question: What is a fraction? Seemingly, learners did not have any prior knowledge of fractions. They gave many answers but not all were correct. So Sabina was compelled to tell them what a fraction is. While learners seemed not to understand the concepts of numerator and denominator, Sabina told them not to get frustrated. She assured them that each learner would understand these concepts as the lesson progressed.

Then she gave each learner four circle shaped papers. She asked them to fold the first paper once and to open it again. Then she posed questions to the learners to find the number of parts the paper had been divided into.

Sabina: How many parts the paper has been divided into?

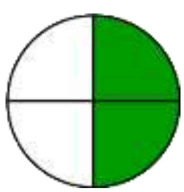
A Learner: 2 parts.

Sabina: It was a whole; now it has been divided into 2 parts.



She asked learners to colour one part, then to put the paper aside. Sandra also drew a schematic representation of the paper that had been folded on the chalkboard.

As the lesson unfolded, she asked learners to take a second paper and to fold it twice and then to open it.

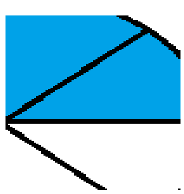


Sabine: How many parts has the paper been divided into?

Class: 4 parts.

Sabina: Colour 2 parts.

She also sketched on the board.

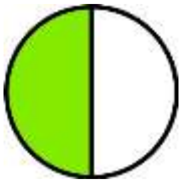


Sabina: Now fold your last paper into 3 folds and then open it. How many parts do you have?

Class: 8 parts.

Sabina: Colour 6 parts.

When learners had used all the papers Sabina asked them to put them aside and to look at the board. She then used her schematic representations to explain the concepts of numerator and denominator. This was probably intended to help learners develop fractions abstract mental schemata.



Sabina: This circle is divided into how many parts?

A learner: 2

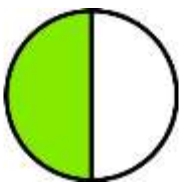
Sabina: How many parts are shaded?

A learner: 1

Sabina: So give me the fraction of the shaded part. What fraction does it represent?

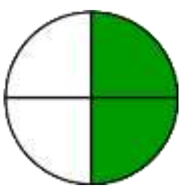
A learner: 1 over 2.

Sabina: Good. 1 part out of 2 has been used.



$^{1}/_{2}$

She then wrote the fraction ½ next to the schematic representation, and then moved to the second representation.



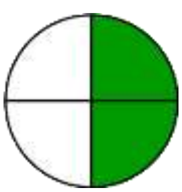
Sabina: How many parts has this circle been divided into?

A learner: 4 parts.

Sabina: What fraction is represented by the shaded parts?

A learner: 2 over 4.

Sabina: Well done!



$^{2}/_{4}$

She then wrote the fraction number $^{2}/_{4}$ next to the representation.

The lesson followed the same pattern until all the sketches were used.

In the remaining time of the lesson her focus was to help learners discover for themselves the difference between a numerator and denominator.

Sabina: A fraction has two parts: There is a numerator and a denominator. Tell me now, which one is the numerator in this fraction?

A learner: It is the number that is up.

Sabina: It is the number that is on top [the teacher refined the learner's mathematical language]. Where is the denominator?

A learner: The numbers that are down.

Sabina: The numbers that are at the bottom.

Sabina moved the conversation forward to encourage learners to give a descriptive explanation of the concepts of numerator and denominator.

Sabina: From what you see here, how can you explain to me what a numerator is? Look at your papers and the drawings we have on the chalkboard.

A learner: A numerator is a number you can divide and you can count.

Sabina: Please help him. What is a numerator based on your observation and your experience of what we did?

A learner: A numerator is the number on the top of a bottom number.

Sabina wanted to take learners' thinking beyond mere representations of the fractions that were on the chalkboard. So she paraphrased her questions using examples to see if learners would develop a conceptual understanding of the numerator and denominator.

Sabina: Practically we divided papers; we divide a whole into parts. We divided the first paper into …

Class: … 2 parts.

Sabina: We divided it into 2 parts and we only highlighted 1. What is a numerator?

A learner: A numerator is a shape that is coloured in half.

Sabina: Huh, help him! What is a numerator?

A learner: It is a fraction that is coloured or marked.

Sabina: I can say to you that a numerator is the part that has been used or the part that has been coloured. Did we colour the whole circle?

Class: No!

Sabina: We only used this one. We are using this part. Therefore, the numerator for this one is 2.

The lesson progressed in the same way until learners were able to identify the numerator for all fractions written on the chalkboard. Then Sabina moved to the denominator.

Sabina: Now go back to your papers. How many parts do we have in total?

Class: 4

Sabina: We divided the whole into 4 parts, so our denominator is 4. How many parts are here?

Class: 8

Sabina: The denominator is…?

Class: 8

For the assessment activity, Sabina wrote fraction word problems on the chalkboard then asked learners to use the Chalk application to present the same problem using different fraction models while indicating the numerator and denominator. Here are some examples of the word problems:

1. If I had a farm and divide it equally between my four children, three boys and one daughter. What is the fraction of the farm that will be allocated to boys?
2. If Tom has already eaten 2 of his 8 pieces of pizza, what is the fraction of the pizza that is left?

She also asked each group to create their own fraction word problem and to present the solution using fraction models. Some groups used circles, others rectangles. The first two groups presented their answers to the class. However, due to language challenges some learners opted to write and present their word problems in their home language.

4.4.4.1 The analysis of Sabina's lesson

The analysis of Sabina's lesson shows a balanced classroom environment in which participation in mathematics discourse was a collective responsibility. There was a dynamic exchange of ideas between the teacher and learners and learners themselves with Sabina leading and guiding the conversation toward the topic goal. She helped learners think through the topic, prompted their thinking, provided feedback and adjusted her teaching approach to provide learners with the appropriate scaffolding. Sabina's lesson will be discussed in the following instructional events: the discursive event and the experiential event.

a) The discursive mathematics event

The discursive event was characterised by Sabina presenting and discussing her understanding of the topic with her learners. It looked like the learners were being introduced to the topic for the first time so Sabina started by diagnosing their prior knowledge of fractions. The question she posed "What is a fraction?" at the beginning of the lesson aroused learners' cognitive and behavioural engagement in the classroom discourse. They tried to draw from their knowledge repertoire the answers to the question the teacher had posed. It was interesting to see that many learners freely offered to respond to the question about the new concept. Although the learners were not able to give an answer that satisfied the teacher, the question captured their interest and brought their attention to the lesson. In other words, it made them ready to learn about the topic. It also allowed Sabina to know what the learners knew about the topic; therefore, she was able to start at a lower level. All this was done without technology.

The learners did not know anything about fractions, and therefore Sabina started by explaining what fractions are. Even after she had explained, learners were still finding it difficult to conceptualise fractions, especially the abstract concepts of numerators and denominators. She therefore supported her explanations with the use of manipulatives and visual representations. Engaging learners through hands-on activities of folding papers and colouring parts of the paper provided learners with procedural knowledge of fractions and helped making the fractions concepts more concrete to learners. Progressively, her teaching became more complex as the learners became acquainted with the fundamentals.

The questioning approach helped to reveal learners' misconceptions about fractions. In all their answers learners were referring to numerators as something you can divide in half and colour. This proved the importance of the discursive event to expose gaps in the learners' knowledge. She kept asking unending questions until gaps in their knowledge were exposed, thus allowing her to remove the misconceptions about the concepts. In this regard, Sabina changed her teaching approach to make the topic easy for learners to understand. She shifted from using tangible folded papers to explaining the numerator and denominator concepts and started explaining using numbers and visual representations sketched on the chalkboard. This was to help transform concrete representations into abstract representations of fractions.

Although numbers and visual representations helped to explain what numerators and denominators are, the questions Sabina posed at the end of the discursive event revealed that some learners were still viewing the numerator and denominator as separate numbers rather than a unified number. Therefore, she ended the discussion with a general remark that numerator and denominator are parts of the whole, with the numerator representing the part that has been used and the denominator representing the total parts of the whole. It is not clear that this helped learners to understand the two concepts as a unified number because there was no follow-up question after Sabina's general remark.

The discursive event in Sabina's lesson showed the importance of helping learners develop mathematical language proficiency. Learners lacked specialised mathematics language to converse about fractions but this did not stop them from engaging in the discourse. Their motivation and interest in the lesson encouraged them to try to express their ideas, and the teacher helped them make their ideas much clearer.

Sabina's lesson also demonstrated that it is possible to have a fruitful discursive mathematics event even in classes where the medium of instruction is not the learners' home language. She had the ability to influence learners' communication and participation, to inspire learners to express their thinking and to embrace the thinking of their peers as they participated in the discourse. However, as the gaps were exposed, Sabina spent ample time attempting to the bridge gaps in their knowledge before she moved on. Therefore, the discursive event also requires a teacher who is patient and who understands learning difficulties learners may be experiencing. It is important to remember that Sabina mediated the discursive event using manipulatives and fraction diagrams sketched on the chalkboard. Tablets were used in the experiential event to engage with the knowledge constructed in the discursive event.

b) The experiential mathematics event

The discursive and experiential events were so intertwined that it was difficult to separate the two. Throughout the lesson there were practical activities followed by discussions and vice versa. Even after the major activity at the end of the lesson, there was a follow-up discussion as learners presented their work. However, this study will consider as experiential task the major practical task the learners did on tablets at the end of the lesson as this was intended to give them the opportunity to experience fractions independently from the teacher's guidance.

Sabina's experiential activity required learners to use the Chalk application to produce fraction models based on the fraction word problem they were given. Fractions word problems helped learners to see fractions in their everyday life. For example, the fraction word problem like "If Tom has already eaten 2 of his 8 pieces of pizza, what is the fraction of the pizza that is left?" can help learners to relate the knowledge of fractions to the notion of sharing they are familiar with in everyday life. This was different from activities observed in other classrooms in the same school where teachers simply asked learners to play educational games.

While this study is not contesting the use of educational games, in some instances, like in Jabulani's class, game-based activities diverted from the topic goal and required learners to respond to activities of which they had no prior knowledge. In addition, game-based activities were either below or above learners' grade level. In other instances, game-based activities allowed learners to simply guess answers without understanding. Sabina's experiential task involved the higher-order cognitive skills of creating their own fraction models. It was interesting to see the variety of models learners produced to demonstrate higher level of understanding. Learners used numbered lines, circles, and rectangular shapes. It should be remembered that Sabina had only used circle models in the discursive event. Therefore, learners demonstrated their own creativity by using other models they were not taught with. The two groups that finished first were asked to present their work to the entire class, and then the audience asked questions pertaining to the choice of the model and the fraction word problem. This again allowed hearing from learners how they conceptualised the topic.

Reflection was an important aspect of Sabina’s lesson. It occurred spontaneously and this was demonstrated through a quick change of the teaching approach. For instance, when Sabina saw that learners could not explain the numerator concept without referring to the papers they had just folded, she quickly asked them to put papers aside and then explained the concepts using visual representations. That seemed to be an immediate response to the reflection of own teaching approach. She also fostered learners to reflect on their actions and responses by asking unending questions, providing feedback and paraphrasing questions throughout the lesson. She encouraged the class to pose questions and to respond to the questions posed. Obviously, learners had to recall the knowledge they learned for them to be able to ask questions or to respond to them.

In Sabina’s lesson, tablets were used at the end of the lesson to provide learners with tools to demonstrate a higher level of understanding. In this regard, learners used the Chalk application that provided them with tools such as pen, brush, eraser and colours for them to produce their own fractions models. Learners could draw and erase until they had the model they were happy with.

Tablets allowed learners to communicate their ideas to the whole class. Two groups were selected to share with the entire class what they had produced. The presentation resulted in many learners asking questions with regard to the choice of the model, and an explanation of the concepts of numerators and denominators. It can therefore be argued that using tablets for producing and sharing the fraction models helped to build learners’ thinking and communication competences.

For learners to produce a fraction model, they had to engage with the content that was covered in the discursive event. They also had to understand the fraction word problem to be able to present the solution using fraction models. Therefore, they worked together as a group. They were observed having interactive discussions in their groups as they used the Chalk application to produce their own fraction models and to generate their own word fraction problem. Tablets played a significant role in the problem-solving process. The materials that formed the object of the discussion was on the tablet screen.

While trying many alternatives to solve the problem, the tablet provided learners with an array of graphical representation tools to present their solutions.

In brief, Sabina's constructed mathematics conversation appears to have captured certain important pedagogical aspects of the instructional conversation, which are important to meaningful learning. The teaching and learning process was participatory and conversational. Learners deliberately participated in the sharing of ideas in the whole classroom instruction, with Sabina clarifying and expanding on shared ideas. Sabina mediated the conversation using different approaches including manipulatives, visual representations, questioning approach, and a collaborative task with an attempt to reach every learner's need in the classroom. The experiential task was anchored in social practices. It was also knowledge creation oriented and involved learners actively working together to come up with solutions to fractions word problems. Learners used tablet productive tools to construct a model that would best present their solutions. Obviously, the problem-solving process and presenting the solutions was a messy process that required effective communication, joint decision-making and working, and reworking on the model until learners were happy with the model. It was fascinating to see that learners who did not seem to have the knowledge of fractions when the lesson was introduced were able to solve fractions word problems at the end of the lesson. The lesson did not only build the understanding of fractions but it also developed learners' mathematical language. It also removed the misconceptions learners had about the topic.

4.5 Section Summary

This section presented the analysis of the data relating to the second research question of this study: How are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics translated into pedagogical actions in the actual teaching of sixth grade mathematics?

The data were collected through the observation of teachers teaching with tablets during five mathematics lessons. The analysis of the data showed that the use of tablets in sixth grade mathematics is promoting a move toward a meaningful mode of teaching. It enabled the majority of teacher participants to visualise mathematics concepts using tablet media. In most classrooms learners were not passive receivers of mathematical knowledge and facts but were meaningfully engaged in instructional mathematics conversation. The use of tablets enabled teachers to intertwine mathematical discussions with practical tablet activities. It promoted shifts from the use of physical manipulatives and objects in the classroom for concrete representation of mathematics concepts. It allowed to the use narrative and interactive media for abstract representation of concepts. It also provided opportunities for differentiated learning by providing an adaptive learning environment in which mathematics tasks were completed by learners themselves using the instant feedback the application provided. The easy portability of the devices promoted social learning. Learners moved around in the classroom to share the information on the device screens and to seek assistance from their peers. Productivity tools such as the Chalk application allowed learners to produce mathematical knowledge and to present mathematical ideas and solutions in different ways to demonstrate higher-order learning.

The most important point to remember in this section is that teachers' mediation is important if learners are to have meaningful learning experiences from the teaching that uses tablets. In the studied schools, teachers mediated the discursive events using a combination of tablets and traditional media to bridge the content gap between the tablet applications and the CAPS, to accommodate the diversity of learning needs, and to help learners make mental connections between the curriculum, the tablets and their everyday lives. The mediational role of the teacher in the instructional events allowed them to remove mathematical misconceptions by learners and promoted the development of specialised mathematical language as opposed to the everyday language learners used to express mathematical ideas.

This section also shed light on the teachers' agency in designing meaningful tablets mathematics tasks. It showed that the teacher is the driving force for effective learning to take place using tablet technology in the classroom. On one hand, some mathematics teachers such as Sandra and Sabina designed an instructional conversation that involved both the discursive and the experiential events. They designed tasks that compelled learners to carefully engage with the content trying to make sense of it and to use the knowledge constructed at the discursive event to generate many possible solutions to mathematical problems. In their classrooms, the use of tablets allowed learners to apply mathematical knowledge to real life problems and create knowledge using tablet productive tools. In other words, the use of tablets in their classrooms promoted higher cognitive processes. On the other hand, Jabulani struggled to construct a full instructional conversation. In one instance, the lesson had an experiential event only. In the other instance, the experiential event did not link well with the discursive event. The use of tablets in the instructional conversation in his classroom was focussed on the lower knowledge. Learners were engaged in multiple-choice tablet tasks that some learners completed just by guessing. There was no opportunity available for learners to transfer the knowledge to new situations and to use the knowledge to solve real mathematical problems. Such teaching cannot be said to provide a long-lasting effect as it involved the lower cognitive level. While the majority of the participants taught in ways that aligned with their perceptions about the pedagogical value of tablets in their teaching, this section showed gaps between Jabulani's perceptions and his actual teaching.

