

# **Investigating the use of computer tablets in the teaching of mathematics in a grade 9 classroom**

by

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# Declaration

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I, Anthony Marlon Williams, declare that

1. The research reported in this thesis, except where otherwise indicated, is my original work.
2. This thesis has not been submitted for any degree or examination at any other university.
3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.
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Signed:

Date: 1 December 2019

Anthony Marlon Williams (Student Number: 8715680)



# Acknowledgments

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*"We the willing, led by the unknowing, are doing the impossible for the ungrateful. We have done so much, with so little, for so long, we are now qualified to do anything with nothing."*

- Mother Teresa of Calcutta

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# Abstract

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The use of technology in mathematics education has many potentially positive outcomes. There is, however, little evidence to show where the use of technology has made a significant impact on mathematics education in South Africa. This study aims to address the issue of how computer tablets are currently used in the mathematics classroom. The researcher drew a comparison between learners who were taught with computer tablets and learners who were taught in the traditional way by evaluating the learners' progress after being taught on the topic of 3D images. This assessment was done in the form of a pre-test and a post-test that were administered to both classes on a topic of 3D images that was taught during this allocated time. The research is located in the third-generation activity theory. It is based on the socio-cultural theory of Lev Vygotsky, but it is blended with modern western theories as described by Engeström. The researcher made use of a mixed methods approach starting with a qualitative survey, followed by a pre-test, observations and concluding with a post-test. The pre-test and post-test determined whether cognitive knowledge was gained. The participants in the study were a group of 15-year-old learners at a private school where the one class was taught using computer tablets in the mathematics classroom, and the other class was taught the same content without computer tablets.

A qualitative survey was sent to 27 schools within a particular school group where teachers indicated the popular Apps that were used in the mathematics classroom in this school group. Teachers also gave reasons why these were the Apps of choice and elaborated on how they were using these Apps. The quantitative part of this research was guided by the results of the survey and the 5 most popular Applications (Apps) were used in the teaching experiment. The quantitative part focused on two classrooms within the same school where the one class were taught with computer tablets and the other class were taught without the use of computer tablets. The t-test for this research showed that the group of learners who were taught with computer tablets achieved significantly better results than the class of learners who were taught using hard copy textbooks with traditional methods of teaching. This study showed that having computer tablets in schools can be effective in the mathematics classroom. The recommendations emanating from this study indicates that school who are planning to use

computer tablets in the mathematics classroom should first plan their wi-fi capabilities with enough access points and internet access. These schools also need to decide on a type of computer tablet and what operating system to use. This decision has implications to the accessibility of quality Apps, battery life and storage space of the computer tablet. Schools are recommended to have a plan for training teachers in the use of this computer tablets especially regarding the pedagogical practice when interacting with learners. A last recommendation is to nurture a culture of computer tablet use amongst the learners to discipline themselves to charge and maintain their computer tablets and apply it to educational use.

This study includes a pedagogical framework in respect of the effective use of computer tablets in the mathematics classroom.

# Keywords

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21st Century teaching and learning, Application programmes (Apps), Blended learning, Computer tablets, Educational software, Flipped classrooms, Learner-centred, Online tutorials, SAMR, Scandinavian activity theory, TPACK.

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# Chapter 1

## Introduction

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### 1.1. Introduction

We are living in a rapidly changing world with regards to technology in education. The world where teachers were raised and the world that our current learners are facing are very far apart (Liebenberg, 2016). Most teachers grew up in an analogue world, a world of vinyl records and clocks with hands and faces. Our learners are growing up in a digital world where every input is converted into binary code, and the output is the learners' choice. Kolk (2011) called these learners "digital natives". They have embraced technology, while many teachers are still struggling with usernames and passwords.

Some learners wake up in the morning checking their SMSs, going online to their chat rooms, checking their Facebook, changing their status and, on their way to school updating their blog or their vlog with the latest news. They are living in the cyber-world, and when they get to class, in some cases they face teachers with a piece of chalk in their hand using friction against a blackboard to make a mark and cause a dust cloud to hang in the air.

This is in most cases the traditional way of teaching in South Africa. The chalk board might have changed to a whiteboard and markers that are dust-free, but most things remain the same. Learners are still sitting in rows working as individuals and the teacher is still the instructor in the classroom. Learners are still expected to open their hard-copy textbooks on a certain page to follow the teacher in his or her teaching. These learners are now stepping out of their cyber-world of blogging and vlogging (video logging) into the teacher's primitive world where teachers are trying to prepare them for their future – the cyber-world. It is within this context, that this study sought to investigate the use of computer tablets in the teaching of mathematics to grade 9 learners.

This chapter introduces the study and the background of the study, followed by the rationale, and problem statement. It also presents the aims and objectives pursued by the research questions and the significance of the study. Furthermore, the theoretical orientation of the study and justification for adopting a mixed methods approach is introduced. Finally, the presentation

of the scope of the study and the definition of key terms used in the study will conclude this chapter.

## **1.2. Background**

A private school group introduced computer tablets in five of its schools in the Western Cape Province and Gauteng in 2013 as a pilot project to determine whether it would be viable to cascade the computer tablet programme to all schools under its management in South Africa. The school in the Western Cape is situated in Durbanville with learners from an affluent part of the society. The four schools in Gauteng are situated in Johannesburg and Pretoria. The Pretoria school overlooks the opulent Silver Lakes area. The Johannesburg schools are in Rand Park Ridge, Boksburg and on a golf estate in Kempton Park. The learners attending these schools were from the upper-middle class income group. This school group introduced computer tablets as a pilot project from grades 7 to 9 in these schools and subsequently rolled it out to all its schools from grade 4 onwards. Yet no-one has done any analysis or study as to the success thereof.

One of the immediate advantages of this computer tablet project is that learners do not have to carry heavy school bags as all their textbooks are in e-format on their computer tablets. The teacher can also add other mathematics resources to this e-book such as videos, quizzes, presentations and any relevant websites (Liebenberg, 2016). The learners can prepare for class even a day before, since they can watch the mathematics videos that the teacher pushed to their computer tablets, at home. These videos are downloaded when they are in class, and therefore they do not need the Internet at home (Liebenberg, 2017).

The teachers received the same e-books on their laptops and project lessons on interactive whiteboards. The learners have the facility to highlight important parts of the lesson in the e-books and the relevant programme summarises it for them for study purposes. These summaries can also be printed for learners who prefer to study from a hard copy. The teacher can even set tests which the learners complete on their computer tablets. The test gets marked immediately on submission, and results are subsequently presented graphically as feedback to learners (Liebenberg, 2016). In this way, the computer tablet provides immediate feedback.



Initially, there were many teething problems with this project. Firstly, the participating schools had to have a server which could communicate with all the computer tablets. Wireless access points had to be installed for learners to connect their computer tablets and these included stress testing for uninhibited transfer of information to the computer tablets. The downloading of e-textbooks at the beginning of the year clogged the system, and consequently it took approximately three weeks to complete the downloading before the learners could access any information from their computer tablets.

It is clear that there are quite a few challenges before one can start using computer tablets in a school.