4.6 Challenges impacting teachers' use of tablets

The theme above relates to the third research question of the study- What challenges impact teachers' use of tablet technology in the teaching of sixth grade mathematics? The data to answer this research question were collected from lesson observations and interviews. The ICT documents also provided the information that was used to supplement teachers' views. Three main challenges were identified to affect the teachers' use of tablets in mathematics teaching: the lack of supporting technological infrastructure, the lack of onsite support and the lack of ICT policy support.

In the previous sections teachers expressed how the lack of internet connectivity affects their teaching negatively. They complained that it deprives them the opportunity to access many educational applications that could benefit their learners' learning. In respect of this, Samantha shared that she would like her learners to know different mathematics applications and how to do some research using the internet. Sandra also shared that the lack of internet connectivity does not allow her to have specific educational applications on each topic. She shared the same sentiment with Sabina who also expressed her unhappiness regarding the lack of access to YouTube videos to enrich learning.

All the concerns above show that there are several opportunities that are missed due to the lack of connectivity. Jabulani opined that it would still be difficult to have access to educational applications even if internet connectivity was available in the school. He blamed the socioeconomic status of the school for the lack of educational applications they wish to have.

> To get new applications is about money. The school has no budget for that. ... Truly, we need more applications on how to calculate the square root, and how to change the percentage into decimal fractions. We need all those applications but it is a lot of money. - Jabulani

While Jabulani's comment provides more insights into the factors affecting access to more educational applications, it is worth adding that there are thousands of educational applications that are free of charge. Teachers could be using them if they were able to connect the school tablet devices to the internet.

The lack of enough devices was also another challenge believed to affect teachers' use of tablet technology in the classroom negatively. In most classrooms tablets were used for small group learning because each learner could not get his own device to use. There were very few working devices. Samantha felt the school should buy more tablet devices so that each learner can at least have an opportunity to be tested individually, and that the teacher is able to try with different teaching approaches.

> It would be nice if we can have every learner with his own tablet so that we are able to test them individually. We were hoping that by this time of the year we will have more tablets so that every child can have a tablet of his own, but that did not happen. –Samantha

> We only have two suitcases which are full. In some instances the Foundation phase wants to use them, the Intermediate phase wants to use them, and the senior phase, all at the same time. How can you share them? You see, this does not make you work effectively? -Samantha added

> I think you have seen it, whatever class you enter, it is group work, you go to that teacher, it is group work, you go to another teacher, and it is group work. The

> reason for group work is the limited number of the devices that we have. - Samantha

During lesson observations, sharing the tablet did not allow every group member to be fully engaged in the tablet activity. The screen was too small to be read by five learners; therefore, some learners did not show interest in following what their peers were doing on the device. Using tablets in pairs or in a group of three could probably have helped to engage all learners in the group activity.

Lessons observations showed that the lack enough data projectors and the screen to project on was another challenge affecting the use of tablets in mathematics teaching. In School B for example, all teacher participants shared one projector. This means, it was not possible for all sixth grade mathematics teachers to teach a tablet integrated mathematics lessons at once. Furthermore, teachers did not have the screen to project on, so they projected on A4 papers pasted on the chalkboard. The surface projected on was too small. The lighting from the papers projected on was not ambient and this made it difficult for learners to read the materials that were projected.

Also in both schools teachers did not have onsite support. In School A, Teacher Sandra was assisted by her learners. In school B on the other hand, Teacher Jabulani moved between classrooms to provide support, leaving her learners unattended. Samantha's lesson was delayed for about ten minutes waiting for Jabulani to assist with connecting her tablet to the data projector. This could not have happened in schools that have onsite ICT support.

Teachers make decisions about their teaching but this has to be in line with the national educational policies. As in Chapter Two, the White Paper on e-Education, which currently is the sole document guiding the integration of technology in schools in South Africa, suggests a shift from memory based learning to a learning where learners use technology to investigate, to explore, to collect and to analyse information. In other words, it suggests that technology be used for meaningful learning as opposed to drill and practice. The previous sections indicated that the use of tablet technology in one of the classrooms was for mere drill and practice of multiple choice activities. This aroused the need to investigate what informed each teacher's teaching, and whether their teaching was e-

Education policy driven. To achieve this, I asked teachers to recount how they interpreted the White Paper on e-Education policy in their teaching. Teachers' responses to the question indicated that the lack of the knowledge about the e-Education policy and the lack of the physical policy document in their schools are also challenge that may affect teachers' use of tablets in the classroom. All responses indicated that it was for the first time teachers had heard about the e-Education policy. The following are examples of the comments received:

> It is the first time I am hearing this. Please enlighten me on what the White Paper on e-Education policy is all about. –Sandra—ICT coordinator in School A
>
> I am sorry; I am not able to respond to your question. I do not know what the White Paper on e-Education entails. –Samantha
>
> I am not sure whether our school has it. I am not a member of the ICT committee. –Seraphina
>
> We do not know about the White Paper on e-Education policy. We have our own ICT policy. –Jabulani—ICT coordinator in School B

The comments above clearly show that the White Paper on e-Education policy has not yet reached school level. If it had, ICT coordinators would have known about it. Jabulani claimed his school has its own ICT policy, and therefore, he did not see the need to have the e-Education policy. Normally, the school ICT policy derives from the national e-Education policy and is seen as a strategic plan to implement the national e-Education policy. If the drafting of the school ICT policy followed the right process, then Jabulani should be familiar with the e-Education policy.

Teachers were then asked to elaborate on other ICT policies, if any, they consult when they integrate tablets in the classroom teaching. The intention was to know whether teachers had a school-based policy that informed the use tablets in the classroom teaching. In School A, Sandra, the school ICT coordinator, presented an ICT policy document the school drafted when it received the Gauteng Online Computer Laboratory. The analysis of this document showed that it had little to offer in terms of using tablets in the curriculum, pedagogy and assessment. It focussed on the safety and the management of the computer laboratory and how learners were to behave in the computer laboratory. It should be remembered that the Gauteng Computer Laboratory for which the school ICT policy was drafted is no longer functional because of the failure of the Gauteng Online project. It was even noted that in School A, all desks and tables had been removed from the Gauteng Online laboratory. Computers were on the floor, which means the devices were no longer being used for teaching and learning. These findings highlight the need for a robust school ICT policy that does not only address the management and safety of the devices but also informs teachers on effective ways of using tablets in teaching and learning to achieve the national e-education goals. The policy should inform teachers what is expected of them so that the value of tablets in the policy can be enacted. The current school ICT policy is not relevant to the classroom use of tablets.

In School B, Jabulani, the ICT coordinator, mentioned that the school ICT policy was still under development.

> We have a school ICT policy, I participated in the drafting of that policy but the School Governing Body has not approved it. –Jabulani

A follow-up question was posed to ask him about the content of that school ICT policy.

> We talked about the issuing of tablets to learners and what might happen if the learner loses the device. We also talked about the storage, safety, and the programs that are installed on the devices. –Jabulani

It appears that the school ICT policy that Jabulani mentioned does not address the pedagogical use of tablets. Efforts to get a copy of this policy for further analysis were not successful. The school leadership felt it was not convenient to share the policy document until the relevant stakeholders have approved it. It was surprising to note that Jabulani's colleagues were not aware of the work that has been done in the school thus far to develop the school ICT policy. When asked whether there is a school ICT policy they consult, some teachers shook their heads and then gave the following comments.

> I think there is. I never went through it. –Sabina

> I am not sure. –Samantha

> There should be one but I have never seen it. The ICT committee cannot function without a policy. –Seraphina.

The above comments sent the message that the ICT committee did not consult teachers and did not involve them when the school ICT policy was written. This is likely to have negative consequences during the implementation of the policy after it has been approved. Teachers may demand to have their voices in the policy and many resist it.

Teachers are located at the meeting point of policy and practice, and expected to translate the policy into pedagogical actions in the classroom. This means, the reforms in the national e-Education policy are less likely to impact the classroom practices due to the lack of teachers' knowledge of the policy at stake. After realising that teachers did not have any ICT policy they consulted, the study then sought to understand what informed the classroom use of tablets. Teacher Seraphina indicated that her use of tablets was informed by the CAPS.

> I have to consult the CAPS on a daily basis. I have put it on my table so that it always available. –Seraphina

In reality, Seraphina consulted the CAPS simply to check the content to teach and the sequence in which the content should be taught. There is no way she could have consulted it for the purpose of checking how she was supposed to use tablets in her teaching. The CAPS is silent about the classroom use of technology. It does not tell teachers whether or not to use technology to enrich their teaching. It also does not align the educational application or software application to the content areas.

While Seraphina claimed she consults the CAPS, Sandra mentioned that her use of tablets in the classroom mathematics teaching was informed by:

1) Her pedagogical knowledge and her experience of teaching mathematics:

> I have 20 years teaching mathematics and 30 years teaching. When I am teaching mathematics, I introduce the lesson so that every child is comfortable and sees things around as part of mathematics. I make sure that every child can see mathematics in everyday life. You, as an educator, have to be initiative, try to use technology in a way that is going to make your lesson to be alive. I use it to

> introduce new concepts, explain, and to enhance. I also use it to test mental sharpness.

The above shows that Sandra had a pedagogical method and that she used tablets to enrich her pedagogical method.

2) Her experience with technology she developed from the early years:

> I grew up having a typewriter in the house. So I had such knowledge. In addition, I have this love for technology to an extent that my daughter took it upon herself to love it. She has a Bachelor of Science in Technology degree. All the times when she does things on the computer I am there to watch. So it is as if technology is in me. When it was introduced here as part of the Gauteng Online project I became the ICT coordinator. For me to try things become easier.

The comment above suggests that Sandra believed that she is technologically fluent and able to use her technological knowledge to enrich her lessons. The comment also shows that Sandra is obsessed with technology. It is probably because of this self-assurance and obsession that Sandra was able to try things with tablets in her teaching.

> I can use one application or take another application and combine them to make something new. It is very brilliant, children love it and it is very exciting. I can use more than four applications in one lesson-Sandra

3) As it was mentioned in the previous sections, Sandra participated in many training programs on the use of technology in the classroom. Through participation in these programs, she developed more knowledge than any of the teacher participants. She knew when it was appropriate to use tablet technology in her lesson. The use of tablets in her geometry lesson was spontaneous. Her comment bellow shows that it has become natural for her to use tablets in mathematics lessons.

> There are lessons that are taught well with tablets while others need the old technology, especially when the concepts can be explained using tangible and real object in the learners’ environment. Tablets work well when those objects cannot be made available. –Sandra

Samantha and Sabina indicated that their use of tablets in the classroom was informed by the philosophy about teaching and learning they held.

> I believe in learner-centred. Whenever I use tablets I try to make my lessons more interactive and engaging. –Samantha

> Learners learn mathematics through practice. I allow them to play mathematics games on the topic and by doing so they are learning. –Sabina

Classroom observations in Samantha and Sabina's classrooms concurred with their learning philosophies. The use of tablets in their teaching was anchored in learner-centred activities.

In conclusion, the use of tablets in sixth grade mathematics was not policy guided. It was rather informed by the teaching and learning philosophies teachers hold and their technological experience. However, the analysis of the data from the lessons observed indicated that the majority of teacher participants enacted pedagogical practices that were in line with the White Paper on e-Education policy, although teachers did not know about the existence of this policy. Discrepancies were observed only in Jabulani's classroom. It cannot be guaranteed that the teachers' use of tablet technology will always be in line with the e-Education policy in schools where this policy is not available and where teachers do not have the knowledge about it. Teachers are expected to have the knowledge of the policy at stake because they are expected to translate it into pedagogical actions in the classroom.

This section explored the challenges impacting teachers' use of tablet technology in sixth grade mathematics teaching. It was clear from this section that the lack of supporting technological infrastructure such as the internet connectivity and enough tablet devices and data projectors, and the lack of onsite technical support are the main issues impacting the teachers' use of tablets in mathematics teaching negatively. The section also shed light on the lack of policy support in both schools. In both schools, teachers have not been trained in the guiding e-Education policy. The national e-Education policy has not reached their school and both schools do not have their own ICT policies to demonstrate their strategies to achieve the national vision in the national e-education policy. Therefore, in the long run, the e-Education policy is less likely to impact the classroom practices in schools like School A and School B where teachers do not know about it.

4.7 Chapter Summary

This chapter presented the data on the pedagogical value of tablet technology in the teaching of sixth grade mathematics in township schools in South Africa. The data were collected from two township schools, using interviews, observations and documentary data collection methods. Five teachers were interviewed on their experience of using tablet technology in sixth grade mathematics teaching, five sixth grade mathematics lessons that integrated tablets were observed, learners' work completed on tablets was reviewed.

The analysis of the data emanating from the interviews with teachers showed that teachers have positive perceptions about the pedagogical value of tablets in their teaching. They believed the use of tablets in their teaching promotes a shift from teacher-abstract teaching to meaningful teaching pedagogies. This technology provided access to various forms of media to mediate the teaching of abstract concepts, most importantly, concepts like long division and fractions that were previously difficult to teach and learn. Teachers appreciated that the use of tablet media in instructional mathematics conversation has contributed to learners' positive attitude toward mathematics and increased their interest in mathematics lessons. Learners are spending more time on mathematical tasks and are using the same technology every day after school hours to practice mathematics.

Teachers positioned themselves as agents who instigate the pedagogical value of tablet technology to support meaningful learning of mathematics concepts by learners. Their mediation helped to bridge the content gaps between the curriculum and tablet resources and to make the tablet resources meaningful to the curriculum and learners' everyday life. While most comments pointed to the use of tablets for meaningful learning of mathematics by learners, teachers also opined that regular use of tablet technology and playful time with educational applications promoted teachers' growth in the use of tablets in pedagogical practices. They expressed the need for a professional development program in the use of the tablet in the curriculum teaching and assessment so that they are able to maximise the use of tablet technology and then make significant changes in their teaching.

The data from the analysis of the lessons that were observed concurred with teachers' perceptions in many ways. The majority of teacher participants enacted classroom practices which reflected the events of an instructional conversation, and this helped to confirm that there really have been shifts in the teachers' teaching as a result of using tablet technology in instructional conversation. A few irregularities were observed though. One teacher claimed the use of tablets for meaningful learning but the use of tablets in his classroom was for drill and practice of multiple-choice activities as opposed the use of the devices for higher-order learning.

The use of tablet media in the instructional conversation allowed merging narrative descriptions of mathematics concepts by the teacher with practical tasks by learners. The use of tablet adaptive and productive applications in the experiential events also provided learners opportunities to practice mathematical knowledge on their own, to produce mathematical knowledge and to present the knowledge created using an array of tools the tablet provided. The use of adaptive media especially at the beginning of the lesson in some classrooms aroused learners' interest, and then teachers were able to captivate their attention and to draw them into their new lesson.

The data from the lesson observations confirmed the importance of the teacher's mediational role in tablet mathematics instruction. Teachers used a combination of teaching materials, including traditional teaching materials, to bridge content gaps between the tablets and the CAPS. They used different approaches including questioning to unveil learners' mathematics misconceptions and to uproot them. They used gestures and code switching to help learners understand the tablet activities. They also helped learners to develop specialised mathematics language to use when expressing mathematical thoughts and ideas.

The majority of teachers taught in ways that aligned with the conceptual framework of the study and their perceptions about the value of tablet technology in their teaching. However, the chapter showed the need to raise teachers' awareness of the knowledge of the e-Education policy, as none of the teachers knew it existed. The analysis in this chapter showed that the lack of the supporting technological infrastructure, the lack of internet connectivity, the lack of enough tablet devices and the teachers' training in the pedagogical use of tablets in mathematics lessons affect the use of tablet technology in mathematics teaching negatively. The next chapter will discuss salient findings of this chapter.

CHAPTER FIVE: DISCUSSION

5.1 Introduction

This study investigated the use of tablet technology in the teaching and learning of mathematics in township schools in South Africa. As highlighted in the problem statement, despite the effort the South African Government has made to provide township mathematics teachers with tablet technology, the pedagogical value of using this technology in township schools is not documented in South Africa. Therefore, this study was an attempt at filling in that gap by providing research-based evidence on whether and how tablet technology supports teaching of mathematics in township schools in South Africa. The purpose of this chapter is to interpret and describe the significance of the findings presented in Chapter 4 in light of the conceptual framework that guided the study and the current literature relating to the research problem. The chapter teases out unusual and unexpected findings that emerged from the analysis of the data in Chapter 4 and what it means in relation to the research problem pursued in the study. The discussion is organised around the following research questions:

4. What are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics?
5. How are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics translated into pedagogical actions in the actual teaching of sixth grade mathematics?
6. What challenges impact teachers' use of tablet technology in the teaching of sixth grade mathematics?

Before engaging in a deeper discussion of the findings it is worth recapping the conceptual framework that guided the present study.

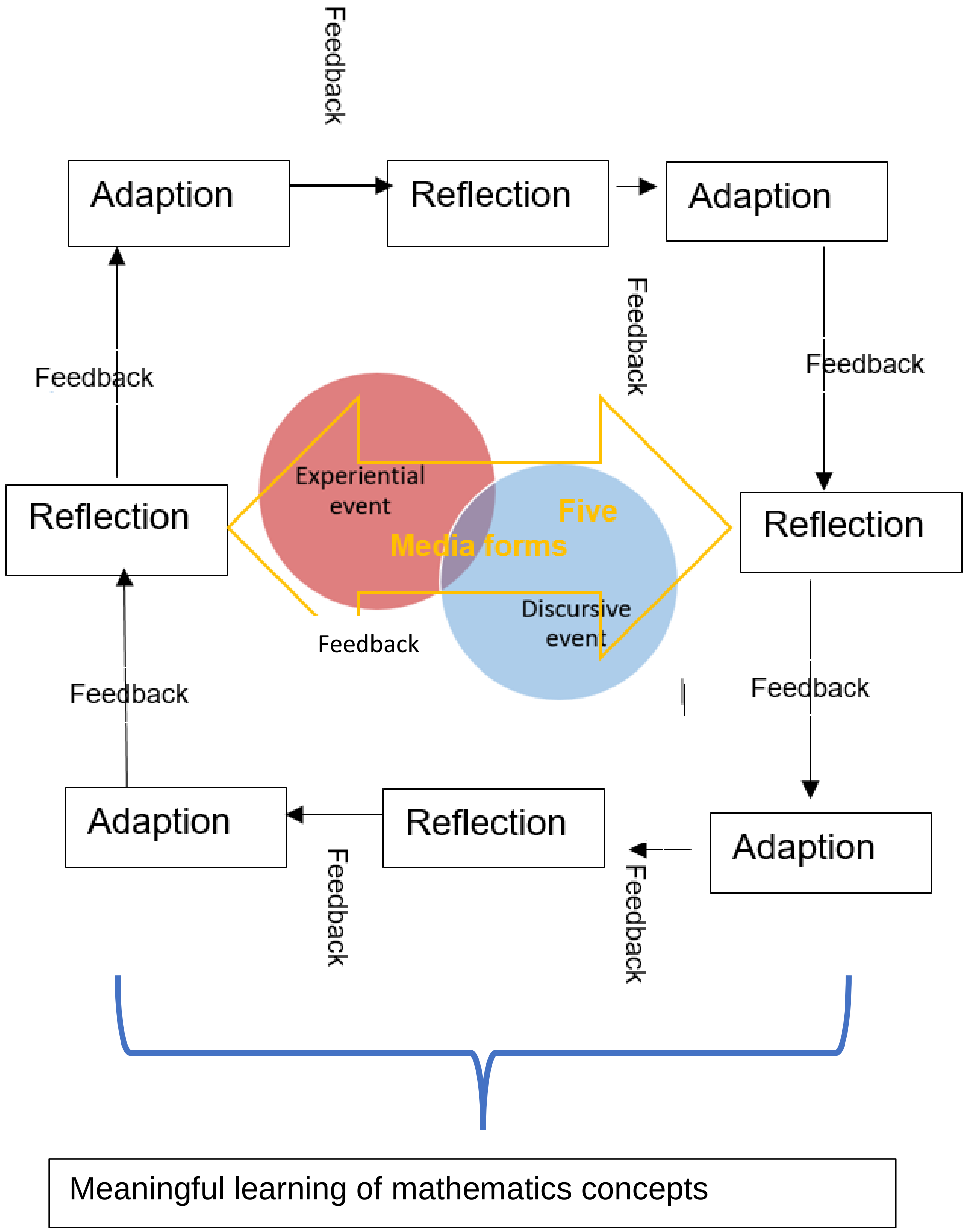


Figure 24 Reminder of the conceptual framework

In recap, the conceptual framework in Figure 24 above, which guided the study, has six key aspects:

1. The participants in the instructional mathematics conversation (the teacher and learners) actively participate in instructional mathematical conversations through two major intertwined events: The discursive and the experiential events.

2. The discursive event takes a narrative form aimed at promoting conceptual understanding of mathematics concepts. It involves an iterative dialogue between the teacher and learners focussed on a topic goal.
3. The experiential event involves activities by learners aimed at deepening the understanding of mathematics knowledge and skills of the discursive event.
4. Interactions in the instructional events are mediated by five media tools, including narrative, interactive, adaptive, productive and communicative media.
5. While interacting and engaging with mathematics in the instructional events, the participants in the instructional mathematical conversation concurrently give and receive feedback and reflect on the teaching and learning experiences. Feedback and reflection lead to adaptation of mathematics learning experiences by learners and teaching practices by teachers. Reflection and adaptation are intended to refine and perfect mathematical knowledge constructed by learners and the teachers' teaching with media.
6. A successful instructional conversation mediated by media leads to meaningful learning experiences of mathematics by learners. In this regard, the pedagogical value of media, tablet technology in this context, is the opportunities it provides to teach for meaningful learning of mathematics concepts. Meaningful learning attributes were explained in Chapter Two.

5.2. Research Question 1: What are Teachers' Perceptions about the Value of Tablet Technology in the Teaching of Sixth grade Mathematics?

The literature reviewed in Chapter Two showed that access to technology does not translate to its use in classroom instruction. Teachers first need to believe in the pedagogical potential of technology to improve teaching and learning (Venkatesh, 2011). It was known from the beginning of the present study that teacher participants were using tablet technology; hence, they were selected to participate in the study. However, what was not known were their perceptions of using this technology and the benefits from the use of tablet technology in their teaching. To address this, teachers were asked to recount the lived experience of teaching mathematics before and after the introduction of tablet technology in their schools and the changes that occurred as a result of using tablet technology in their lessons. Teachers' responses indicated that they perceive tablet technology to be a valuable pedagogical tool to transform their teaching. It gives access to various media forms they did not have previously. Furthermore, it provides opportunities for them to grow in the pedagogical use of tablets in instructional mathematics conversation. While placing a high value on the use of tablet technology to transform practices, teachers indicated that the latter cannot transform teaching and learning on its own unless it is well mediated.

5.2.1 Access to various forms of media

The findings in Chapter Four indicated that access to tablet technology resulted in significant pedagogical shifts in the studied schools. Previously, due to the socioeconomic status of their schools, teachers' participants did not have enough teaching materials to teach mathematics concepts in meaningful way. Teaching was predominantly abstract. Obviously, this was disadvantageous to learners' learning because the later did not have enough representational tools to assist with the interpretation of mathematics concepts. Laurillard (2002)'s conversational framework cautions teachers to use a combination of media in the effort to provide learners with enough tools to assist with deeper understanding of concepts. Multiple representation of concepts is also supported by social constructivism theory, which states that higher order learning be mediated using various semiotic tools and signs (Daniels, 2016). The data relating to teachers' perceptions of the value of tablet technology in their teaching showed that, currently, tablets are providing access to various media forms including narrative, interactive, adaptive, productive and communicative to support meaningful teaching of mathematics concepts.

5.2.1.1 Narrative and Interactive Media

If teaching was abstract as the above indicated, that means the participants relied on the static narrative media of the textbooks and chalkboard illustrations to teach mathematical knowledge and facts. The disadvantage of the static narrative media to learners' learning is that they are linear and non-interactive. They do not offer enough tools for learners to interact with and to explore concepts (Laurillard, 2002). In other words, they can lead to rote learning. For a deeper understanding of concepts, learners are supposed to be provided with opportunities to experience learning in various forms such as discussion, debate, exploration, analysis, investigation, articulation and expression of ideas, and using multiple representations (National Department of Education, 2003). The lack of media tools for multiple representation of mathematics concepts could be the reason why sixth grade learners in the studied schools underperformed in mathematics prior to the introduction of tablet technology in the teachers' teaching.

Teacher participants appreciated that tablet technology is providing access to various narrative media including pictures, models and videos to visualise abstract mathematics concepts. Narrative media that tablets provided during lesson observations were not mere static visuals. They were interactive and animated to represent dynamically mathematics relationships. In line with the conceptual framework of the study, narrative media support attending and apprehending. They allow the teacher to explain theories and concepts in a structured narrative form. However, they cannot detect learners' misunderstanding or respond to learners' questions. Hence, during the discursive event teacher participants supported the narrative presentation using the questioning and discussion approach to unveil learners' misconceptions and to provide appropriate scaffolding. The use of tablet interactive media like fraction models as reported by the participants and witnessed during lesson observations supported investigating and exploring mathematics concepts. They enabled to present a relational mathematics concept like Fractions more clearly by deconstructing it into all forms of variations of its parameters (denominator and nominator), and then allowed all learners to experience it as a whole. This supported the construction of a deep understanding of Fractions by learners.

5.2.1.2 Adaptive Media

Teacher participants appreciated the value adaptive media which were offered in the form of educational mathematics games. The findings in Chapter Four indicated that educational games have caught the attention of the study participants because of their intrinsic features to accept the learner's input and to respond to it in a way that closely resembles the human teacher. They offered personalised instruction to allow learners to progress on their own within their zone of proximal development. They provided a series of mathematics activities, marked learners' answers and then provided the feedback and hints to help learners achieve the task goal. This means, learners kept practicing to improve their performance without the teacher intervention because they received intrinsic feedback from the application. Because of the interactivity and the opportunities to learn in a user-controlled learning environment, it can be said that adaptive educational games fit well with the requirements of the conversational framework, and constructivism and social constructivism learning theories that informed the conceptual framework of the present study. The findings above concur with the findings of Hubber et al., (2016a) and Zhang, Trussell, Gallegos, and Asam (2015a) studies in which the use of adaptive game based mathematics applications improved learners' mathematical ability due to the feedback and several opportunities to practice the applications provided.

Furthermore, the use of adaptive media means a lot to teacher participants. They no longer have to mark each individual learner because adaptive applications do it. This means, they now have more time to prepare their lessons and more time to focus on learners who need more assistance. During lesson observations, adaptive applications enabled teachers to detect learners' weaknesses simply by checking their progress from the application. The ability to keep the record of the learner's progress encouraged reflective and adaptive teaching on the part of the teacher and reflective and adaptive learning on the part of the learner. Teachers changed the instructional strategies and instructional media to provide proper scaffolding; consequently, learners were encouraged to adapt their conceptual understanding of mathematics concepts. The findings concurs with Laurillard (2002)'s assertion that adaptive media marshal all forms of media by covering almost all aspects of the instructional conversation. As the findings have showed thus far, the use of adaptive media in sixth grade mathematics teaching in the studied schools allowed learners to engage with mathematics activity directly supported feedback, and reflection and adaptation features of the conceptual framework. Teachers' boastful comments like "We are no longer a township school but a school every parent wants his child to come to", is an expression of how the use of adaptive media in instructional mathematics conversation has turned the teaching of mathematics concepts around. The comment shows that teachers' participants are now feeling empowered to offer the teaching that is equivalent to the teaching in former Model C schools. In the South African context, it is in these schools that every parent would desire to enrol his child because of improved physical infrastructure and the good quality teachers these schools attract.

Another pedagogical value of adaptive media as perceived by the research participants is the attractive and fun activities they provide. The latter as the participants shared, have affected learners' interest and attitudes towards mathematics positively. Learners are attending mathematics lessons in number because of the expectation to be taught using educational mathematics games. This finding was unusual and unexpected. While reviewing the literature, we did not come across any similar case where the use of tablets affected the attendance turnout in mathematics lessons. As in Chapter Four, this is a great advantage for teacher participants because they are now teaching mathematics lessons in the way they have planned. They do not have to go back to help absentees catch up with the previous mathematics lesson.

The participants opined that adaptive educational games also proved their value to support peer teaching, allowing intellectually less competent learners to learn from their peers who are more competent. While acknowledging how adaptive media in the form of educational games has changed the teaching of mathematics concepts in the studied schools, two shortfalls relating to the multiple-choice activities they provided were observed though. The first shortfall is that the intrinsic feedback they provided was not descriptive enough to support struggling learners. The feedback included comments like "That's great", "Well done", "That is incorrect, try again". While these comments can reinforce learning for gifted learners they are not descriptive enough to help the less competent learner identify where the mistake and how to rectify it. Fortunately, teacher participants visited learners in their groups to provide assistance.

The second shortfall is that learners who did not know the computational procedures or were lazy to work answers out could hit the right answer just by guessing. Espinosa and Gardeazabal (2010) cautions that, in order to minimise guessing on multiple choice, a score penalty must be applied whenever the learner chooses the wrong answer. However, an empirical study (Krawczyk, 2011) found that learners still guessed even when a score penalty was applied. This could not be verified in this study because teachers did not apply this rule. What the present study noted though, was that guessing did not happen when learners were informed that they would present their problem solving process to the entire class. In such instances, learners in their small groups shared mathematical solutions and alternative ways to solve mathematical problems before choosing the right answer from many possible answers adaptive games provided.

Another finding which was unexpected was the teachers' perception of the value of adaptive applications to model the teaching of difficult topics like Fractions and Long Division. As mentioned in Chapter Three, the participants were selected based on the assumption that they did not have gaps in the content and pedagogy. However, as they indicated in Chapter Four, they did not know how to teach the concepts above prior to the introduction of tablets in their schools. They appreciated that adaptive applications break these topics into small steps activities that are simple for learners to master. The pacing is also individualised to allow learners to move on their pace. The support adaptive applications provided teachers may be the reason why learners' performance in the national mathematics examination improved for three consecutive years after the introduction of tablets in School B. The findings concurs with the findings of the study conducted in poor schools in Malawi (Pitchford, 2015), in which the use of tablet adaptive mathematics applications also supported mathematics teaching. Malawian learners who used to perform poorly in mathematics improved their conceptual mathematics knowledge by 4% and by 18 % on curriculum knowledge after the introduction of tablets in their schools.

5.2.1.3 Productive and Communicative Media

The findings in Chapter Four showed that the participants believe in the potential of the Chalk application to support many instructional activities in sixth grade mathematics teaching. They shared that the same application is used by learners to work answers out, to record them, and to create mathematics artefacts to express own mathematics understanding. This was also confirmed during lesson observations in Sandra and Sabina classes. Learners were observed using the Chalk application to engage with the content directly and to represent mathematics solutions using the fraction models and shapes they created. In this way, the chalk application was used as a productive media. Laurillard (2002, p.163) indicates that, learners who use productive media to create their own models have a different learning experience than learners in the traditional classroom who use the models that have been created for them. The reason is that when creating own model, learners apply higher order cognitive skills including inspection, reflection and revision as a result of the feedback. This suggests that the Chalk application as a productive media is promoting higher order learning of mathematics than previously was feasible. The Chalk application also allowed using the tablet as a communicative tool. Learners connected their devices to the projector to share their outputs. This had a significant pedagogical value because it helped to motivate further mathematics discussion. It promoted feedback from the peers and cognitive elaboration by challenging each other's mathematics ideas, articulating and critiquing their points of views. The scholarship on teaching mathematics as a conversation (Haroutunian-Gordon & Tartakoff, 1996; Schoenfeld & Kilpatrick, 2008; Setati, 2001) shows that when learners are given such opportunities for iterative mathematics discussions and opportunities to clarify their points of doubts they "become confident in their abilities to do mathematics and become mathematics problem solvers" (Haroutunian-Gordon & Tartakoff, 1996, p. 2). This highlights the improvement in mathematics teaching in the studied schools as a result of using tablet media in mathematics teaching.