### **1.3. Rationale**

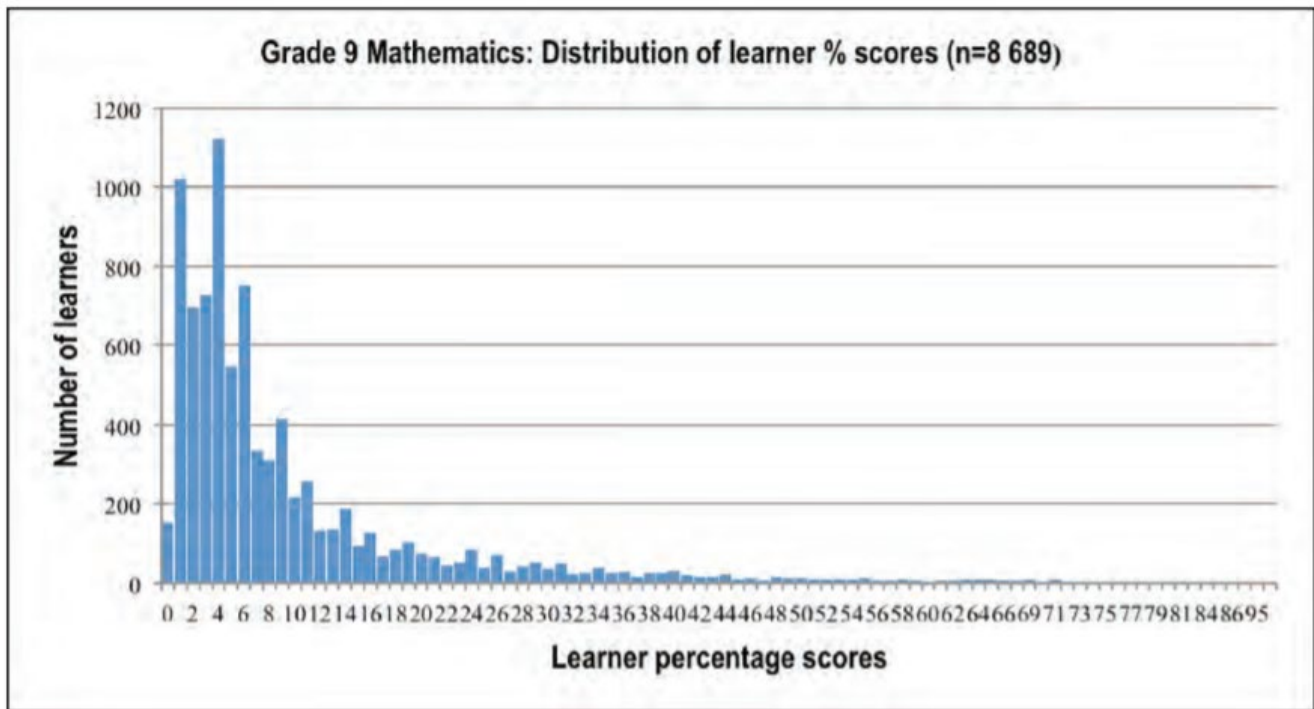
South African schools are underperforming in mathematics compared to the rest of the world, measured by standardised tests like the Trends in International Mathematics and Science Study (TIMSS). TIMSS is an international assessment that monitors trends in learner achievement in mathematics on an international scale (IEA, 2019). This assessment started in 1995 and has been conducted at regular 4-year intervals for grade 4 and grade 8 learners (IEA, 2019). In 2015, South African learners scored the second lowest marks in 39 countries (Reddy, et al., 2016). This is despite the fact that we enter grade 9 learners to do the grade 8 TIMSS assessment (Reddy, et al., 2016).

The national benchmark test in South Africa is called the Annual National Assessment (ANA). In 2014 the Minister of Basic Education (DBE), Angie Motshekga published the ANA results for mathematics in the General Education and Training Band (GET). According to Mybroadband (2014), the ANA displayed the average national mathematics performance per grade as follows:

- Grade 1 – 68.4%
- Grade 2 – 61.8%
- Grade 3 – 55.4%
- Grade 4 – 37.3%
- Grade 5 – 37.3%
- Grade 6 – 43.0%
- Grade 9 – 10.8%

In 2014, the grade 9 ANA results in South Africa showed a 10.8% pass rate, with only 5% of the learners achieving more than 50% (Nkonkobe, 2014). When one looks at the rate at which the performance declined from grade 1 to grade 9 in the list above, ways need to be found to remedy the grade 9 situation.

The Department of Basic Education published the ANA grade 9 distribution per learner % scores as their key finding in the figure below.



**Figure 1.1 Grade 9 ANA Mathematics Distribution of learner % scores (n = 8 689) (DBE, 2015)**

The figure above shows thousands of grade 9 learners scored less than 10% and the score most frequently attained was 4%. Clearly the distribution of learners’ scores in grade 9 mathematics shifts towards the lower end of the scale. The Minister of Basic Education appealed that all interventions should seek to correct this pattern (DBE, 2015). The main reason for the low score is the inability of learners to answer the Geometry part of the assessment (DBE, 2015).

The World Economic Forum (WEF) ranked the quality of mathematics education in South Africa in 2014 as last out of 148 countries (Schwab, 2014; Wilkinson, 2014). This paints a very bleak picture. This rating has improved in 2018 to being 128<sup>th</sup> out of 137 countries (Schwab, 2018).

Another benchmark test that South Africa has participated since 1995 is the Trends in International Mathematics and Science Study (TIMSS). The TIMSS is done every four years and focuses on grade 4 and grade 8. The results in the TIMSS of 2015 showed that South African learners had less than half the mathematical content knowledge of their international peers (May, 2017).

Kobus van Wyk, CEO of the Khanya Project, claimed that there is little evidence that the use of technology has made a significant impact on mathematics education in South Africa (Van Wyk, 2015). The Khanya Project was started as a pilot programme with the objective of establishing at least one computer laboratory in selected schools in the Western Cape (Mahlati, 2012).

The Khanya project aimed to enhance computer technology learning and maximise teacher capability by blending appropriate, available and affordable technology into the curriculum (Zille, 2006). This was done by installing computer laboratories in schools. The project focused on removing the digital divide between affluent and impoverished schools and on empowering teachers, learners and community members to use technology freely (Zille, 2006).

The vision of the project was that by the start of the 2012 academic year, every Western Cape school teacher would be empowered to use computer technology to deliver curriculum to all learners in the Western Cape (Zille, 2006). The primary aim of the Khanya Project was to improve teaching and learning in subjects like mathematics and science. In the decade that it operated, the Khanya project trained about 31 000 teachers to use technology in the classroom (Mahlati, 2012). Yet, when one looks at the ANA results in mathematics, no significant impact is seen.

Research done in Australian schools by Galligan, Loch, McDonald, and Taylor (2010) revealed that computer tablets can create a learning environment that escalates student learning opportunities, empowering both student and teacher. They stated that, "If used to its full potential it captures clear and recordable mathematical thinking in action and can provide purposeful and timely feedback" (Galligan, Loch, McDonald, & Taylor, 2010, p. 38). However, the computer tablet project, the "Big Switch On", that was launched in South Africa in 2015 by Gauteng MEC, Minister Panjaza Lesufi, did not reach this desired outcome. This project cost R17 billion but were faced with many challenges. More than 100 smartboards were stolen, and

many learners failed to give their computer tablets back to the school after their year of intervention (NewsCentral Media, 2016). Many were reported stolen and broken. It is against the backdrop of these statistics that the researcher decided to investigate whether the introduction of computer tablets could make a positive impact in our schools, and more specifically, could enhance learning.

#### **1.4. Research problem**

The iPad entered the educational arena in 2010 and has had some educational value in certain fields (Karsenti & Fievez, 2013). The benefits and the challenges are being weighed up to determine whether it should be implemented in the classroom or not. This is the dilemma that the researcher explored in this investigation.

In looking for ways to improve the standard of mathematics in South Africa, the government turned to technology. Deputy President, Cyril Ramaphosa announced in January 2015 that the government would roll out a R17 billion computer tablet project to remedy the situation (Micampus, 2015).