5.2.2 Teacher Mediation

Teacher participants were convinced that, although tablets can support meaningful teaching of mathematics concepts, especially the opportunity they provide for a personalised mathematics learning experiences, the teacher's mediation is more important. Firstly, teachers must help learners to choose the right learning material to engage with and the proper sequence. As teachers mentioned, "not all the materials on the tablet are good for learners"; therefore, teachers, as more knowledgeable others, must guide learners in choosing the materials that will not harm their intellectual development. Teachers also assist learners to know the order in which they should engage with the content. This helps to maintain the content progression. While agreeing with the participants views, it was noticed that it was a challenge for them to control the order in which learners engaged with the content, because all the materials on the devices were readily accessible. Control over what could be explored and in which order could possibly have been possible if teachers had the ability to lock some applications or some sections in the application and to unlock them when needed. It also could have been possible if teachers had an application that allowed them to see from a distance the materials learners were exploring on the devices.

In relation to teacher's mediation, some teachers were of the view that the tablet content does not exactly fit into their learners' everyday world of experience and the curriculum in particular. Educational application on the devices, as teachers said; seem to have been developed for overseas children and not for South African learners. Therefore, their mediational role is crucial to make the tablet mathematics content relevant to their learners. This is achieved by using CAPS aligned textbooks, pictorial tools, body language and chalkboard explanations. Teaching sixth grade mathematics using a combination of tablet and non-tablet teaching materials is in line with (Drijvers, 2015)'s assertion that teaching mathematics with technology should not be treated as something independent from the educational context and the classroom mathematics practices. He suggested that teachers use combinations of technological and non-technological tools to generate powerful and meaningful mathematics learning experiences.

Another important aspect, which requires the teacher's mediation, is the language that the applications use. The applications use the English language while the majority of learners in the studied schools come from the surrounding communities that predominantly use indigenous languages for communication. In addition, most people in these communities do not have formal education, thus making difficult for learners to encounter mathematics discourse at home. Previous studies (Méndez et al., 2019) found a positive relationship between the language of instruction and the development of numeracy skills by learners. Language provides tools for expression of mathematical thinking and the understanding of mathematical concepts (Kleemans et al., 2011). Teacher participants are providing linguistic support by using concrete objects learners can relate to and code switching to ensure that learners understand the tablet mathematics content. They are also using the 'Important Terms' section that most adaptive mathematics applications have to develop appropriate mathematics vocabularies. In Chapter Two, Papanastasiou (2000) raised the concern that the majority of South African learners fail in international mathematics competitions because of the language the mathematics exam papers use. He indicated that the exam papers use English while the majority of South African learners use indigenous languages. The findings of the present study in this section indicate that adaptive mathematics applications may be one of the potential pedagogical ways to develop learners' mathematics language.

5.2.3 Teachers' Professional Growth

Well-planned tablet integration involves providing teachers with professional development on the use of the devices in the curriculum and pedagogy and the creation of school based communities of practice in which teachers share understanding and experience they gain while using the devices in their teaching (Pegrum, Oakley, & Faulkner, 2013). However, most professional development programs lack this aspect. They tend to be one-size-fits-all and are often a once off event focussed on the acquisition of mere ICT skills (Bingimlas, 2009). That means they forget that at the heart of successful technological integration is the teacher's knowledge of how to use technology in the curriculum (Mishra & Koehler, 2008).

Chapter Four showed that teacher participants participated in some forms of professional development programs on the use of the technology. Yet, just like many technological professional programs, these too adopted a corporate approach of modelling how to operate tablets devices and cute rhetoric of how the applications on the devices will improve teachers' teaching and learners' learning. No effort was made to model how tablets could be used to enhance teaching and learning of mathematics concepts. However, despite the concerns above, teacher participants have made some progress in the use of the devices in their lessons. Most of their skills were self-taught. Playful time with the tablets and online research by those teachers who have their own tablets have helped them to be where they currently are in terms of integrating the devices in their lessons. They expressed appreciation toward modelling applications that have taught them how teach Long Division and Fractions, the topics they struggled with. Through these applications, they claimed to have learned the effective way of sequencing and pacing these topics to make them easy to teach and easy for learners to learn. This finding was unexpected as it relates to teachers use of the devices for their own learning rather than learners' learning. If this approach worked for them, then all teachers should be provided with their own tablets so that there can be ample time for self-development at home and after school.

5.2.4 Section Summary

This section discussed the data corresponding to the first research question: What are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics? The data were collected through interviews with five sixth grade mathematics teachers. The section also used part of the data from the classroom observation for triangulation purposes.

The findings in this section suggests that the use of tablets in the studied schools resulted in significant pedagogical shifts allowing teachers to teach for meaningful learning of mathematics concepts and to develop their own knowledge of how to use the devices in mathematics teaching.

Tablets are proving access to various forms of media including narrative, interactive, adaptive, productive and communicative media teachers did not have previously. These media are used together with traditional teaching materials to provide learners with multiple tools to relate to and to interpret mathematics concepts.

Adaptive game based applications are believed to have promoted reflective and adaptive mathematics teaching and learning. Learners no longer have to wait for the teacher to mark their work for them to move on but can use the feedback the applications provide to reflect on and to adapt their mathematical thinking and reasoning and to progress. One worrisome concern was that the feedback is not descriptive enough to help less competent learners identify their mistakes and that learners can succeed on drill and practice tasks just by guessing without necessarily understanding the conceptual reasoning behind the mathematics facts and procedures.

While various forms of media tablets provide have proved their value to support teaching of mathematics concepts, this section showed that the teacher's mediation is more important. Teachers help to bridge the content gap currently existing between tablet mathematics content and the CAPS, and help to learners develop appropriate mathematics language gaps using a combination of tablet and non-tablet media.

5.3 Research Question 2: **How are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics translated into pedagogical actions in the actual teaching of sixth grade mathematics?**

The previous section discussed the data relating to teachers' perceptions about the value of tablet technology in the teaching of sixth grade mathematics. It was clear from the previous section that teacher participants appreciate the value of having access to various forms of media, which they are now using to teach for meaningful learning and for own professional growth. This section will discuss how teachers used tablet technology to support teaching and learning events in the actual mathematics lessons. This aspect of the study enhances understanding of the pedagogical value of tablet technology as enacted in the actual mathematics lessons rather than relying on teachers' self-report data. The data will be discussed in relation to the instructional events depicted in the conceptual framework. These events were informed by Laurillard (2002)'s conversational framework. The later provides minimum instructional events a lesson that integrates technology should have in order for technology to add value to teaching and learning. In the light of the conversational framework, a technology-integrated lesson must include four instructional events if the use of technology is to provide learners with a full learning experience. It should include the discursive, adaptive, reflective and experiential events. These are not standalone instructional events, but interactive and overlapping. For example, reflection happens in both the discursive and the experiential event and even adaptation can occur in both the discursive and the experiential events. Therefore, this study reduced the four events into two major events namely the discursive and the experiential events with reflection and adaptation occurring at both events.

In line with the conversational framework, the discursive event will focus on the development of conceptual mathematical knowledge, particularly how the participants used tablets in the instructional conversation to access concepts, knowledge, ideas and theories. It will also include how they used the technology to share ideas, debate ideas, and reflect on ideas to adapt their actions. The experiential event will focus on opportunities learners received to practice the knowledge developed at the discursive event, how they used technology to share the knowledge, and how they reflected on their practices. While cross-examining the use of tablet in the instructional events, the section will also discuss how the use of tablets in the discursive and experiential events linked to teachers' perceptions and how it promoted meaningful learning.

It is possible that teacher participants were not familiar with the conversational framework and therefore were not aware of the instructional events above. However, the findings of the study indicated that most lessons had the minimum instructional events. The majority of the participants also taught in ways that reflected their perceptions about the value of tablet technology in their teaching, although they taught differently.

Teachers' lessons will be discussed following two main themes representing the discursive and the instructional events:

- The discursive mathematics event
- The experiential mathematics event

5.3.1 The discursive mathematics event

Research indicates that mathematical discourse helps learners to develop conceptual and procedural mathematics understanding (Bussi & Sun, 2018). Through participation in the discourse, learners are able to access each other's theories, ask questions, answer questions of their peers, offer their own ideas, and reflect on their learning experience, and all of this allows them to construct a robust and deep knowledge understanding (Laurillard, 2007). According to Sfard et al., (1998), for a productive mathematical discourse to occur, the participants in the discourse have to be constructive and creative, communicate mathematically in a productive manner. The findings that emerged from the analysis of lessons observations in Chapter 4 showed that the use of tablet technology is indeed offering exciting new opportunities for productive mathematics discourse. Teachers and learners are now having opportunities discuss and share mathematical ideas in groups and in whole class instruction using tablets. Learners are now involved in the process of negotiating and creating mathematical knowledge using tablet productive tools. The next section will discuss how these were reflected in each teacher's teaching.

5.3.1.1 The discursive mathematics event in Sandra's class

Sandra framed the discursive event around the knowledge of shapes. However, before engaging the class in the deep learning of shapes, she indulged learners in a practical collaborative tablet task on knowledge taught previously. The recalling of prior knowledge is crucial for mathematics learning because it awakens learners' minds and helps to assimilate the new knowledge into the existing knowledge (Saarelainen et al., 2007). The group activity on the previous topic resulted in substantial mathematical conversation among learners. It allowed accessing their peers' knowledge and ideas and ways of doing mathematics. The National Council of Teachers of Mathematics (National Council of Teachers of Mathematics (NCTM), 2014) also found that mathematical discourse among learners allows for the development of shared mathematical understanding through the analysis and comparison of varied mathematical approaches and ideas from the peers.

Laurillard (2002) asserts that if tailored to the content and educational goals, adaptive educational games have much to offer in the instructional conversation. The use of the Bingo, Fun Math and Pop Math games allowed learners to practice the knowledge taught previously and provided a number of benefits, which could hardly be obtained if the lesson had not used the tablets in the discursive event.

Firstly, game-based learning environment provided learners with a safe teaching and learning environment in which they practised the previously taught mathematical knowledge in their own space and with little guidance from the teacher. During the activity, learners received prompt feedback and hints to improve their performance in the activity. Sidhu and Srinivasan (2018) argued that instant feedback supports better understanding and long-term retention of mathematical knowledge by learners. Feedback also leads to meaningful learning (Hakkarainen, Paavola, Kangas, & Seitamaa, 2013). In Sandra's class, instant feedback not only helped with the understanding of the knowledge taught but also allowed learners to correct the mistakes without having the teacher staring at them, hence boosting their confidence and ability to do mathematics. The teacher intervened only when requested by learners who required additional support.

In addition to instant feedback, educational games provided interactive and multimedia-rich content that motivated learners to practice mathematics in groups while having fun. The adaptive game environment supported collaborative learning by allowing multiple players. Each player created own profile which recorded each player's progress in terms of the questions the player answered correctly, the questions the player did not answer correctly, and the time the player spent on each question. This record allowed Sandra to monitor learners' progress in real time, and to adapt her teaching. These findings concur with several studies (Attard, 2013; Hilton, 2018; Loong & Herbert, 2018) that have pointed to the value tablet educational mathematics applications to increase learners' engagement in learning activities and to allow teachers to monitor learners' understanding in real time.

In the new lesson, Sandra promoted iterative mathematics discussion using an interrogative approach to motivate learners to share their understanding. Learners' contributions in the mathematics conversation were reinforced with motivating comments such "Well done" and "I never expected that". This proved the importance of the teacher's mediation in tablet integrated mathematics lessons. Recognising learners' effort served as an extrinsic motivation to maintain their participation in mathematical discussion. Learners were also invited to comment on the contributions from their peers. Mathematical discourse in Sandra's class matched Pratiwi et al. (2018, p. 71) "motivation discourse" concept that refers to the classroom discussion that is not limited to the praising of learners but that also supports their participation and engagement in the instructional conversation. Praising learners for meaningful contribution motivated them to offer their ideas, which then Sandra refined or elaborated on to elicit positive changes in learners' understanding.

Sandra believed in the use different forms of media to help learners understand mathematical concepts and to make mathematical concepts real. NCTM (2014) and Busisi and Sun (2018) asserted that the use of multiple representational forms helps learners to connect mathematical ideas. In the discursive event, Sandra supported mathematical discourse with concrete objects that were accessible in the physical classroom environment. Visualisation using concrete objects is very important in the teaching and learning of geometric shapes. It provides learners with “the ability to take a figure apart in the mind, see the individual elements, and make sufficiently good conjectures about their relationships to guide the choice of further experimental and analytic tools” (Fujita, Jones, & Yamamoto, 2004, p. 2). Use of tangible tools learners were familiar with in their everyday life allowed them to recognise a plethora of shapes and to construct mental schemata, which they demonstrated by identifying and distinguishing geometric patterns in the experiential event.

Sandra’s constructed mathematical discourse also used interactive and productive media to help learners understand the intrinsic properties of shapes like the rectangle. This was in line with the social constructivism theory, which states that higher mental functions are mediated by psychological [semiotic] tools (Vygotsky, 1978). There was evidence that the use of narrative and productive media allowed learners to construct higher-order thinking about the topic. Learners were able to talk about the relationship between the width and the length of the rectangle. They were also able to talk about geometric relationships and to extrapolate the knowledge of the rectangle to other shapes such the square and the pentagon. This concurs with the perceptions shared by the majority of teacher participants, which pointed to the use of interactive multimedia resources for abstract learning.

Tablets in the discursive event provided Sandra and learners with tools to bridge the divide between theory and practice. The discourse on the properties of shapes was enriched using drawings and shapes constructed by learners themselves on the Chalk application. Learners annotated the properties and were able to discover the relationships between parts within the shape and between different shapes. Participants were able to erase and produce a new shape, which means the Chalk application allowed to adapt their understanding as they reflected on their own practices and as they were challenged by ideas that were generated in the discursive event.

In brief, the discursive event in Sandra’s class supported conceptual understanding of the topic by learners through the sharing of ideas, answering questions, and through collaborative practical tasks that helped to bridge the gaps between theory and practice. The discursive events used a variety of media to accommodate learners' learning experiences. The discursive event confirmed Sandra's claims about the value of tablets in her teaching. She claimed she no longer teaches mathematics concepts in abstract manner, and that her lesson uses a variety of tools to make abstract concepts visual. She also claimed that she no longer teaches to passive learners but that learners have become active co-constructor of mathematical knowledge. Indeed, the use of tablets media helped to make the concept of shapes visual. It helped to engage learners and provided productivity tools learners used to produce their own shapes.

5.3.1.2 The discursive mathematics event in Sabina's lesson

Rather than starting with a tablet collaborative activity as Sandra did in her lesson, Sabina posed oral question to diagnose learners' prior knowledge of fractions; a topic she was about to introduce to them. Van Kesteren, Krabbendam, and Meeter, (2018, p. 4) argued that "reactivation of prior knowledge during learning of new information indeed results in stronger association of new information with existing knowledge networks". Therefore it can be said that Sabina's effort to check learners' prior knowledge of fractions sharpened their mental functions and prepared them to assimilate the new information she was about to teach. Their responses on the oral activity indicated that they did not know much about the topic. This allowed Sabina to know how to tune her lessons. She started with the basics so that learners had foundational knowledge to build on. She also motivated learners and assured learners that by the end of the lesson each one of them would have a complete understanding of the important concepts the lesson will explore. Research (Sun, Xie, & Anderman, 2018) indicates that learners who believe in their capabilities to learn and succeed are more likely to use cognitive strategies and to reflect on their performance during classroom instruction to achieve the learning goals. Motivating learners gave them confidence and possibly encouraged them to channel all their effort toward the understanding of the topic.

Sabina facilitated the discursive event on fractions using traditional narrative media. These included physical manipulatives and fraction models sketched on the chalkboard. Use of manipulatives consisted of the folding and unfolding of circle shaped paper, and the counting of the number of parts the paper had been partitioned into. In line with the conversational framework, physical manipulatives can be on one hand be categorised as narrative media because they allowed for the description of the topic of fractions, thus supporting learners' apprehension. They can also be categorised as productive media on the other hand, because through folding and unfolding of papers learners produced own fractions models. Physical manipulatives led to the use of graphic representations on the chalkboard. Use of graphical representation models allowed for numerical annotation of fractions, which, according the Vygotsky (1978), leads to the construction of higher mental functions. Flores, Hinton, and Taylor (2018) showed that the use of concrete and semi concrete teaching materials helps learners develop firm conceptual and procedural understanding of fractions.