Mbola (2015) said: “Classrooms at Boitumelong Secondary have been transformed into digital learning spaces with top of the range information communications technology, while the traditional chalkboard has become a thing of the past for these teachers. Chalkboards have been replaced with big computer screens at the front of the classroom”. This project was called the ‘Big Switch On’ and the Gauteng Education Department dreamed of a paperless education system. “Unlimited 4G data connectivity will ensure that learners can also do their work from home” (Mbola, 2015). Boitumelong was one of seven schools where this project was launched. Ramaphosa believed that this would transform education for the better in the future. Mbola (2015) added that “it enables teachers and learners to access resources that exist beyond the four walls of the classroom”.

This project failed dismally due to burglaries and theft, and very few computer tablets were recovered (Mbola, 2015; BusinessTech, 2015). The researcher initially had the intention to determine what the problems were and how to avoid this from happening again.

## **1.5. Aim of the study**

The aim of this study is to investigate the efficacy of using computer tablets in the mathematics classroom. Schools have been integrating computer tablets into their curriculum, hoping that this will enhance learning without them having to rely on empirical research for guidance. Research done on the use of computer tablets in the classroom is very much sporadic still.

## **1.6. Objectives of the study**

The objectives of this study are:

- to determine what mathematics software applications (Apps) are available for use by teachers and the educational quality of these Apps.
- to determine how and why teachers are using the tablet computer and which methodology adds to the success of the learning.
- to determine if there is any significant difference in learning between the grade 9 mathematics class taught with the use of Apps and the class taught traditionally.

## **1.7. Research questions**

The issues discussed in the aims and objectives led to the following research questions:

- (i) What are the computer tablet applications (Apps) that mathematics teachers use in mathematics classrooms in South Africa?
- (ii) Why are the mathematics teachers using the specific Apps identified in (i)?
- (iii) How are the mathematics teachers' using the specific Apps identified in (i)?
- (iv) How effective is the use of computer tablets in the mathematics classroom compared to the traditional way of teaching?

## **1.8. Theoretical orientation of study**

The researcher opted for a conceptual framework, which merged new learning models like the 21st Century learning model, the TPACK, the SAMR, and blended learning with Activity Theory to guide and facilitate this study. According to Regoniel (2015), the conceptual framework lies

within a much broader framework called the theoretical framework, which in this case is Activity Theory (Regoniel, 2015). Third generation Activity Theory, as propounded by Engeström (1999), allows for the blending of modern western theories (Engeström, Miettenin, & Punamaki, 1999). The modern models that address the integration of computer tablets in the classroom are firstly the 21st Century learning model, followed by the TPACK model, the SAMR model, and other blended learning models. The diagram below is a representation of this conceptual framework.

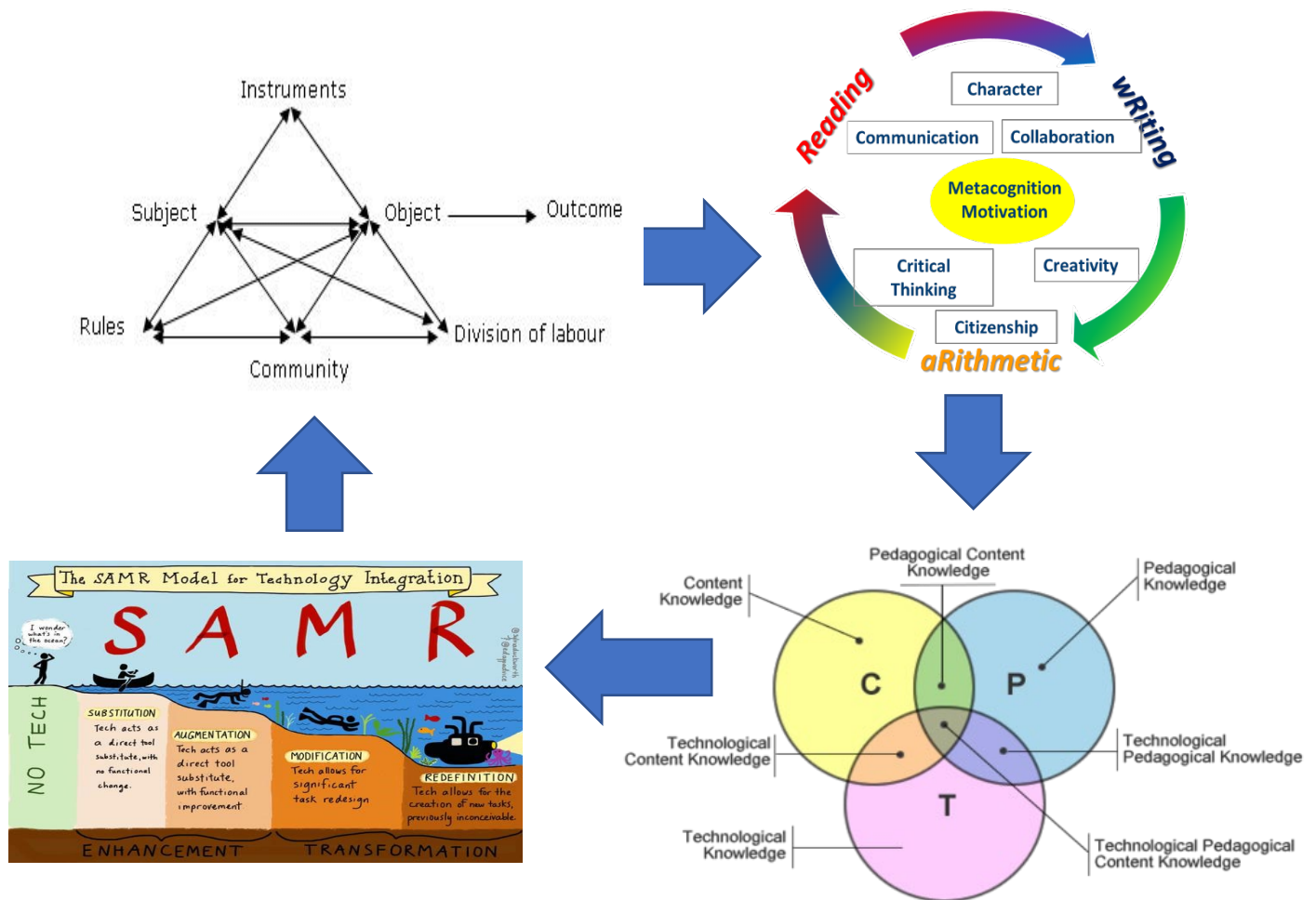


Figure 1.2 Representation of the conceptual framework of this study (Engeström, 2009; Puentedura, 2016; Koehler & Mishra, 2009)

## **1.9. Research design, sampling methods of data collection**

The researcher used the explanatory sequential mixed method design whereby he first explored the first three research questions and using this data to inform the fourth and main research question.

To answer the first three research questions, namely what Apps, why these Apps, and how computer tablets are used in these blended learning classrooms, the researcher drew up a survey asking mathematics teachers how they integrated computer tablets in their classrooms. This survey was sent to 27 high schools representing all provinces in South Africa.

To investigate the fourth critical question of whether this intervention would be effective, the researcher devised a pre-test and a post-test and focused on the progress made. The researcher firstly looked for a suitable sample of grade 9 learners to test, as well as one teacher who taught two classes of the same grade in the same language. Using purposive sampling, the researcher looked for 2 classes that have a similar class average mark. The one class was taught without the use of computer tablets in the mathematics classroom, and the other was taught using computer tablets extensively. The teacher had the same amount of teaching-time in both classes. The learners wrote the same test before and after the intervention, and the improvement of marks were compared. These two groups were called the computer tablet integrated group (TIG), and the traditional teaching group (TTG), and strict control was exercised to ensure the validity of the study. To improve validity the researcher made use of an independent statistician and he made use of triangulation through classroom observation to justify his results.