Also in the discursive event, Sabina used the questioning approach to access her learners' knowledge and to promote conceptual understanding of the concepts of numerator and denominator. Learners' engagement in the discussion about the topic allowed Sabina to pick up learners' misconceptions about the concepts of numerator. For example, learners viewed a fraction as made up of two separate numbers, the numerator and denominator, instead of understanding it as a unified number. Learners also described the numerator as the number that is up and the denominator as the number that is down. Unveiling misconceptions helped to make the concepts of numerator and denominator transparent and to develop appropriate mathematical language learners were to use when conversing about fractions. It was crucial that learners' misconceptions about fractions were corrected as early as possible as this could affect their abilities to do mathematics at secondary school, college and universities.

Although Sabina's discursive event did not use tablet media to support the construction of mathematics knowledge, it highlights the importance of teaching mathematics as conversation. Through the dialogical process between Sandra and her learners, misconceptions were removed and specialised language was developed. This is important especially in the studied schools where the medium of instruction is not learners' home language and where learners rarely get opportunities for mathematical discourse outside the school walls.

5.3.1.3 The discursive mathematics event in Jabulani's lessons

The discursive event in Jabulani's class was predominantly a one-way communication, with learners listening passively to Jabulani's descriptions of fractions. There was no opportunity for individual learners to demonstrate their understanding or to ask questions. Based on the conversational framework (Laurillard, 2002; Laurillard, 2007) and the scholarship on learning mathematics as a dialogical activity (Costa, 2018), teachers should provide learners ample opportunities for mathematical talk and opportunities to ask questions, express own ideas, contrast ideas, and produce and compare their own fraction models. When the conversation is reciprocal as it is suggested in the conversational framework, participants in the discourse are able to access each other's knowledge and theory and to use it to transform their own understanding.

Jabulani used sketches on the chalkboard only to describe the topic of fractions. Nevertheless, teachers should teach fractions using a combination of media forms if learners are to construct a deeper understanding of the topic. Moyer et al. (2008) argued that children do not develop mathematics understanding when they are taught in an abstract manner. They require more concrete and drawing experiences. Using tablets in the discursive event could have provided interactive fraction models to support chalkboard explanations. Unfortunately Jabulani did not use the devices in the discursive event.

5.3.1.4 The discursive mathematics event in Samantha's lesson

Sandra and Sabina played a significant mediational role in shaping and reshaping the instructional conversation. They supported the instructional conversation using different forms of representations, tablets, physical manipulatives, semi-concrete representations on the chalkboard, and semiology to achieve their instructional goals. The findings of the study indicate that Samantha opted for a different teaching approach, which involved the experiential event only. This approach is effective when learners already know the concepts. Therefore, with regard to mathematical discourse in Samantha's class, we remain neutral because we did not see it happening besides assuming that it happened in the previous lesson.

5.3.2 Section summary

Clearly, Sandra's and Sabina's enacted practices in the discursive event supported meaningful learning in that they facilitated the discursive event using an array of teaching materials including tangible objects and tablet interactive and adaptive media to promote conceptual mathematics understanding. Questioning and praising learners for their input and participation in the discourse made the teaching conversational. Participants in the discourse were able to access each other's knowledge about the topic and had opportunities to develop specialised mathematical language. Misconceptions were also uprooted. This was not possible in Jabulani's class where learners were passive in the discursive event. Sharples, Taylor, and Vavoula, (2010) asserted that the teacher and learners who are involved in the classroom conversation need to have a shared mathematical language and a way of capturing and communicating their knowledge, experience and skills. The discursive event in Sandra's lesson unveiled limited formal mathematical language to converse about the properties of geometric shapes by some learners. They used everyday language to describe the properties of geometric shapes. However, the use of everyday language sometimes distorted the meaning and ideas they wanted to convey. This allowed Sandra to emphasise the specialised mathematical language learners were to use to converse about the properties of geometric shapes.

The use of tablets in the discursive event added another advantage. In Sandra's class where tablets and non-tablet teaching materials were used interchangeably, educational applications allowed for self-regulated learning by learners and timely monitoring of learners' progress by the teacher, which then led to reflection on and adaptation of teaching strategy by the teacher and conceptual understanding by learners. It also allowed mathematical conceptual knowledge and practice to be brought together. The use of tablets also expanded the range of learners' expression. Learners who were not confident to speak publicly used the Chalk application to produce shapes and to annotate their properties using semiotic tools. This helped to guarantee learners who did not speak in the discursive event understood the topic too.

5.3.3 Experiential mathematics event

The experiential attribute of the conversational framework and meaningful learning allows learners to transform and internalise the knowledge they acquired at the discursive event. Piaget argued that through activity “an individual learns to see the world as coherent and as structured, to the extent that he acts upon the world, transforms it, and succeeds in coordinating the actions and transformations” (Duckworth, 1964, p. 172). This is also in line with the social constructivism theory that states that learning occurs on two planes. It firstly occurs on the social plane when individuals are participating in a socially organised activity mediated by a more knowledgeable other (discursive event in this case) and then on the individual plane when the individual is in their own space contemplating the experience from the social interactions (experiential activity) (Vygotsky, 1978). Without the experiential activity, we cannot claim to have provided learners with a meaningful and full learning experience. Evidence from lesson observations suggests that teacher participants are using tablets to provide learners with opportunities to practice mathematical knowledge and to produce their own mathematical knowledge as a demonstration of higher-order learning. This occurs through collaborative activities.

5.3.3.1 Experiential teaching in Sandra’s lesson

After the discursive event, Sandra gave learners an experiential task in which they used the tablet Chalk application to experiment the mathematical knowledge that was covered at the discursive event. The experiential activity required learners to produce and describe the properties of geometric figures as a demonstration of deep understanding, to share their geometric figures produced with peers in the group, and to present the products of their work to the entire classroom during group presentations. This linked to the view she shared in the interview that she gives learners opportunities to use tablets to discover and to be creative.

During the discursive event Sandra worked jointly with learners and Sandra limited her guidance and support in the experiential event in order to see how much learners could do on their own and what support they required. The Chalk application made the experiential event possible by providing tools for learners to produce and describe their own geometric shapes. The devices also eased the communication and the sharing of learners' products as they could be connected to the projector when the selected groups presented their products to the class. Higher understanding of the shapes was demonstrated through the ability to respond to peers' questions during the presentations. In line with the conversational framework (Laurillard, 2002), shared comparison of output improves learners' conceptual understanding by motivating them to reflect on and to adapt their own mathematical output. These findings are in congruence with Calder and Murphy (2018) who found that tablets differentiated learning for learners in elementary mathematics classrooms by allowing them to use productive applications to create their own content and to explain their own thinking in many ways.

5.3.3.2 Experiential teaching in Sabina's lesson

Sabina provided learners with an experiential task that involved solving real world fractions problems and using the Chalk application to represent their solutions using different fractions models. She challenged learners to formulate their own fraction problems and to devise solutions thereafter. This was in line with her conviction that mathematics content must be real and meaningful to learners' lives. Just like in Sandra class, tablets in Sabina's class allowed learners to create their own fraction models using the tools in the Chalk application and to share their models with the entire class. Learners tried different models to represent their solutions until they got the models they were happy with. In this, the Chalk application made reflection and adaptation possible. Learners presented their solutions using models different form the ones Sabina had used in the discursive event, and this is a sign of problem-solving skills coupled with creativity. Critical thinking was promoted through the sharing of fraction problems from different groups.

Sabina's use of tablets concurred with her belief about the value of tablets to provide learners with rich opportunities to practice mathematics content. She thinks collaborative learning should be followed by individual tasks to assess each learner's strength and weakness, hence, after the experiential task, individual learners were asked oral questions that proved they have developed a conceptual and procedural understanding of fractions. The use of tablets allowed linking the conversation at the discursive event with learners' actions in the experiential task. In the experiential task, the Chalk application allowed learners to directly act on fractions, to articulate their understanding and to produce their own fraction models in response to the fractions word problems that were posed. These findings support Ertmer et al.'s (2012) study in which teachers enacted pedagogical practices which closely aligned with the their beliefs.

5.3.3.3 Experiential teaching in Jabulani's lesson

In his first lesson, Jabulani provided learners with a tablet activity to help them practice the knowledge he had just transmitted. However, the activity was too early in CAPS. It included division and simplification of fractions, while he had just introduced learners to the concepts of numerator and denominator. The activity was also mere drill and practice. Learners could guess the answers without necessarily understanding the computational procedures involved.

In the second lesson, Jabulani asked learners to use tablets to complete an activity on addition and subtraction. This too was mere drill and practice and did not relate to the topic of fractions he had introduced in the first lesson. The lack of alignment between the activity and the lesson he had taught resulted in no substantial mathematical discussion between learners in their groups, instead, learners were making noise.

Jabulani's lesson in comparison with his colleagues' lessons reveals the lack of a systematic approach in the adoption and integration of tablets in School B. While the use of tablets in the experiential by his colleagues was to reinforce or to enrich the knowledge taught at the discursive event, in two formal lessons observed in Jabulani's class, tablets experiential activities did not align well with the discursive event. This suggests that there is a lack of collaboration among sixth grade mathematics teachers and that they do not share their experiences of teaching with tablet technology. The same can also be said for School A: The fact that the school principal refused me permission to access any other teachers except Sandra, shows that Sandra might have monopolised the use of tablets and that no other teachers are able to integrate the devices effectively. Previous studies (Glazer, Hannafin, & Song, 2005; Smith & Robinson, 2003) caution teachers to approach the integration of technology as a collaborative effort in which they support one another, share ideas to improve their practices, and model the effective use of technology within their teaching context. If this can be applied in the studied schools, then sixth grade mathematics teachers will grow together in the effective use of tablet technology in the classroom. The current situation shows that each teacher participant is growing individually in the use of tablet technology.

5.3.3.4 Experiential teaching in Samantha's lesson

The experimental task in Samantha's class was preceded with a mental mathematics activity. The CAPS requires elementary school mathematics teachers to allocate 10 minutes daily to mental calculations (DoBE, 2011). It is thought that this will help to boost learners' numeracy and mathematical mental agility and to curb the ongoing underperformance in international mathematics competitions(McCarthy & Oliphant, 2013). Unlike Sandra's lesson where learners did the initial activity with the tablet, learners in Samantha's class read the activity from the chalkboard, worked answers out using papers, and then recorded their answers on the tablets. This meant that the tablets were not the main instructional tool. The activity could even have been completed without tablets.

Gibson (2014) asserted that an object can offer different affordances depending on the user and the purpose of using the object. This is in line with Dron (2012) who also maintained that a technology can become many technologies to different users. He used the screwdriver as an example. In his argument, a screwdriver is a different technology when it is used by an artist open the lid of a pot of paint than when it is used to mix the paint; it is also a different technology when it is used by a criminal as a murderer weapon than when it is used by a carpenter to tighten a screw.

In this study, the Chalk application also became many technologies to different teachers. It was a productive tool when learners in Sandra's and Sabina's classrooms used it to produce their own shapes and own fraction models. It became a record keeping tool when it was used in Samantha's class to record answers. When used as a productive tool, there were substantial discussions going on between the learners as they shared their views and tried different options to produce the best agreed upon outputs. However, in

Samantha's class where the application was simply used for recording, there were no rich discussions. Therefore, we can say that the pedagogical value of tablet technology depends on teachers' instructional methods and the lesson activities that use it.

The actual experimental task allowed learners to practise the addition of fractions of common denominators through tablet fractions application. Learning through a practical activity needs to meet four pedagogical requirements for it to offer the value expected by the conversational framework. The activity must be based on clear goals, it must encourage learners' actions, it must provide learners with meaningful feedback, and it must allow for the revision of actions (Laurillard, 2013). Samantha's experiential task met the four requirements. She made her goals clear when she introduced the activity and told the learners that she wanted them to practice the addition and subtraction of fractions of common denominators. Tablets mediated the experiential event by providing instant feedback, multiple representations including fractions models, fractions annotations, and several opportunities to practice. It also afforded learners the option to explore descriptions of important concepts before engaging with the activity, thus covering part of the discursive event. Samantha moved around to provide descriptive feedback on request and to ensure learners' discussion was about the activity and nothing else. As mentioned earlier, learners' marks on the activity were quite good. This was probably because of repeated practice and the instant feedback on their actions. It could also be that learners were familiar with the activity.

Samantha believed tablet applications do not sufficiently cover the breadth and depth of the curriculum content. Hence, after the core experiential activity she provided learners with homework from the DBE book in which learners had to solve fraction word problems and use different representational forms to present the solutions. This was in line with the conversational framework. Laurillard (2002) suggested that no one media form is self-sufficient in itself to provide learners with the full learning experience. It calls on teachers to enrich learning using different media. The DBE book is tailored to the CAPS document, which stipulates the knowledge learners should know by the end of sixth grade.

5.3.4 Section summary

Overall findings relating to the second research question showed that the majority of teachers used tablets in instructional mathematics conversation in ways that aligned with the conceptual framework of the study and their perceptions of the value of tablet technology in instructional practices.

Most lessons had the discursive event to develop conceptual understanding of mathematics concepts through iterative goal oriented dialogue and the experiential event to deepen the understanding of the knowledge constructed at the discursive event. While participating in both events, the participants received ongoing feedback to reflect on and to then adapt conceptual understanding and mathematics actions.

In most classrooms the use of tablets provided teachers with different media forms to illustrate mathematical concepts and to provide learners with a platform to do mathematics on their own. It also provided tools for learners to author their own knowledge. The devices also provided interactive tools to share and communicate mathematical solutions and feedback to progress on their own with little support from teachers.

In all the classrooms, tablets were used together with traditional tools to support learning. The findings agree with previous studies (Hilton, 2018; Kay & Lauricella, 2018) that tablets have the potential to add value to mathematics teaching and learning. The use of tablets allowed engaging learners in the teaching and learning process. It also provided learners with tools to create knowledge, to represent knowledge and to share the outputs. Instant feedback promoted self-directed learning, timely reflection and adaptation of mathematical understanding.

The study argues that in the context of township schools, both the discursive and the experiential events of the instructional conversation have to be present in the teacher's teaching. Generally, townships learners rarely encounter mathematical conversations outside the school because of the socio-economic status of township residents. This could be why learners were using everyday language to talk about mathematical relations; they lacked the specialised language. Significant time should be devoted to mathematical talk for learners to develop concepts, specialised language and ways of doing mathematics with feedback to support learning. Through mathematical conversations learners develop both the ability to talk about mathematics and to talk and think mathematically; a skill they need for meaningful participation in the information based economy. Enough time should also be devoted to doing mathematics with learners solving mathematical problems, sharing solutions, and creating knowledge on their own.

The findings of the study in this section pointed to the importance of multilevel teacher professional development programs on the use of tablets in mathematics curriculum and pedagogy. It was surprising that teachers who are in the same school and who teach the same subject at the same grade level exhibited different tablet integration practices, with some practices not being pedagogically sound. A school based community of practice is needed so that teachers support one another in their endeavour to integrate tablet technology in sixth grade mathematics.

The findings also reveal the need to help teachers develop the skills to design their own learning activities that use tablets. There were more learning gains when teachers provided their own activities than when learners worked on pre-designed activities loaded by the sponsor. While pre-designed activities were simple multiple-choice activities and did not align with the local context, teacher designed activities were complex and imbedded in the learners' world of experience, thus helping learners to know how to apply mathematical knowledge in everyday life.

5.4 Research Question 3: What challenges impact teachers' use of tablet technology in the teaching of sixth grade mathematics?

Chapter Four identified four major challenges that impact or may have an impact on the teachers' use of tablet technology in sixth grade mathematics teaching. These are the lack of the supporting technological infrastructure, inadequate teachers' training, and the lack of familiarity with the e-Education policy.

5.4.1 Lack of Support infrastructure and inadequate teacher training

The lack of the supporting technological infrastructure (Pitchford, 2015) and inadequate teacher training in the use of tablets in mathematics teaching (Attard, 2013; Hubber et al., 2016b) are identified in the literature as the major challenges impacting the pedagogical use of tablet technology in mathematics teaching (Attard, 2013; Hubber et al., 2016a; Pitchford, 2015). The findings of the current study also showed several opportunities that are missed by teachers and learners due to the lack of the supporting technological infrastructure such as the internet connectivity and the lack of enough tablet devices in the school and the lack of teachers' training. The training teacher participated in did not model how to use educational applications in the classroom situation. Hence teachers are not able to use some education applications available to enhance learning. Another challenge relating to this is the lack of e-materials that comply with the curriculum. Existing e-materials do not cover the depth and breadth of the curriculum. They expressed concern that regular use of the same applications will render them uninteresting to learners.