The researcher also carried out site visits at the school to observe the blended learning sessions by sitting in on mathematics classes. The researcher was, however, aware of the need to avoid triggering the Hawthorne effect, which makes results unreliable. The Hawthorne effect refers to a phenomenon whereby individuals may improve their behaviour in response to their awareness of being observed (Franke & Kaul, 1978). To minimize the diffusion effect between the learners, the researcher decided to experiment with two different classes. If the experimental and the control group was in one classroom, due to the close interaction amongst learners, the data might have been contaminated (Craven, Debus, & Jayasinghe, 2001). By

using two different classes where the one class is the experimental group and the other class the control, the researcher minimised the risk of contamination.

### 1.9.1 Stages of the research

The table below summarises the stages of the research.

**Table 1.1 Stages of the research**

Stage	Description of Stage	Activity
1	Searching the literature	Review of prior studies on the research topic
2	Teacher survey	Survey on the use of computer tablets as a tool in the mathematics classroom
3	Pre-test	Completion of a pre-test by half of the learners of the experimental and control groups
4	Classroom observations	Classroom visits to observe how teachers used the computer tablets and how learners interacted in the computer tablet integrated lessons, and to record video footage in order to triangulate the findings
5	Post-test	Completion of the same post-test by both groups of learners in order to compare progress made by the computer tablet integrated group and the traditional teaching group

### 1.9.2 Participants of this study

The researcher made use of purposive sampling to select the institution and 40 the learners. The researcher decided to locate this study in grade 9 as one can derive from the rationale that the grade 9 national mathematics average for 2014 was 10,8%. From the 25 schools that took part in the survey of questions one to three, the researcher searched for a school that had more than one grade 9 class. Another criterium was that the two grade 9 classes had to have a similar class average in mathematics. Then the researcher was looking for a school that was close enough for him to visit and observe the process. The researcher handpicked “the cases to be included in the sample on the basis of the judgment of their typicality” (Cohen, Manion, &



Morrison, 2002, p. 103). For assessing the role of computer tablets in a mathematics class, the researcher worked with a school in the Western Cape that was implementing the computer tablet project for the first time. Another participant in this study was the mathematics teacher who taught both these grades before and during the intervention. It was imperative that this teacher was willing to be part of this study. During the last stage, the focus shifted towards the learners who had to complete a post-test to conclude the process.

### 1.9.3 Data collection methods

The table below served as a guide as to what collection methods were to be used in answering a particular question.

**Table 1.2 Data collection plan**

Research Questions	Instruments				
	Literature	Teacher survey	Pre-test	Lesson observations	Post-test
What are the computer tablet applications (Apps) that mathematics teachers are using in the mathematics classrooms in schooling in South Africa?	✓	✓		✓	
Why are the mathematics teachers using these specific Apps?	✓	✓		✓	
How are the mathematics teachers using these specific Apps?	✓	✓		✓	
How effective is the use of computer tablets in the mathematics classroom compared to the traditional non-computer mathematics classrooms?	✓		✓	✓	✓

## 1.10. Thesis outline

The format of the thesis consists of six chapters, and the layout of these chapters is outlined in Table 1.3.

**Table 1.3 Layout of chapters**

Chapter 1 Introduction	Idea for the thesis and motivation for the study Justification of the research topic Statement of the research problem Research design and methodology
Chapter 2 Literature Review	Outline of the literature covered Definitions of key concepts Discussion of literature pertaining to the problem statement Summary of the main conclusions
Chapter 3 Conceptual Framework	Description of the epistemological stance of the researcher Definition of the research direction, theories and models Conceptual framework and scientific justification for the investigation
Chapter 4 Research Methodology	Conceptualisation, definitions and outline of critical variables Instruments used in the measurement of the key variables Design of the sample, sampling techniques employed, choice of sample size Data collection methods and fieldwork practice employed Data editing, errors, data analysis procedures and rationale, shortcomings and sources of error

Chapter 5 Data Presentation, Analysis and Findings	Results of the fieldwork, sample profiles and presentation of the results Interpretation of the main findings, highlighting both negative and positive
Chapter 6 Conclusions and Recommendations	Interpretation of literature results Gaps, anomalies, and deviations in the data Broader significance of the results Recommendations for further study

## 1.11. Explanation of keywords

The following table defines some of the keywords that are used in this thesis:

<b>Keyword</b>	<b>Interpretation</b>
Tablet computer	A computer tablet, or tablet PC, is a portable computer that uses a touchscreen as its primary input mode. Most computer tablets are slightly smaller and weigh less than the average laptop (Christensson, 2011).
Learner-centred	Learner-centred teaching is an approach that places the learner at the centre of the learning. This means that the learner or student is responsible for learning while the tutor is responsible for facilitating the learning (Smith, 2017).
Educational software	Computer software is a general term that describes computer programmes. Related terms such as software programmes, applications, scripts and instruction sets all fall under the category of computer software (Christensson, 2011). When a programme is written for or has educational value, it is called educational software.

21st Century teaching and learning	The term 21st Century skills is generally used to refer to certain core competencies such as collaboration, digital literacy, critical thinking and problem-solving, that advocates believe schools need to teach to help students thrive in today's world.
Application programmes (Apps)	App is short for 'application' which is the same as a software programme. While an App may refer to a programme for any hardware platform, it is most often used to describe programmes for mobile devices, such as smartphones and computer tablets (Christensson, 2011).
Scandinavian activity theory	The Scandinavian activity theory, as a third-generation theory, seeks to merge traditional Vygotskian socio-cultural beliefs with western intellectual developments such as Cognitive Science and Constructivism (AIU, 2016).
Online tutorials	An online tutorial is a self-study activity designed to teach a specific learning outcome. They are usually delivered via blackboard but can also be made available via the Internet or on a DVD. There are two main types of online tutorials, which are referred to as Recorded and Interactive (Bristol University, 2019).
Blended learning	Blended learning (Mindflash, 2012) is a term increasingly used to describe the way e-learning is being combined with traditional classroom methods and independent study to create a new, hybrid teaching methodology.
Flipped classrooms	The flipped classroom model (RIT, 2013) is one in which traditional in-class activity, the lecture, is delivered outside of class via video recorded lectures and other web-based materials. In class, time is used for collaborative project work, small group problem-solving, and other such activities that allow students to engage at a deeper level with the content they viewed outside of (and before) class.

## **1.12. Summary**

Chapter 1 has described the context in which the research occurred. Information was given regarding the relevance and significance of the study. Research questions were posed, and the purpose of the study was explained. The research design was discussed in brief. It will be discussed in detail in Chapter 4 of this thesis.

The next chapter will discuss the literature reviews on the topic of the use of computer tablets in the mathematics classroom.

# Chapter 2

## Literature Review

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### 2.1. Introduction

The researcher reviewed the relevant literature to find out what lessons had been learned with respect to the integration of computer tablets in the mathematics classroom, the nature of the unanswered questions and the pitfalls to this interaction.

The review started by inquiring about the history of application programmes (Apps) and computer tablets. The investigation then covered the implementation of computer tablets in the classroom on a global scale, and what the affordances embedded in the computer tablets were that made them an educational tool. The disadvantages of using these Apps were also noted. After searching for computer tablet integration projects around the world, the researcher focused on mathematics Apps that were effective globally and what Apps were available in South Africa to be used in the mathematics classroom. A brief description of these Apps was included. The researcher went on to investigate why teachers were using these specific Apps and the pedagogy on the implementation of these Apps.

### 2.2 The history of Apps

An App is essentially a small computer programme that can be downloaded quickly on a mobile device such as a phone or a computer tablet, to be used immediately without rebooting the device (Cherner, Dix, & Lee, 2014). The first Apps were introduced by International Business Machines (IBM) on its smartphone in 1993 and consisted of a calculator, a world clock, a calendar and a contact book (Rajput, 2015). The company Potter Scientific Instruments or Nothing (Psion) released Apps like word processing, spreadsheets and databases on a device called a portable digital assistant (PDA) which, running on a 16-bit machine, was very limited. Palm then developed the Garnet OS in 1996 with a touch screen graphic user interface (GUI). This GUI changed the whole concept of an App as it was now possible to keep the Garnet in one hand and press the desired App with the other hand. It was no longer necessary to type text although one could still do it as the screen had an on-screen keyboard.

Psion later collaborated with Nokia, Motorola and Ericsson to create the Symbian platform (Marshall, 2013). This platform caused an App explosion as Nokia took the lead in developing Apps for smartphones. The image in Figure 2.1 shows these new touch interactive Apps on the Nokia Smartphone.



**Figure 2.1 A typical screen of the Nokia Smartphone in the 2000+ years (Vijay, 2018)**

The next major step was the introduction of the BlackBerry in 2002 with the innovative concept of wireless email (Rajput, 2015). By this time, the tablet PC was already in existence, but its operating system was not designed to work with a touch screen (Nair, 2014). After the tablet PC was manufactured with a touch screen, App development once again increased, driven by this new platform. Since 2015, the Apple App Store has added more than 20 000 Apps on average monthly (Rajput, 2015). On the 1st of August 2019, the number of Apps available on the Google Play Store was about 2,46 million, the Apple App Store had about 1,96 million Apps, and the Windows Store had about 670 000 Apps (Clement, 2019). Cumulatively, the number of mobile App downloads in 2017 was more than 178 billion (Clement, 2019). This is critical for schools that want to venture into computer tablet implementation as they need to use computer tablets that will support a specific operating system where educational Apps are accessible and freely available.

### **2.3 The history of the educational use of the computer tablet**

In 1968, Alan Kay conceived specifications for the Dynabook tablet, which he believed to be the most powerful educational tool (Steele, 2011). He imagined “a pad-like computer no larger than a notebook that weighs less than 4 pounds, works via a touch screen with a floating keyboard, connects to the Internet and costs about \$500” (Steele, 2011). This Dynabook was

never built because the dream was too radical, and the technology to support it was not yet developed.

In 1988, Hawkins designed the Gridpad as the world's first computer tablet (Stengel, Gridpad, 2017). Stengel (2017) describes the Gridpad as having a handwriting-recognition software interface called the Palmprint which allowed the computer tablet to interpret human handwriting. It had an attached Stylus as the default method of interaction. It also had a slot for a memory card and used DOS 3.3 as an operating system. The Gridpad was portable, but at a cost of \$2370 it was out of the reach of many and "its popularity was largely limited to healthcare and law-enforcement institutions" (Steele, 2011).



**Figure 2.2 The Gridpad (Stengel, 2017)**

In 1989, Wang Laboratories joined the market with its Freestyle tablet (Steele, 2011). The added affordance was that it allowed for annotation and it could record voice notes via a phone handset, which could be emailed. AT&T launched its GO and EO tablet in 1993 with the addition of a modem, fax and microphone (Steele, 2011). When the device failed to sell, the company closed.

The new millennium brought about new technologies, and Bill Gates of Microsoft built a computer tablet that fitted all the functions of a personal computer into a flat device (Steele, 2011). It came pre-installed with the Windows XP tablet operating system, which was not



designed to be used with touch screens (Nair, 2014; Steele, 2011). Nair (2014) criticised it as being heavy and cumbersome to use.

The first Tablet PC was launched in 2000 by Bill Gates and ran with Windows XP (Bort, 2013). This was the first time that the device was referred to as a Tablet and it supported the touchscreen function.

In 2010 Apple introduced the iPad, with an operating system that supported a touchscreen (Nair, 2014). What made this touchscreen so remarkable was that it not only recognised the stylus but was designed for use with bare hands through a capacitive multi-touchscreen (Nair, 2014). This device had the attributes that were pictured by Kay in 1968. People immediately loved this device (Nair, 2014). With a library full of Apps, it became the priority device for downloading rather than uploading data. Learners used it mainly for data consumption compared to data production (Nair, 2014; Steele, 2011).



**Figure 2.3 The Apple iPad 1 in 2010 (Winkelman, 2019)**

Other PC companies like Samsung, LG, and Dell also jumped on the computer tablet bandwagon as they did not want Apple to have the monopoly. As a result, computer tablets became popular devices, and by 2011 computer tablet sales tripled compared to the previous year (Nair, 2014).

## **2.4 How widespread is the integration of computer tablets in classrooms globally?**

As the use of computer tablets in the classroom started so recently, with the first iPad being introduced in 2010, not much research has been done on the effect that it has in the classroom (Clark & Luckin, 2012). Global thinking is that because learners are digital citizens, they will have an inherent inclination to use technology effectively (Richardson & Milovidov, 2019). Yet globally, there have been successes and failures with the implementation thereof. The researcher looked at various countries around the world to get a sense of how successful these interventions were. These interventions will be discussed, starting in the East, moving through Europe to the West, down to Jamaica, and ending with Africa and South Africa.

In Thailand, the Thai government had the largest roll-out of computer tablets in 2012 as it deployed 1.8 million computer tablets to schools (Clarke & Svanaes, 2014). In 2014, following the military coup, these computer tablets were recalled. The Malaysian government also rolled out its computer tablet programme in 2012, intending to bridge the gap between the rich and the poor, and this recorded huge successes (Rajan, 2015). The Malaysian company, Xchanging Malaysia had great success in connecting 10 000 computer tablets and 5.5 million students around the country on a virtual platform (Clarke & Svanaes, 2015; Sharma, 2015). When this same company replicated this roll-out in India in 2014, it faced numerous setbacks (Sharma, 2015). It had to replace the hardware with a better processor, and reduce the price from £25 to £14, which made it unprofitable to continue (Clarke & Svanaes, 2015). A year later, some of the institutions had still not received the computer tablets they were promised. Meanwhile, the Kazakhstan government planned to roll out its computer tablet project to all schools, but five years later only 16% of all schools had received their hardware (Pons, et al., 2015). The computer tablet project in Turkey was not successful at all (Clarke & Svanaes, 2015). The Turkish Government aimed to supply 10.6 million devices over four years, starting in 2012. In 2014 only 10% of the projected vision was realised. By then the budgeted cost for the whole project, which was estimated to be \$1.5 billion, had already surpassed \$8 billion. The one-tablet-per-child programme was then cancelled.

The computer tablet implementation project in Europe had more success. In Finland, every learner received a computer tablet, and cursive writing was substituted with typing, as the

government believed that these digital citizens would not need to write with a pen and paper any more (Blair, 2015). Steve Job Schools, a group of private schools in the Netherlands, reported that they had achieved success in the motivation and independent learning of learners (Marsh, 2014). Yet, this was only a perception as no longitudinal study had been done on the use of computer tablets. In 2015 and 2016, a technology company in France called Archos gave 1.5 million computer tablets to learners at a subsidised price (Chen, 2015). They had not done a study either.

In the British Isles, the Irish rolled out computer tablets to 100 of their 700 schools. They used them primarily as a replacement for hard copy textbooks (Traynor, 2014). The most significant cause for the unsuccessful implementation of this project was that teacher training was not adequately done, and very few teachers used the computer tablets. The Alness Academy in the highlands of Scotland, on the other hand, reported that learners produced better work since moving to computer tablets (Candlish, 2015).