5.4.2 Lack of Familiarity with e-Education Policy

The South African Government strongly recognises changes that the use of technology has brought about in many aspects of the human endeavour worldwide. Therefore, in 2004, the Government introduced the White Paper on e-Education to show its commitment to the use of ICT in South African schools (DoE, 2004). The White Paper on e-Education emphasised how technology will transform classroom practices and how it will help to achieve the national educational goals spelled out in the CAPS. It envisioned learners who are ICT capable. This means learners, who are able to use technology to collect, analyse, interpret and communicate information and learners who can use technology to solve problems. It also envisioned qualified teachers who are able to use ICT in the curriculum and assessment and in their daily administrative and managerial duties. At the pedagogical level, the e-education policy offers promissory of learner-centred constructivism pedagogy, which is likely to occur if teachers effectively integrate technology into teaching and learning.

In view of the above, it is imperative that teachers know the e-education policy and its aspirations well so that there is a compromise between what they do in the classroom and the policy. A critical analysis of the e-education policy shows that the changes in teaching and learning it aspires are also infused in the conversational framework and in meaningful learning. Therefore, the conceptual framework used in the current study was not conflicting with the policy.

The findings of this study indicate that teacher participants are not familiar with the e-education policy. They did not even know about its existence. Not even the two ICT coordinators who participated in this study knew about the e-education policy. Given that the main mandate of the school ICT coordinators is to model and to promote effective integration of ICT in the classroom, it was shocking that they did not know about the policy they are supposed to promote. This raises a red flag because the knowledge of the national ICT policy as well as the supporting school based ICT policy is the requirement for effective integration of technology in the classroom(Hennessy et al., 2010). It cannot be certain whether in the long run the end the goals of the e-Educational policy will be achieved.

There can be many reasons why the teacher participants did not know about the e-education policy. Howie and Blignaut (2009) noted that although there are many ICT initiatives that are assisting in the dissemination of technology in schools in South Africa, many of these initiatives do not align with the e-education policy. They limit what they do to the provision of hardware while ignoring the development of teachers in the pedagogical use of technology in the classroom. Provision of hardware is less demanding than teacher development, which is costly and continuous. This is one of the reasons why there are significant gaps between the e-education policy and the realities in the classroom. It could be that the tablet sponsor in the studied schools did inform the teachers about the e-education policy. Although the sponsor provided some training sessions, the interviews with teachers indicated that the training they received was limited to how to operate the tablet device. The pedagogical aspect, which possibly could have developed their understanding of the e-education policy, was not part of the training.

Previous research (Vandeyar, 2013, 2015) indicates that the lack of familiarity with the e-education policy is a systemic problem that goes beyond the school level. In the study that sought to understand how the provincial and the district eLearning facilitators were trained to enforce the implementation of the e-education policy, Vandeyar (2015) found that these officials too had a shallow understanding of the purpose and the content of the policy they were paid to promote. They understood their role as being the physical distributors of the policy document to schools as opposed to being preachers of the policy. The study also found that these officials did very little to support teachers in the pedagogical use of technology. In his previous study, Vandeyar (2013) had also found that school principals in township schools did not know about the existence of the e-Education policy nor did they recognise it as a resource document they need for the integration of ICT in the curriculum. It is therefore not surprising that the teacher participants did not know about the e-education policy, given that their superiors who are supposed to mediate this understanding and provide support are not trained to carry out their role.

Schools in South Africa have the autonomy to set up a school-based ICT policy. Therefore, in the absence of the e-education policy there should have been a school-based ICT policy to direct classroom use of ICT. Tondeur et al. (2007) asserted that in the school where there is no formal policy to consult, the use of ICT in the classroom becomes an ambiguous practice. Teachers use the technology in the ways they feels are right and decide on their own whether to use it or not, and this might undermine the effort to achieve the goals in the national policy. This study also found that every teacher participant used tablets in their own way: some in learner-centred and other in teacher-centred pedagogies. Sandra relied on her technological pedagogical knowledge and her philosophy about teaching and learning to integrate tablets in her teaching. She was the most experienced in the teaching of mathematics and had participated in many training programs. She had also had early exposure to technology in her home. She believed in active and collaborative learning. The use of tablets in her class was learner-centred and in line with the policy and the conversational framework. Sabina and Samantha, although they did not have as much training opportunities as Sandra, too have been teaching the subject for many years and believed in learner-centred teaching. Their teaching too was in line with the conversational framework and e-education policy. Despite we cannot confirm that the practices we observed during lesson observations are sustainable. A longitudinal study is needed in this regard to confirm whether the use of tablet technology in the classroom will consistently align with the policy despite the policy not being invisible in the school.

The findings of the study show the gaps between the e-Education policy aspirations and Teacher Jabulani's enacted classroom practices. He used tablets to amplify his traditional role and for drill and practice. Nevertheless, the e-education policy advocates for classroom practices that which transcend this simplistic use of technology. It states that e-education about using technology to create knowledge and information (DoE, 2004). However, his colleagues, although they did not know about the e-education policy, created opportunities for learners to use tablet productive applications to create mathematics knowledge artefacts as a demonstration of higher-order learning. Specifically, in Sandra and Sabina's classes, learners used tablet productive tools to create knowledge, solve problems, present and communicate the solutions to problems. These are the attributes of a changed pedagogy.

The White Paper on e-education identified ICT literacy as one of the critical skills learners need to develop in order for them to participate effectively in instructional practice that integrate technology. There were no opportunities to develop ICT skills in Jabulani's class. He did all the activities with this potential by himself. In contrast, in other classrooms his colleagues gave learners opportunities to develop ICT skills under their guidance. This means there is a lack of common understanding and vision among teacher participants with regards to how tablet technology should be used in the teaching of sixth grade mathematics.

The findings unveiled the lack of communication between the ICT coordinating team and the teaching staff. Jabulani, who is the ICT coordinator in School B, said that the school ICT committee was in the final stage of drafting the school ICT policy but his colleagues did not know about this development. Although the study could not confirm that this draft policy really existed, the fact that the teachers were left out of the planning of the document might complicate the implementation of this policy after it is finalised. Teachers need to be involved in the writing of the policy so that its implementation becomes a shared responsibility. The findings highlight the need for a formal ICT policy to inform the use of tablets in the studied schools. There is also a need for a collegial understanding of the use of tablets in sixth grade mathematics in the studied schools.

The lack of a formal policy to inform the use of tablets in the studied schools translates into to the use of the devices in teachers' teaching being a voluntary effort and not the e-Education policy mandate. This was also confirmed through the interviews. In the interview, Jabulani complained that majority of his colleagues have resisted the use of technology in their teaching, despite several attempts he has made to persuade them. Obviously, if there is no formal policy then his colleagues do not feel obligated to use tablets. All teacher participants indicated that they responded positively to the use of tablets to get access to multimedia resources to enhance teaching and learning. One teacher added that she is using tablets in her teaching to prepare learners for life. She commented that, "we cannot divorce from technology, technology is everywhere". Another teacher's comment highlighted the need to teach with tools learners are familiar with in everyday day. She opined that learners used cell phones and tablets every day in their homes, therefore teachers have to use this to their advantage to invigorate their teaching. In view of these comments, the use of tablets by teacher participants is voluntary and driven by professional ambitions to teach well, to adapt to technological changes and to prepare learners for the future. It is not policy mandate driven.

5.4.4 Section Summary

In conclusion, the discussion of the findings relating to the third research question of the study provides additional insights to have a holistic understanding of how teachers used tablets in mathematics instructional events and the pedagogical value thereof. The findings indicates that the lack of supporting technological infrastructure and the teacher's training undermine the teachers' effort to optimise the use of tablets in sixth grade mathematics teaching. The findings also show that teacher participants do not have the knowledge of the White Paper on e-Education policy and do not consult it in their teaching. This can have a devastating impact in the future. Teachers are at the meeting point of policy and practice; therefore, the vision in the e-education policy cannot be realised unless teachers interpret the aspirations in the White Paper on e-Education into pedagogical actions in their classrooms.

5.5 A Model for Optimising the Benefits of Tablet Technology in Township Schools

As stated in Chapter 1, the significance of this study is to use the analysis and interpretation of salient findings of the study to conceptualise a model that could be used to guide the instructional use of tablet technology in mathematics teaching in township schools. The findings of the study indicated that although teacher participants have made tremendous changes in their teaching using tablet technology, the digital content they have was not designed for township learners. It was developed elsewhere and then made to fit into the township context. Issues that were raised include the language and examples educational mathematics applications use, the sequence and the pacing that differ from the curriculum, and the depth and breadth of the content that are not sufficient to cover all the curriculum topics. It seems this technology was meant to be used in well-resourced independent schools, where teachers and learners have sufficient resources to support teaching and learning and where the use of tablet technology can be a luxury. However, teaching and learning resources in township schools, particularly in Schools A and B, are scanty. Therefore, tablet technology in these teaching and learning environments is the main teaching and learning resource teachers and learners rely on. Hence, the findings caution that tablet e-resources should not be imported and then forced to fit into the local context. It should be designed to address the needs in the context in which it will be used in order to allow teachers and learners to derive maximum teaching and learning benefits from the use of tablet technology. The initial framework the study started with did not include the context aspect, and therefore, it needs to be revisited to indicate that the context in which tablet technology is developed and used affects how it is used in sixth grade mathematics.

The findings of the study showed that learners in township schools have learning difficulties deriving from the township environment they grow in. One of them is lack of fluency in the medium of instruction, and because of this, they have challenges constructing and expressing mathematical ideas and thoughts. They also do not have opportunities to encounter mathematical discourse outside school; hence, they express mathematical ideas and thoughts using everyday language they are exposed to in their communities. The discursive event of the instructional conversation showed its potential not only for the development of conceptual understanding but also for the development of specialised mathematics language. The development of specialised mathematics language should be promoted to enable learners to think and speak mathematically. The initial conceptual framework emphasised the importance of the discursive event to develop structured understanding of mathematical concepts. In the revised conceptual framework, the discursive event seeks to develop conceptual understanding of mathematical concepts but also specialised mathematical language.

The experiential event of the conversational framework also showed the potential to promote mastery of mathematical concepts. The findings of the study showed that an experiential task yielded more learning gains only when it was linked to the discursive event and when it involved higher-order cognitive levels., e.g. problem solving and knowledge creation as opposed to drill and practice of multiple-choice activities. Hence, the revised conceptual framework, which is offered as a model for the use of tablet technology in instructional mathematics conversation in township schools, emphasises that the experiential event must include all cognitive domains as opposed to lower cognitive domains, which are developed through drill and practice of multiple-choice activities.

It was clear that tablet technology alone could not provide learners in the studied schools with meaningful learning of mathematical concepts but that the interweaving of all possible teaching resources to make a bundled technology is necessary. A bundled technology in this context means the combination of traditional technology, like chalkboard, tangible objects in the classroom, textbooks, code switching, body language, and the digital resources teacher participants used to scaffold learning in instructional mathematics conversations. My initial framework had digital technology as its focus, but the findings showed that in the context of the studied schools, the instructional mathematics conversation should employ digital and non-digital technologies to achieve instructional goals. The revised conceptual framework uses the concept of bundled technology to cater for both digital and non-digital technology in instructional mathematics conversations.

Initially the study assumed the e-Education policy was common knowledge to teacher participants and a social capital embodied in their teaching practices. Hence the e-Education was not included as one of the constructs of the initial conceptual framework. However, the findings of the study showed otherwise. No teacher participant was familiar with the e-Education policy and they did not know that it existed. It is very important that teachers be acquainted with the policy to ensure that what they do in the classroom works toward achieving the national e-education goals. Normally, the e-education policy should set out what the nation wants to achieve from the use of tablet technology in instructional conversations and have guidelines to achieve these aspirations. Failure to consult the e-Education policy made the use of tablet technology in sixth grade mathematics in the studied schools a process guided by teachers' personal beliefs about how technology should be used in classroom teaching. In the long run, this can be a big obstacle to achieving the national educational goals. In the revised conceptual framework access to this policy as well as the knowledge of how to interpret it in instructional mathematics conversations are as important as access to tablet technology. In this regard, the concept of bundled technology will also include the guiding ICT policy to emphasise that it is a necessary tool to have in the instructional mathematics conversation.

Based on the aforementioned, the following model is proposed.

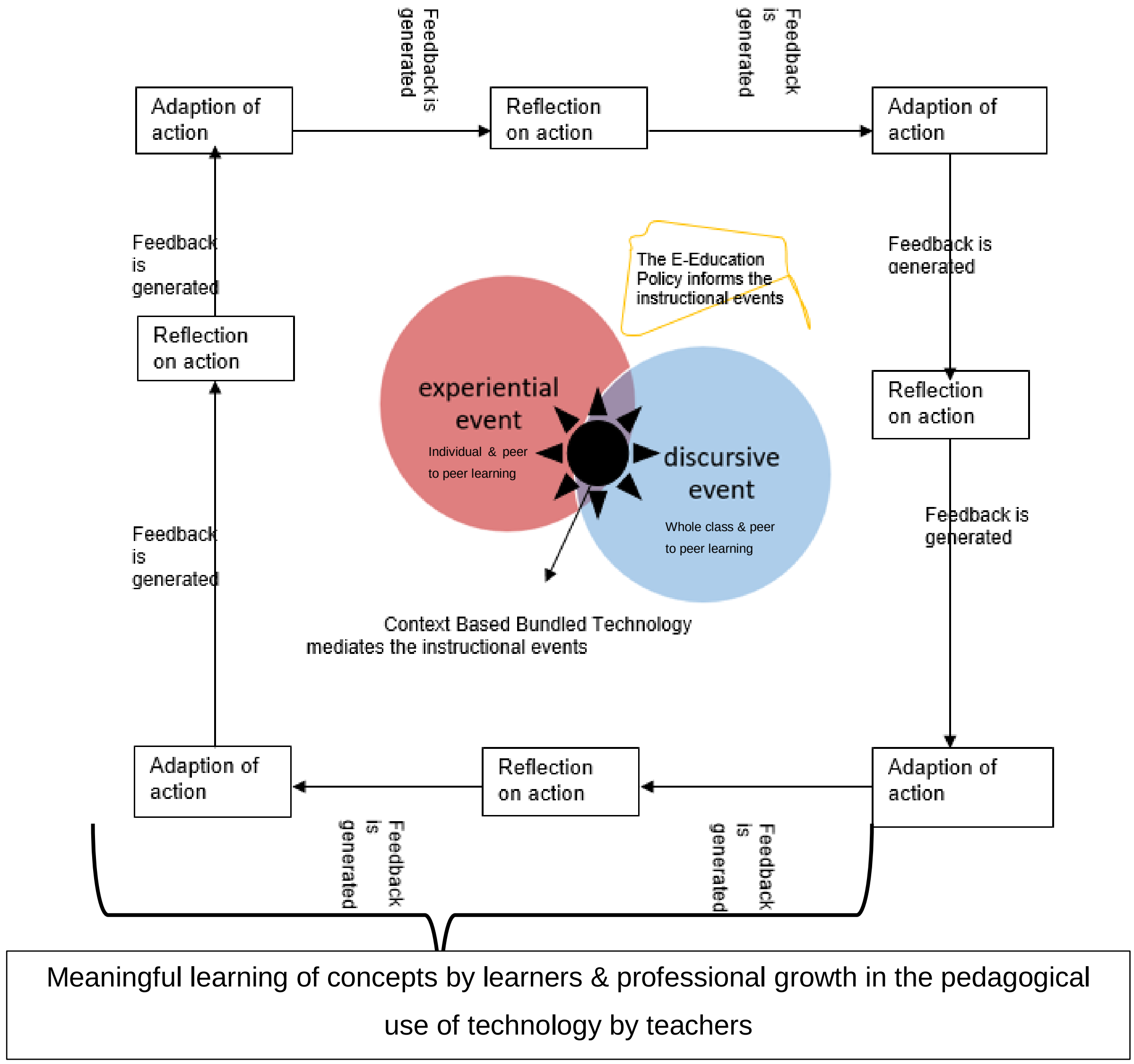


Figure 25 Instructional Mathematics Conversation Model

As the model in Figure 25 above indicates, the participants in the instructional mathematics conversation (the teacher and learners) interact iteratively through the two intertwined discursive and experiential events of an instructional conversation. The discursive event is teacher mediated and is aimed at developing learners' conceptual understanding of concepts and developing learners' specialised language through engagement in discourse. The discursive event takes a dialogical form. The experiential event is aimed at promoting the mastery of concepts through learners' own engagement with the content. It takes an experiential form and involves all cognitive levels. The discursive and the experiential events must provide opportunities for whole class, individual and peer to peer learning. It is indeed a challenge to provide individual learning in township schools where the class sizes are big. However, teachers should not shy away from it as it allows monitoring each learner's progress and providing individualised support. The school should ensure that each learner has a tablet for use in the classroom to make individual learning possible. Having their own device can help the learners to move around in the class to seek support from their peers and from the teacher. It can also help the teacher to focus on learners who require additional support.

The participants in the instructional conversation use a combination of tools to achieve instructional mathematics goals. The concept of "Bundled technology" has been used in this regard to include digital technology, and non-digital technology such as chalkboard explanations, textbooks, concrete objects, and body language. The bundled technology is represented by a dented black wheel in the model above. The digital technology needs to be contextualised, in other words, the resources and educational applications on this technology must align with the needs of the classroom environment in which the technology will be used. Non-digital technologies are contextual because they are tools already existing in the teaching and learning environment. The guiding e-Education policy in the model above is a consultation tool that participants in the instructional conversation use on a daily basis to make sure that the use of the bundled technology in the instructional events do not diverge from the national e-educational goals.

In the model above, three processes are very important for a successful instructional mathematics conversation: Feedback, reflection and adaptation. These three imply that when the participants engage in any of the events of an instructional conversation, they must receive ongoing feedback on their actions. The feedback received then leads to reflection on actions and adaptation of actions in relation to instructional goals. They must use the feedback emerging from their reflection to adapt their practices toward achieving their instructional goals.

The pedagogical value of any of the technology in the bundled technology relates to the way that participants in the instructional conversation use it in the instructional events to achieve instructional goals. The result, as the findings of this study indicated, should be meaningful learning of concepts by learners and professional growth in the use of the technology in instructional conversation by teachers

CHAPTER SIX: CONCLUSION

6.1 Introduction

This study explored the pedagogical value of tablet technology in the teaching and learning of sixth grade mathematics in two township schools in Gauteng, South Africa. The study used a qualitative approach to explore this phenomenon. Firstly, the study explored the pedagogical value of tablet technology through teachers' perceptions as they shared their lived experiences of using this technology in their teaching practices. The conceptual framework helped to sieve teachers' accounts of the value of tablet technology and to tease out the perceptions that related to use of tablet technology to promote meaningful learning of sixth grade mathematics. Secondly, the study examined the value of tablet technology through observing teachers' enacted classroom teaching. The features adopted from the conversational framework helped to analyse the instructional events. Lastly, the study identified the challenges that impact teachers' use of tablet technology in sixth grade mathematics teaching.

Three research questions guided the study:

1. What are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics?
2. How are teachers' perceptions of the value of tablet technology in the teaching of sixth grade mathematics translated into pedagogical actions in the actual teaching of sixth grade mathematics?
3. What challenges impact teachers' use of tablet technology in the teaching of sixth grade mathematics?

In view of the research questions above, the study aimed to achieve three research aims:

1. To ascertain teachers' perceptions about the value of tablet technology in the teaching of sixth grade mathematics
2. Examine how teachers' perceptions are translated into pedagogical action in the actual teaching of sixth grade mathematics.

3. To explore the challenges that impact teachers' use of tablet technology in sixth grade mathematics

6.2 Salient Findings

Based on the analysis of the data collected it is concluded that teachers identified tablet technology as a valuable pedagogical tool to transform teaching and learning of sixth grade mathematics. There were six significant findings relatable to their perceptions about the pedagogical value of tablet technology in the teaching and learning of sixth grade mathematics. These findings are summarised as follow:

1. Teachers expressed that the greatest benefit from the integration of tablet technology is the access various media forms including narrative media, interactive media, adaptive media, communicative and productive media. This was a significant pedagogical value to teachers given that their schools had been suffering from infrastructure and teaching materials backlog. Previously, difficulties to access teaching and learning materials resulted in sixth grade mathematics teachers teaching the subject abstractly. Now various media are readily available on the tablets for multiple representations of sixth grade mathematics concepts and meaningful engagement of learners in instructional mathematics conversation.
2. The use of educational applications has contributed significantly to meaningful teaching and learning of mathematics. A combination of tablet media with traditional teaching materials helps to make mathematics lessons alive and to help learners develop abstract learning of mathematics concepts.
3. Teachers appreciated the value of adaptive applications to promote individualised learning and to model the teaching of concepts that were previously difficult to teach. The topic of fractions and long division were the most challenging topics for both teachers and learners. Tablet adaptive applications break these topics into smaller learning objects, sequenced from simple to complex. While engaging with the objects, learners receive instant feedback and hints about the mathematics operation they have to carry out. In the case of long division, one teacher admired

that the applications flickers to tell learners whether they must add, multiply or divide.

4. The use of tablet adaptive applications in the form of educational games has promoted positive attitudes toward the subject by learners. Teachers happily opined that there has been increased learner engagement in mathematics lessons and with the content in the classroom and after school hours. Attendance in mathematics lessons has also improved because of using educational games in mathematics lessons.
5. Teachers positioned themselves as the agents who instigate the pedagogical value of tablet technology to support meaningful learning of mathematics concepts by learners. Their mediation helps to bridge the content gaps between the curriculum and tablet resources and to make the tablet resources meaningful to the curriculum and learners' everyday life.
6. Teachers are using the technology for their own professional growth in the pedagogical use of educational applications in mathematics lessons. This occurs through modelling and playful time with this technology. Teachers identified this as an important benefit, given that most professional development programs they attended did not prepare them for the use of tablet technology in classroom teaching.

The analysis of the data relating to how teachers used tablet technology in the instructional conversation and relatable value of tablet technology as enacted in the teachers' actual teaching revealed five major findings, which are summarised as follow:

1. The majority of teachers used tablets in ways that aligned with their perceptions about the pedagogical value of tablet technology in their teaching and the conceptual framework of the present study.
2. Adaptive media in the form of educational games, the instant feedback on learners' actions in particular, promoted reflection on mathematics actions and adaptive of those actions by learners. The ability of adaptive media to record the learners' progress also promoted reflective and adaptive teaching on the part of the

teachers. Teachers were able to identify the content majority of learners struggled with, then provided appropriate scaffolding, sometimes by changing the teaching approach. This was a great advantaged for township schools. Overcrowding would make it difficult for teachers to check the learners' progress in real time.

3. The use of productive media in the form of the Chalk application allowed bridging the gap between theory and practice. It provided learners with tools to produce their own mathematical knowledge as a demonstration of higher-order learning. It also extended learners' expression of mathematics solutions, especially learners who were not able to speak publicly in the instructional conversation because of lack of fluency in the medium of instruction.
4. The discursive event of the instructional conversation showed the potential to promote the development of learners' mathematical specialised language and to address learners' mathematical misconceptions.
5. Learning gains from the use of tablet technology in instructional mathematics conversation related to how teachers mediated the technology to promote meaningful learning of concepts by learners. There were no significant learning gains in the classroom where the technology was used for drilling multiple choice mathematics activities.

The findings relating to the challenges affecting teachers' use of tablet technology in sixth grade mathematics showed that:

6. The lack of adequate supporting technological infrastructure, including the lack of internet connectivity, the lack of enough tablet devices and teacher training are the major challenges impacting the optimal use of tablet technology in sixth grade mathematics conversation.
7. Teacher participants are not familiar with the e-Education policy and the e-Education policy document does not exist in their schools. That means, teachers have a challenge to translate the vision in the e-Education policy into pedagogical actions in the classroom.

8. Despite the lack of the knowledge about the e-Education policy, the majority of teacher participants exhibited pedagogical practices which aligned with the pedagogy envisioned by the e-Education policy. However, it is remains uncertain whether the practices observed can be sustainable in the classroom environment where there is no ICT document to consult.

6.3 Implication of the Findings for Future Research

The study explored the pedagogical value of tablet technology in township schools drawing from teachers' lived experience of using tablet technology in instructional mathematics conversation. Though of a narrow base, the findings of the study opens the ground for more robust research at the national level. Future research should explore learners' lived experience as well in order to have a complete understanding of the pedagogical value of tablet technology in mathematics teaching in township schools.

The findings of the study indicate that tablet technology might have the potential to be used to develop teachers' knowledge in the pedagogical use of educational applications. Future research should seek to investigate in more detail how the use of tablet educational applications technology develops teachers' knowledge in the pedagogical use of educational applications. If successful, this can help to address the issue of developing teachers in the use of technology that the country has been grappling with.

The study was conducted in two township schools and in Grade 6 classrooms. Currently, there is an incremental increase of township schools and teachers embracing this technology as part of the Government plan to transform traditional classrooms into paperless smart classrooms. Therefore, there is need for large-scale and longitudinal research to be conducted in order to investigate the value of tablet technology in township schools in the country.

6.4 Recommendations

Based on the findings from this study some recommendations can be made to the studied schools and teacher participants.

6.4.1 Recommendations to Participating Schools

6.4.1.1 Recommendation 1: Provision of supporting technological infrastructure

The findings of the study showed that teachers' effort to integrate tablet technology in sixth grade mathematics is constrained by the lack of internet connectivity. Schools should provide teachers with access to connectivity so that they have enough e-resources to make significant changes in their teaching.

Schools should provide enough devices so that teachers can integrate different pedagogical approaches for meaningful learning of concepts by learners. Currently teachers cannot engage learners individually using tablets because they lack enough tablet devices.

There is need to have mounted projectors and projection screens in the classrooms. It was frustrating for teachers to wait for the projector to be brought into the classroom and frustrating to project onto A4 papers pasted on the chalkboard.

6.4.1.2 Recommendation 2: Provision of a job-embedded technological professional development program on the use of technology in the classroom

Teacher participants expressed a lack of confidence in the use of some of the applications loaded on the devices because of inadequate training. The training they received focussed on technical skills of how to operate tablets. However, the knowledge of how to operate the device is not enough for teachers to provide learners with meaningful learning experience using tablet technology. The training must seek to help teachers make connections between technological knowledge, their pedagogical knowledge and the content (Ertmer & Ottenbreit-Leftwich, 2010). Therefore, there is a need for ongoing professional development programs aimed at modelling how to use tablet technology in sixth grade mathematics curriculum.

6.4.1.3 Recommendation 3: Provision of e-Education policy document and joint development of school ICT policy

The findings of the study indicated that the e-Education policy document does not exist in the schools that were studied; hence, teacher participants were not aware of it. There is a need for the school leadership to make this policy available to all teaching staff and to hold staff meetings on how best to implement the policy in the school. This will help to ensure that the policy is translated into practice and that what is done in the classroom with tablet technology helps to achieve the national e-Educational goals.

Teachers should work together to draft a school based ICT policy that translates the national e-Educational policy into context based achievable gaols and that defines the means to achieve those goals. The findings also indicate that there is lack of communication between teachers regarding their experiences of using tablet technology in the classroom. Therefore, there is a need for occasional school meetings/workshops on policy implementation in the school.

6.4.2 Recommendations to Teacher Participants

6.4.2.1 Recommendation 4: Many opportunities for mathematical discourse

Evidence from this study shows that in classrooms where there were opportunities for mathematical discourse, learners developed both mathematics concepts and specialised language to share mathematical thoughts and ideas. Previous research (Pratiwi et al., 2018) also indicated that mathematical discourse promotes the development of the ability to think and speak mathematically. Hence, this study encourages all teacher participants to give learners many opportunities for mathematical discourse in their classroom teaching.

6.4.2.2 Recommendation 5: More integration of tablet technology in problem solving as opposed to multiple-choice activities

The findings show that there were more learning gains when teachers used tablet technology for problem solving than when learners used the technology for drill and practice of multiple-choice activities. Research (Mayer, 2002) indicates that many attributes of meaningful learning are achieved when learners are involved in problem-solving activities. Therefore, the study encourages teachers to provide more problem-solving opportunities that involve higher cognitive levels.

6.4.2.3 Recommendation 6: Invest in own professional development

Teachers seemed to be at different levels in the use of tablet technology in the classroom. The teacher who was ahead of others said she acquired her skills from participation in the community of practice and from many training programs she attended, paying with her own money. This study also encourages teachers to invest in their own professional development, starting with collaborating with colleagues who have more experience and knowledge.

6.5 Limitations of the Study

The study was successful in providing insightful information about the pedagogical value of tablet technology into teaching and learning of sixth grade mathematics, using multiple data collection tools for triangulation purpose. This helped to ensure that the data collected were trustworthy. However, data were collected from two township schools and five teacher participants who were selected purposefully. That means, the school and teacher participants are not representative of the South African township school population, although similarities may exist. Therefore the findings of the study might not be generalised to a broader context beyond the schools and teachers that were used in the study, unless if there exist thick similarities.

6.6 Thesis Conclusion

In conclusion, the findings of this study showed that tablet technology has potential to transform teaching and learning of mathematics in schools that are resource constrained. In the studied schools, the use of tablet technology provided access to all the media forms, which are identified in the conversational framework (Laurillard, 2002) as necessary to complete the learning experience. These include narrative media, interactive media, adaptive media, communication media and productive media. All these forms of media were available in the tablet device. The use of adaptive educational applications in particular, showed the potential to upscale support to mathematics teachers in overcrowding classrooms. The applications provided a series of mathematics activities for learners to work on at their own pace. Learners received prompt feedback on mathematics actions, and this allowed them to progress in real time without waiting for the teacher to mark their work. While adaptive applications promoted reflective and adaptive learning on the part the learner, they also promoted reflective and adaptive teaching on the part of the teacher. Based on the findings from the study, it is recommended that township schools that plan to introduce tablets in mathematics teaching must first have e-resources that align with the curriculum. They must also have stable internet connectivity and must ensure that teachers are trained in the use of educational mathematics applications for them to use the technology effectively. Section 5.5 of this report provides a proposed model for effective use of tablet technology in mathematics teaching in poorly resourced schools.

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APPENDIX 1: LETTER TO THE SCHOOL PRINCIPAL

Dear Principal,

My name is Meschac Rafiki. I am doing research for obtaining a Doctor of Philosophy Degree (PhD) in Education at the University of the Witwatersrand. I am inviting your school to participate in my research entitled ***"The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa".*** My research aim is to explore the pedagogical value of tablet technology in the teaching of Mathematics. With your permission I would like to understand how sixth grade Mathematics teachers at your school teach with tablet technology. I am intending to observe five lessons from one sixth grade Mathematics teacher. I also would like to interview the same teacher on his/her experience of using tablet technology in sixth grade Mathematics teaching. The interview is expected to be one hour long and will be scheduled at a mutually agreed upon time that best fits the teacher's schedule. I also would like to use the school's ICT policy to complement the information collected through interview and lesson observations. Your permission to do this will greatly enhance this study.

Participation in this study is voluntary. Research participants will not be disadvantaged in any way by participating in this study. In addition, there are no foreseeable risks in participating in this study. Research participants will be informed of their right to withdraw their participation in this study at any time. All research participants will be kept anonymous. No person's name or school name will appear in my thesis. I will use pseudonyms instead of the school or participants' real names in the research write up. Individual privacy will also be maintained in all publications resulting from the study. All information collected from teachers will be treated confidentially. I will keep the data in a secure file and only my supervisor and I will have access to it. The raw data will be destroyed within 3-5 years of completing this study.

Please do not hesitate to contact my supervisor or me if you require any further information about this study. I can be reached at 0738823889 or via email at r.meschac@gmail.com. You can reach my supervisor Dr Ephraim Mhlanga at 0726048889 or via email at ephraimm@saide.org.za. I look forward to your response as soon as is convenient.

Sincerely,

Meschac Rafiki

APPENDIX 2: PRINCIPAL'S CONSENT FORM (PERMISSION TO USE THE SCHOOL ICT POLICY)

Dear Principal,

Please sign and return the form to give or decline your consent to have your school's ICT policy used for my research project entitled ***"The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*** Participation in this project is voluntary and your school will not be affected negatively in any way for not allowing me to use the school ICT policy.