In 2012, the United States of America planned to roll out computer tablets to all educational institutions (Clarke, Svanaes, & Zimmermann, 2013). This was not possible as 80% of the schools lacked infrastructure such as LAN and access points connected to telecommunication. The then president Barack Obama announced, in June 2013, the ConnectED programme, which “aimed to provide broadband for 99% of schools and teacher training to prepare teachers to use technology” (Clarke, Svanaes, & Zimmermann, 2013, p. 3). As schools were waiting for this upgrade, many schools started “bring-your-own-device” (BYOD) schemes as a temporary solution (Clarke, Svanaes, & Zimmermann, 2013). Approximately 25% of the schools even allowed the use of smartphones in the classroom (Clarke, Svanaes, & Zimmermann, 2013). However, this intervention was not without challenges. The computer tablet programme in Texas, at the cost of \$16 million, was cancelled a year later. In North Carolina, a \$35 million iPad deployment was cancelled due to the cost of breakages.

In Jamaica, a pilot project was started in 2015 by giving 20 000 learners computer tablets (Patterson, 2015). It was found that the school’s attendance improved, especially amongst the boys, and the project was subsequently rolled out to more schools.

In Africa in 2010, Worldreader, a San Francisco-based non-profit organisation, initiated a project in Ghana in two primary schools and four junior high schools (Davis, 2012). This project

involved 500 students who were using Kindle e-readers in schools on a daily basis (Davis, 2012). Their textbooks were loaded onto these devices and they were encouraged to take these Kindles home for reading. Although there was a concern regarding the theft of these computer tablets, only three out of the five hundred were lost. However, breakage was recorded as a problem (Davis, 2012). This programme was also expanded to Kenya, where the lack of infrastructure and broadband technology in the rural areas caused a setback. Although many schools received their computer tablets, they were only used for writing and text messaging (Flood, 2015).

In 2013, teachers from 800 schools in Gauteng, South Africa were trained on how to use computer tablets in the classroom (Wilson, 2013). Eighty-eight thousand computer tablets were distributed to some of these schools. To ensure the process was streamlined, the department appointed five project managers, each covering three of Gauteng's 15 districts as well as "100 IT technicians and 80 e-learning coordinators" (Wilson, 2013). The computer tablet project in South Africa followed the same fate as most computer tablet interventions in the rest of the world. Corruption, theft, self-entitlement and breakages led to the demise of the computer tablet project in Gauteng (BusinessTech, 2015). The project was cancelled due to theft and break-ins at schools. The MEC for Education in Gauteng, Panyaza Lesufi announced that the 88 000 computer tablets regrettably had to be withdrawn and this failed project cost South Africa R17 billion (News 24, 2015).

In many of these countries, the effectiveness of computer tablets in the classroom was compared to the cost of the roll-out, and the return on investment was not justified. Marbach-Ad, Rotbain & Stavy (2008) found that there were other cheaper teaching methodologies that were as effective, if not more so, than the integration of computer tablets. They investigated the effectiveness of computer animation versus interactive activity-based instruction. The participants were divided into three groups: the computer animation group, the interactivity-based group and the traditional chalkboard group. All three groups used the same textbook, but the computer animation and interactive activity groups scored significantly higher than the traditional lecture-style teaching group. What was interesting was that the interactive activity group scored more marks in certain aspects of the lessons than the computer animation group. The authors concluded that even though the computer integrated activities had enormous potential as learning tools, interactive, learner-centred activities were not necessarily inferior to

these (Marbach-Ad, Rotbain, & Stavy, 2008). This raises another point. It is also important to observe what kind of teaching is happening in the classroom. If the teacher is dynamic in getting learners involved in the learning process in the traditional classroom, then the computer tablet might not enhance learning significantly.

## **2.5 The impact embedded in the technology of the computer tablet that led to the successes with the integration of computer tablets in education**

Different technologies have been introduced in education in recent years. From the previous section, one can see a definite trend in how countries implemented technology globally to keep themselves relevant and up to date with 21st century demands. The implementation of laptops and cell phones presented enormous challenges, but the computer tablets somehow were more successful (Clarke & Svanaes, 2014). The challenges with laptops included long rebooting or start-up times and this led to a huge amount of lost teaching-time. Cell phones on the other hand, with their small screens and buttons, were challenging to navigate, especially for people with big fingers.

Steward inspected the technology embedded in a computer tablet and classified it as a “revolutionising tool” (Steward, 2013, p. 16). He stated that it was far more intuitive than traditional computers as it had features such as simulations, touch screens, cameras, mobility, microphones, e-books, digital textbooks and instant feedback (Steward, 2013). The concept of using this computer tablet technology anywhere and anytime was rated by Steward (2013) as ground-breaking.

Henderson and Yeow (2012) observed positive impact on learning and argued that this was partially due to the size of the screen. They believed that because computer tablets were approximately the same size as a storybook, they engaged learners tapping into past experiences of reading a book. The screen was also big enough to fit a person's face, and this made collaboration easier, as if speaking to a person in real life. This interaction and instant feedback were seen to be excellent benefits for independent learning (Henderson & Yeow, 2012).

Steele (2011) argued that mankind always looked for a flat surface to write or draw on. She justified this with cave markings of 30 000 years ago. The computer tablet also offers this opportunity, and this time around learners can even draw with their fingers. Steele (2011) argued that this was one of the reasons why laptops could not achieve successes that computer tablets achieved. In early childhood development, this feature compensates for the development of fine motor skills as the computer tablet makes it easy for children to manipulate and interact with the screen (Goodwin & Highfield, 2012). Some Apps are designed to allow young children to “learn and discover in ways that are commensurate with their preferred learning modes: physical touch, trial and error, and repetition” (Goodwin & Highfield, 2012).

One of the main reasons that computer tablets are preferred over laptops is that they do not have a lid, making them less intrusive in the classroom (Steward, 2013). The lid caused a barrier between the teacher and the learner as the teachers were staring at the back of the lid and could not make eye contact. Teachers were never confident about what was on a learner’s screen (Steward, 2013). The same applies to the teacher having a computer tablet connected to a data projector. That teacher can teach from anywhere in the classroom, even sitting in a group with learners (Steward, 2013). Even when the teacher makes notes, he or she is facing the learners, unlike the traditional chalk-and-talk method where teachers’ backs faced the learners when writing on the blackboard. Compared to laptops, computer tablets are much cheaper, and more learners can afford them, which makes one-to-one access possible. This affordability is crucial for student motivation and independence (Bjerede & Bondi, 2012).

Another advantage is the portable nature of the computer tablet; and when coupled with a wireless Internet connection, it is possible to always have one's content on hand for it can be saved to a cloud (Clarke & Svanaes, 2014). Van’t Hooft (2013) argued that this technology could be used inside and outside the classroom. He referred to this learning as “anytime, anywhere learning” or “seamless learning”. Steward (2013, p. 17) found the computer tablet to be like a mobile classroom, where students had their books, assignments, notes and study resources in one place, without issues like forgetting to bring their stationery to class. For the teacher, this reduced the likelihood of losing or misplacing students’ work.

The use of computer tablets reduces printing costs as teachers do not have to copy worksheets or assessments on hard copies anymore (Clarke & Svanaes, 2014). They can now email content and tests directly to the learners' computer tablets.

The functionality of computer tablets plays a significant role in its integration in the classroom. Tablets reboot much faster than laptops used to do. They have higher processing power to execute Apps faster, and greater battery power. A computer tablet can be charged with a power bank where a laptop needs AC power. Clarke and Svanaes (2014) drew attention to the use of "computers with long boot-up times, during which pupils lose focus, as well as frequent software problems". They said that these were precisely the kind of challenges that became a driving force behind new technologies such as computer tablets.

Nowadays, there is an increasing choice of Apps for education. These Apps are easy to download and less expensive compared to computer software. Many of them are free, and learners can share these Apps by transferring them to each other's devices quickly and easily. Android makes use of an App called Shareit to transfer files easily. The challenge is that despite the increase in educational App offerings, very few of these Apps have real pedagogical value.