Permission to use the school ICT Policy (tick where appropriate)

I, ________________________give/ do not give my consent to have the school's ICT policy used for the research project entitled "*The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*

I know that the school may withdraw from the study at any time and that it will not be disadvantaged in any way by participating in this study.

I know that the information collected will be used for the purpose of this study only.

I am aware that academic papers will be developed and published, and that the researcher will not mention the name of the school in all publications.

I am aware that the researcher will keep all information confidential in all academic writing.

Principal's Signature: ________________________ Date: ___________________

APPENDIX 3: INFORMATION LETTER TO TEACHERS

Dear Teacher,

My name is Meschac Rafiki. I am doing research for obtaining a Doctor of Philosophy Degree (PhD) in Education at the University of the Witwatersrand. I am inviting you to participate in my research entitled ***"The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*** My research aim is to explore the value of tablet technology in the teaching of sixth grade Mathematics. Data will be collected through lesson observations, interviews with Grade 6 teachers, the analysis of your lesson plans, and samples of your learners' work.

I seek permission to observe five Mathematics lessons where you use tablet technology. I also would like to interview you on your perceptions about the value of tablet technology in your teaching and your experience of using such technology in your teaching. The interview will be one hour long and will be scheduled on a mutually agreed upon time that best suits your schedule. Your participation in the study is voluntary and you are free to withdraw from the study at any time. In order to accurately capture and reflect on your interview responses and your lesson presentations, I will seek your permission to audiotape the interview and videotape your lesson presentations. All information collected from you will be treated confidentially. I will keep the data in a secure file and only my supervisor and I will have access to it. The raw data will be destroyed within 3-5 years of completing this study. You will not be disadvantaged in any way for participating in this study. In addition, there are no foreseeable risks in participating in this study. I will use pseudonyms instead of the school or your real names in the research write up. Your privacy will also be maintained in all publications resulting from the study. If you wish to participate in this study, please sign and return the consent forms enclosed.

Please do not hesitate to contact my supervisor or me if you require any further information about this study. I can be reached at 0738823889 or via Email at r.meschac@gmail.com. You can reach Dr Ephraim Mhlanga my supervisor at 0726048889 or via Email at ephraimm@saide.org.za. I look forward to your response as soon as is convenient. Sincerely,

Meschac Rafiki

APPENDIX 4: TEACHERS' CONSENT TO BE INTERVIEWED

Dear Teacher,

Please sign and return the form to give or decline your consent to be interviewed for my research project entitled "The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa." I would like to emphasise that your participation in this project is voluntary and that you will not be affected negatively in any way for not participating in this project.

Permission to be interviewed (tick where appropriate to give or not to give your consent).

I, _________________________ **give my consent**/ **do not give my consent** to be interviewed.

I know that I do not have to answer all the questions and that I may withdraw from the study at any time and that I will not be disadvantaged in any way by participating in this study.

I know that the information collected will only be used for the purpose of this study. I am aware that academic papers will be developed and published, and that the researcher will not mention my name in all publications

I am aware that the researcher will keep all information confidential in all academic writing.

I am aware that my interview transcript will be destroyed within 3-5 years of completing the study.

Teacher's signature: ________________________ Date: _____________________

APPENDIX 5: TEACHERS' PERMISSION TO BE AUDIOTAPED

Dear Teacher,

Please sign and return the form to give or decline your consent to have your interview audiotaped. I will use this audiotape for my research entitled "***The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa.***" I would like to emphasise that participation in this project is voluntary and that you will not be affected negatively in any way for not participating project.

Permission to have my interview audiotaped (tick where appropriate to give or not give your consent to have your interview audiotaped)

I ________________________ **give** my consent/ **do not give** my consent to have my interview audiotaped.

I know that I may withdraw from the study at any time and will not be advantaged in any way by participating in this study.

I know that I can stop the audio recording of the interview at any time.

I know that audiotapes will be used for the purpose of this study only. I am aware that academic papers will be developed and published, and that the researcher will not mention my name in all publications.

I know that the audiotapes will be destroyed within 3-5 years of completing the study and will be kept safely until then.

Teacher's signature: ________________________ Date___________________

APPENDIX 6: TEACHERS' PERMISSION TO BE OBSERVED

Dear Teacher,

Please sign and return the form to give or decline your consent to be observed in the classroom for my research project entitled "***The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*** I would like to emphasise that your participation in this project is voluntary and that you will not be affected negatively in any way for not participating in this project.

Permission to be observed

I, _________________________ **give my consent/ do not give my consent** to be observed in class for this study.

I know that I may withdraw from the study at any time and that I will not be disadvantaged in any way by participating in this study.

I know that the observations will only be used for this project. I am aware that academic papers will be developed and published, and that the researcher will not mention my name in all publications.

I am aware that the researcher will keep all information confidential in all academic writing.

Teacher's signature: _________________________ Date: ____________________

APPENDIX 7: TEACHERS’ CONSENT TO BE VIDEOTAPED

Dear Teacher,

Please sign and return the form to give or decline your consent to have the lesson observations videotaped. I will use the videotapes for the purpose of my research project entitled “***The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa*.”** I would like to emphasise that your participation in this project is voluntary and that you will not be affected negatively in any way for not participating in this project.

Permission to be observed

I, ________________________ **give my consent/ do not give my consent** to have the lesson observations videotaped.

I know that I may withdraw from the study at any time and that I will not be disadvantaged in any way by participating in this study.

I know that the videotapes will be used for the purpose of this project only. I am aware that academic papers will be developed and published, and that the researcher will not mention my name in all publications.

I am aware that the researcher will keep all information confidential in all academic writing.

Teacher’s signature: ________________________ Date: ___________________

APPENDIX 8: TEACHERS' CONSENT TO USE THEIR LESSON PLANS

Dear Teacher,

Please sign and return the form to give or decline your consent to have your lesson plans (five lesson plans of observed lessons) used for my research project entitled ***"The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*** Participation in this project is voluntary and you will not be affected negatively for not allowing me to use your lesson plans.

Permission to use my lesson plans (tick where appropriate)

I, _________________________give/ do not give my consent to use my lesson plans for the research project entitled "The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."

I know that I may withdraw from the study at any time and that I will not be disadvantaged in any way by participating in this study.

I know that my lesson plans will be used for the purpose of this study only. I am aware that academic papers will be developed and published, and that the researcher will not mention my name in all publications.

I am aware that the researcher will keep all information confidential in all academic writing.

Learner's Signature: _________________________ Date: ____________________

APPENDIX 9: INFORMATION LETTER TO THE PARENTS

Dear Parent,

My name is Meschac Rafiki. I am doing research for the purpose of obtaining a Doctor of Philosophy Degree (PhD) in Education at the University of the Witwatersrand. I am inviting your child to participate in my research entitled ***"The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*** My research aim is to explore the value of tablet technology in the teaching of sixth grade Mathematics. Your child has been selected because he/she will be in the classroom when I observe how his/her teacher teaches Mathematics with tablet technology.

Participation in the study is voluntary and your child is free to withdraw from the study at any time. I would like to videotape the teacher's lesson activities in order to accurately capture and reflect on the teacher's teaching with tablet technology. All information collected will be treated confidentially. I will keep the data in a secure file and only my supervisor and I will have access to it. The raw data will be destroyed within 3-5 years of completing this study. Your child will not be disadvantaged in any way for participating in this study. In addition, there are no foreseeable risks in participating in this study. I will use pseudonyms instead of the school or your child's real names in the research write up. Your child's privacy will be maintained in all publications resulting from the study. Please sign and return the consent forms enclosed if you wish to have your child observed and/or videotaped in the classroom for the purpose of this study. There will be unobserved and non-videotaped areas in the classroom for learners who do not feel comfortable to be observed or videotaped.

Please do not hesitate to contact my supervisor or me if you require any further information about this study. I can be reached at 0738823889 or via Email at r.meschac@gmail.com. You can reach Dr Ephraim Mhlanga my supervisor at 0726048889 or via Email at ephraimm@saide.org.za

I look forward to your response as soon as is convenient.

Sincerely,

Meschac Rafiki

APPENDIX 10: PARENTS' CONSENT TO OBSERVE LEARNERS IN THE CLASSROOM

Dear Parent,

Please sign and return the form to inform or decline your consent to have your child observed in the classroom for my research project entitled ***"The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*** I would like to emphasise that the participation in this project is voluntary and that your child will not be affected negatively for not participating in this study. If you do not wish your child to be observed, there will be seats reserved for such learners in the classroom.

Permission to have my child observed (tick where appropriate to give or not to give your consent to have your child observed).

I, _________________________ **give my consent**/ **do not give my consent** to have my child observed in the classroom.

I know that the participation in this study is voluntary and that my child may withdraw from the study at any time. I know that my child will not be disadvantaged in any way by participating in this study. I know that the information collected will be used for the purpose of this study only. I am aware that academic papers will be developed and published, and that the researcher will not mention my child's name in all publications.

I am aware that the researcher will keep all information confidential in all academic writing.

Parent's signature: ________________________ Date: ____________________

APPENDIX 11: PARENTS' CONSENT TO USE SAMPLES OF THE LEARNERS' MARKED WORK

Dear Parent,

Please sign and return the form to give or decline your consent to have your child's marked work used for my research project entitled ***"The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*** Participation in this project is voluntary and your child will not be affected negatively for not allowing me to use his/her marked work.

Permission to use my child's marked work (tick where appropriate)

I, ________________________give/ do not give my consent to use my child's marked work for the research project entitled "The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."

I know that my child may withdraw from the study at any time and that he/she will not be disadvantaged in any way by participating in this study.

I know that my child's marked work will be used for this study only. I am aware that academic papers will be developed and published, and that the researcher will not mention my child's name in all publications.

I am aware that the researcher will keep all information confidential in all academic writing.

Parent's Signature: ________________________ Date: ___________________

APPENDIX 12: PARENTS' CONSENT TO VIDEOTAPE LEARNERS IN THE CLASSROOM

Dear Parent,

Please sign and return the form to give or decline your consent to have your child videotaped in the classroom for my research project entitled "***The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa.***" I would like to emphasise that participation in this project is voluntary and that your child will not be affected negatively in any way for not participating in this project. If you do not wish to have your child videotaped, there will be seats reserved for such learners in the classroom where your child can sit.

Permission to have my child videotaped (tick where appropriate to give or not to give your consent to have your child videotaped).

I, _________________________ **give my consent/ do not give my consent** to have my child videotaped in class for this research project.

I know that my child may withdraw from the study at any time and that he/she will not be disadvantaged in any way by participating in this study.

I am aware that the researcher will keep all information confidential in all academic writing.

I know that the videotapes will be used for the purpose of this study only. I am aware that academic papers will be developed and published, and that the researcher will not mention my child's name in all publications.

Parent's signature: _________________________ Date: ____________________

APPENDIX 13: LEARNERS' INFORMATION SHEET

Dear learner,

My name is Meschac Rafiki. I am doing research for the purpose of obtaining a Doctor of Philosophy Degree (PhD) in Education at the University of the Witwatersrand. I am inviting you to participate in my research entitled ***"The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*** My research aim is to explore the value of tablet technology in the teaching of sixth grade Mathematics. You have been selected because you will be in the classroom when I observe how your teacher teaches Mathematics with tablet technology.

The participation in the study is voluntary and you are free to withdraw from the study at any time. I would like to videotape the teacher's lesson activities in order to accurately capture and reflect on the teacher's teaching with tablet technology. All information collected will be treated confidentially. I will keep the data in a secure file and only my supervisor and I will have access to it. The raw data will be destroyed within 3-5 years of completing this study. You will not be disadvantaged in any way for participating in this study. In addition, there are no foreseeable risks in participating in this study. I will use pseudonyms instead of the school or your real names in the research write up. Your privacy will be maintained in all publications resulting from the study. Please sign and return the consent forms enclosed if you wish to be observed and/or videotaped in the classroom for the purpose of this study. There will be unobserved and non-videotaped areas in the classroom for learners who do not feel comfortable to be observed or videotaped.

Please do not hesitate to contact my supervisor or me if you require any further information about this study. I can be reached at 0738823889 or via Email at r.meschac@gmail.com. You can reach my supervisor Ephraim Mhlanga (PhD) at 0726048889 or via Email at ephraimm@saide.org.za. I look forward to your response as soon as is convenient.

Sincerely,

Meschac Rafiki

APPENDIX 14: LEARNERS' CONSENT TO BE OBSERVED IN THE CLASSROOM

Dear learner,

Please sign and return the form to give or decline your consent to be observed for my research project entitled "The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa." I would like to emphasise that participation in this project is voluntary and that you will not be affected negatively in any way for not participating in this project. If you do not wish to be observed, there will be seats reserved for such learners in the classroom where you can sit.

Permission to be observed (tick where appropriate to give or not to give your consent to be observed).

I, _________________________ **give my consent/ do not give my consent** to be observed in class for this research project.

I know that I may withdraw from the study at any time and that I will not be disadvantaged in any way by participating in this study.

I know that the observations will be used for the purpose of this study only. I am aware that academic papers will be developed and published, and that the researcher will not mention my name in all publications.

I am aware that the researcher will keep all information confidential in all academic writing.

.

Learner's signature: _________________________ Date: ____________________

APPENDIX 15: LEARNERS' CONSENT TO BE VIDEOTAPED

Dear learner,

Please sign and return the form to give or decline your consent to be videotaped in the classroom for my research project entitled "***The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."*** I would like to emphasise that participation in this project is voluntary and that you will not be affected negatively in any way for not participating in this project. If you do not wish to be videotaped, there will be seats reserved for such learners in the classroom where you can sit.

Permission to be videotaped (tick where appropriate to give or not to give your consent to be videotaped).

I, _________________________ **give my consent/ do not give my consent** to be videotaped in class for this research project.

I know that I may withdraw from the study at any time and that I will not be disadvantaged in any way by participating in this study.

I know that the videotapes will be used for the purpose of this study only. I am aware that academic papers will be developed and published, and that the researcher will not mention my name in all publications.

I am aware that the researcher will keep all information confidential in all academic writing.

Learner's signature: _________________________ Date: ___________________

APPENDIX 16: LEARNERS' CONSENT TO USE A SAMPLE OF MARKED WORK

Dear learner,

Please sign and return the form to give or decline your consent to have your marked work used for my research project entitled "The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa." The participation in this project is voluntary and you will not be affected negatively for not allowing me to use your marked work.

Permission to have marked work used (tick where appropriate)

I, _________________________give/ do not give my consent to use my marked work for the research project entitled "The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa."

I know that I may withdraw from the study at any time and that I will not be disadvantaged in any way by participating in this study.

I know that my marked work will be used for the purpose of this study only. I am aware that academic papers will be developed and published, and that the researcher will not mention my name in all publications.

I am aware that the researcher will keep all information confidential in all academic writing.

Learner's Signature: _________________________ Date: ____________________

APPENDIX 17: GDE APPROVAL LETTER

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no: M2017/379

GDE RESEARCH APPROVAL LETTER

Date:	**24 January 2017**
Validity of Research Approval:	**06 February 2017 – 29 September 2017**
Name of Researcher:	**Rafiki M**
Address of Researcher:	**F0034 Manners Mansions**
	60 Joubert Street
	Johannesburg,2001
Telephone Number:	**073 882 3889**
Email address:	**r.meschac@gmail.com**
Research Topic:	**The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics : A case study of Two Township Schools in Gauteng, South Africa**
Number and type of schools:	**Two Primary Schools**
District/s/HO	**Ekurhuleni South**

Re: Approval in Respect of Request to Conduct Research

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

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

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

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

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

Kind regards

....

Dr David Makhado
Director: Education Research and Knowledge Management

DATE: 2017/01/25

APPENDIX 18: ETHICS

WITS SCHOOL OF EDUCATION

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa. Tel: +27 11

717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website: www.wits.ac.za

Date: 18 January 2017

Protocol Number: 2016ECE020D

Student number: 749566

Dear Meschac Rafiki

Application for ethics clearance: Doctor or Philosophy

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate, has considered your application for ethics clearance for your proposal entitled:

The Pedagogical Value of Tablet Technology in the Teaching of Sixth Grade Mathematics: A Case Study of Two Township Schools in Gauteng, South Africa

The committee recently met and I am pleased to inform you that **clearance was granted**.

Please use the above Protocol Number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely,

MMabeta

Wits School of Education

011 717-3416

cc Supervisor – Dr Ephraim Mhlanga

APPENDIX 19: TURNITIN REPORT