Other advantages of computer tablets are the functions of audio and video recordings and playback. Learners can carry out and record presentations easily, as photos and video can be loaded with the push of a button. Learners can view videos multiple times until they understand a concept, and this helps to reduce re-teach time in the classroom. Some learners also fear being exposed for not understanding and therefore prefer not to ask the teacher to redo a lesson.

Lastly, the Becta report stated that the fact that the tablet became a hand-held device, was a huge benefit (Steward, 2013). Teachers could now easily input data without going to a desk or blackboard, and even facilitate a lesson outside and still record data.

## **2.6 Some of the challenges that computer tablets bring to the classroom**

The challenges of implementing computer tablets point to many fundamental obstacles (Clarke & Svanaes, 2015). Firstly, there are connectivity issues. Schools need the Internet as well as access points where learners can connect to wireless networks. Computer tablets are not user-friendly when it comes to the management of files and printing. Clarke and Svanaes (2014) blame connectivity problems as the root of why excitement amongst teachers and learners wear off. Furthermore, every school needs a technical team to troubleshoot hardware problems

as teachers are not trained to know why a computer tablet does not connect, for example (Clarke & Svanaes, 2014).

Many research articles also refer to computer tablets as a distracting factor. Henderson and Yeow (2012) reasoned that the fact that learners constantly have their devices with them tempts them to engage in chat rooms or to play video games which ultimately leads to poor academic performance. The Department of Education in Norway is liaising with researchers on how to manage distractions in schools (Clarke & Svanaes, 2014). One of the options is for teachers to disconnect the Internet when not needed. Teachers in Canada are writing appropriate-usage policies and accountability strategies to counter inappropriate use in the classroom (Karsenti & Fievez, 2013).

The biggest challenge, according to Karsenti and Fievez (2013) is the lack of learner and teacher training. Insecurity with respect to the use of the technology becomes the buffer for both learners and teachers who use it. Three hundred and two teachers in Quebec, Canada, took part in a project to make computer tablet implementation successful, and the biggest fear was that of “not knowing” the device (Karsenti & Fievez, 2013). Figure 2.4 shows the challenges that these teachers reported in descending order from the most challenging to the least.

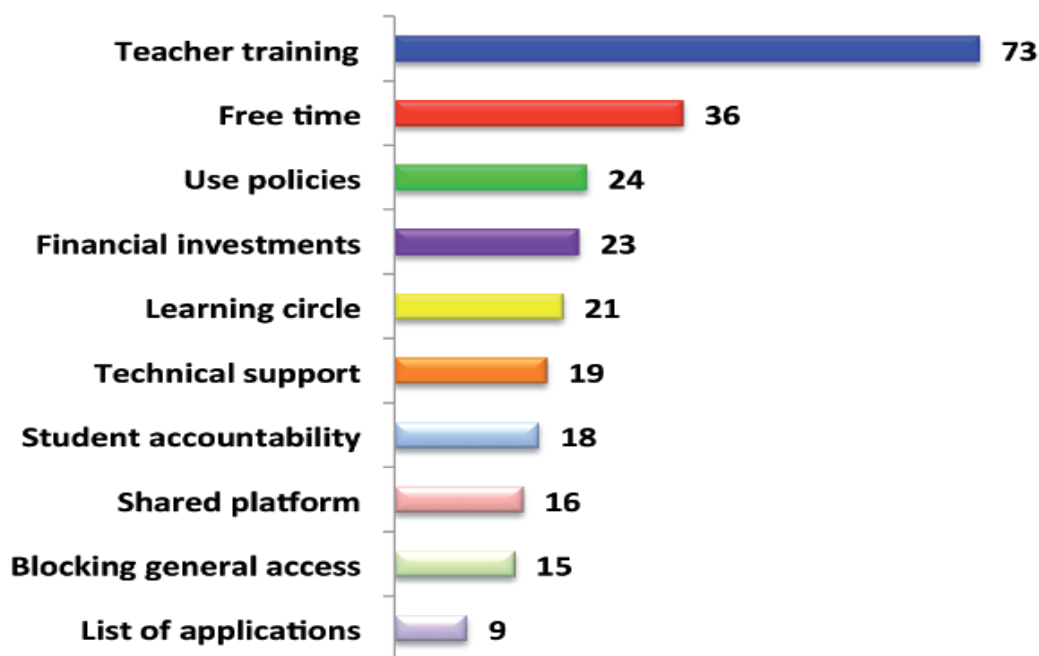


Figure 2.4 Challenges that need to be addressed in implementing computer tablets in education in Quebec, Canada (Karsenti & Fievez, 2013, p. 37)



## 2.7 Research on mathematics Apps used on computer tablets in schools outside South Africa

Due to the limited studies that have been conducted on the application of computer tablets in the mathematics classroom, Zengin proposed that the flipped classroom approach should be examined in greater depth (Zengin, 2017). Zengin (2017) then investigated the effect of the flipped classroom approach by using the Kahn Academy software to teach 28 students on the concept of double integration.

The teachers prepared their lessons outside of the classroom and transferred them to the students' computer tablets before class time. The students watched these Kahn Academy videos at home and used class-time to do active learning where the students collaborated and interacted with each other. The teacher could use this time to clarify any misconceptions. The first five weeks of this eight-week study was used to familiarize learners with the GeoGebra software that they would be using in the class.

Zengin (2017) used a mixed methods approach. He used the experimental method to find the difference in marks from the pre-test to the post-test and the observation method to validate his findings. The pre-test and post-test were the same test on the Double Integral Achievement Test using the integral  $\int_0^2 \int_{x^2}^{2x} (2x + 1) dy dx$  for University students aged between 20 and 26, and the questionnaire contained open-ended questions on the students' perceptions of the flipped classroom approach. The findings of this study showed that students understood the difficult concepts better. The students indicated that seeing the images in the software helped them to visualise the concepts, which helped with the retention thereof. The flipped classroom approach ensured that learners came to the class prepared and that the classwork concretised the topic and made them enjoy the subject (Zengin, 2017). The qualitative data indicated that students welcomed the move away from memorisation. This approach helped them to understand the subject better and increased their motivation.

The limitations of this study were that there was only one group of students without a control group. The consequence was that there was no other group to be compared with. Another limitation was the small size of the sample group and the fact that the researcher used the convenience sampling method. A convenience sampling group does not represent any group apart from itself and it does not seek to generalise about the wider population (Cohen, Manion,

& Morrison, 2002). The study also showed that the students who had difficulty in working on a computer as well as the students who could not work the software efficiently, had a disadvantage and did not like this approach due to their lack of understanding the technology.

In another study, Outhwaite *et al.* investigated the efficacy of a computer tablet intervention on the development of primary school children in mathematics (Outhwaite, Gulliford, & Pitchford, 2017). They examined 61 foundation phase learners (aged five to seven years) who received a six-week computer tablet intervention on mathematics curriculum knowledge and mathematics concepts. They investigated the progress of learners who engaged in learning with mathematics Apps and compared it to the learning of learners who received traditional mathematics lessons. They also differentiated with regards to mother tongue learning in comparison to learners who spoke English as an additional language. Lastly, they also investigated the effects that computer tablet intervention had on learners with different socio-economic status.

These learners were assessed before the computer tablet intervention on mathematics concepts and curriculum knowledge. They were assessed again immediately after the intervention and then again five months later. One group did not receive any computer tablet intervention and acted as the control group. This group also wrote the pre-test and both post-tests. The curriculum knowledge quiz of 50 items included counting, sorting and matching, shape recognition, patterns, addition and subtraction, and time. The mathematics concepts assessment consisted of 48 questions and included number-sense, symbolic understanding, simple and complex addition, simple and complex subtraction, and division and multiplication (Outhwaite, Gulliford, & Pitchford, 2017).

The post-test that was administered immediately after the intervention demonstrated significant learning gains in specific mathematics curriculum knowledge. The gains in the mathematical concepts were smaller, but significant. The “learning gains were sustained when re-assessed after five months, and large effect sizes were found for both maths measures” (Outhwaite, Gulliford, & Pitchford, 2017). No significant effects were found on the grounds of mother-tongue languages or socio-economic status. This meant that computer tablets were accessible to all learners (Outhwaite, Gulliford, & Pitchford, 2017).

The limitations of this study were that the assessments used in the pre-test and post-tests were identical. One can argue that some of the gains could be contributed to the learners' familiarity with the questions. Another limitation is that the study was done over a short period of time.

## **2.8 The best ten mathematics Apps in the world**

The researcher searched the Educational App Store for the best ten mathematics Apps. The Educational App store includes all Apps whether on the iPhone Operating System (iOS) platform, Android platform or Windows-based. The Educational Math Store is “a discovery, review and recommendation platform for educational apps” (Educational App Store, 2018).

The Educational App Store is designed to save precious time and provide access to a curated library of educational apps certified by teachers in a rigorous process that matches the curriculum so that teachers and parents can feel confident that they are supporting their children's learning in the right way (Educational App Store, 2018).

The best ten mathematics Apps, according to the Educational Appstore (2018), are listed and discussed below.

### **I. Komodo Maths**

With Komodo Maths the teacher sets up a baseline and the parents add the rewards. This App focuses on arithmetic and mental mathematics and it takes the learners through “counting, addition, subtraction, multiplication – including times tables, division, fractions, decimals, percentages and many more essential topics” (Educational App Store, 2018).

### **II. Rocket Maths**

Rocket Maths is a game where learners need to respond fast to factual answers. This game also focuses on arithmetic.

### **III. DoodleMaths**

What makes DoodleMaths so effective is that it adjusts to the level of the learner. It identifies the learner's weaknesses and adapts its programme to remediate these weaknesses.

#### **IV. IXL Maths**

“IXL Maths app is an immersive learning experience that provides comprehensive, curriculum-aligned mathematics and English content” (Educational App Store, 2018). This App has unlimited questions for learners to work through.

#### **V. Math Facts Mahjong game**

Math Facts Mahjong is a fun-filled mathematics game based on Mahjong rules. It addresses mathematics facts and the game requires mathematics skills, strategy and a little bit of luck (Educational App Store, 2018).

#### **VI. Fun Expected Maths**

Fun Expected Maths is also game-based and teaches learners algorithmic concepts.

#### **VII. Splash Maths**

Splash Maths is an outstanding App with a dashboard where parents can track their children’s progress. It includes arithmetic and geometry.

#### **VIII. TimeLand**

TimeLand teaches learners the concept of time with a user-friendly calendar and a clock.

#### **IX. Elephant Learning**

Elephant Learning is a very colourful graphic mathematics game with 21 different themes to choose from. Sound adds some excitement for younger learners.

#### **X. Division with IbbleObble**

This App is a multiple-choice quiz that focuses on division.

## **2.9 The mathematics Apps used on computer tablets in South African schools.**

The first research question investigated what Apps teachers are currently using in the mathematics classroom. The South African Department of Basic Education has compiled an Appstore with 112 different educational Apps for teachers to use, of which 38 focus on Mathematics (DBE, Department of Basic Education Appstore, 2017). Of the 38 mathematics Apps, ten focus on Grade 9 mathematics. These are briefly described below.

- **Complete Mathematics**

This App covers basic and high school mathematics and has a mathematics solver to work out the answer to questions. The Complete Mathematics App is “categorised into tutorials, formulas, equations, practical applications with solver, questions and solutions, mathematics dictionary and quizzes” (DBE, Department of Basic Education Appstore, 2017, p. 1). It also has a quadratic graph plotter for easy mathematics graphing, functions, algebra, probability, Euclidean geometry and measurement, trigonometry, statistics and analytical geometry (DBE, 2017).

- **Financial Calculator**

This App includes a currency converter. It can work out loan comparisons, compound interest, percentage rates and return on investment calculations, to name a few.

- **GeoGebra**

GeoGebra is an App that assists learners with algebra and geometry. It is ideal for Euclidean mathematics.

- **iTooch**

The App has five sections, namely statistics, numbers and operations, algebraic structures, functions, and geometry. This App is not completely free, but one chapter in every section is. Although this App covers integers, commutative and associative

properties, probability, the coordinate plane, and the fundamentals of triangles and polygons, it is not aligned with the South African Curriculum Assessment Policy Statement (CAPS) (DBE, 2017).

- **Mathway**

This App is a calculator which solves equations in algebra and calculus. It also simplifies expressions and formulae.

- **Math Exponents**

This App is a set of quizzes on exponents and radicals.

- **Mathematics Formula list**

This App provides definitions, explanations and formulae on algebra, geometry and trigonometry.

- **MultiplicationX25Square**

This is a game that learners play on multiplication.

- **Trigonometry Mathematics**

This App is designed to teach the basics of trigonometric formulas and identities.

- **Viewer for Khan Academy**

This App is a compilation of videos explaining different mathematics concepts.

The most popular of these Apps are the Kahn Academy and GeoGebra (Reyes, 2017). The Kahn Academy is a video-based tutorial programme that explains concepts to learners. It also has a game-like quiz. The positives are that it creates one-to-one learning, and learners can repeat the steps that they find challenging and learn at their own pace. (Campbell, Rafel, & Vezi, 2013). However, a drawback to this software is its monotonous nature, and after a few lessons, learners do not want to hear the voice anymore. It uses one instructional method and

is unlikely to be optimal for all learners (Campbell, Rafel, & Vezi, 2013). The game-like quiz can only be done online, and in South African schools, this is challenging due to the unavailability of the Internet in most schools.

## 2.10 Specific Apps utilised in the mathematics classroom

The researcher investigated the ten Apps that were prescribed by the Department of Education in South Africa, as discussed in 2.9 above, with the focus on why the teachers are using these Apps. Each App will be discussed separately.

### 2.10.1. Complete Mathematics App

The Complete Mathematics App was built around examination preparation. It can be used by teachers to set exams or to find examples of exercises and by learners to test themselves (Inducesmile, 2018).

The Complete Mathematics App has the following sections:

- Tutorials
- Formulas
- Calculations
- Theory
- Questions
- Quiz
- Dictionary
- Scientific calculator
- Graphing calculator
- Mathematics tricks
- Brain teaser
- Unit converter
- Statistics calculator.



Figure 2.5 Screenshot of complete mathematics App (Google Play, 2018)

The downside of this App is that users find the language improper, which leads to the misunderstanding of some of the questions and that the exercises are not sorted by level of difficulty. Most users love the App, and it has a success rating of 82% on Google Play out of 3380 voters (Google Play, 2018).

### **2.10.2. Financial Calculator App**

The Financial Calculator is an all-encompassing calculator App. It includes:

- Finance and investment calculators
- Loan/mortgage calculators
- Retirement calculators
- Stock calculators
- Credit card calculators
- Auto loan and lease calculators

This App is a valuable tool as it includes a standard calculator as well (Bishinews, 2018). It has a rating of 86% on Google Play. The downside is that it only converts the currencies of 22 countries.

### **2.10.3. GeoGebra App**

GeoGebra is free open source software that can be used online and offline. It was developed by Hohenwarter in 2002 for his master thesis at the University of Salzburg (Nguyen, 2014). The International GeoGebra Institute (2014) described GeoGebra as “free dynamic mathematics software for all levels of education, that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package”.

One of the most remarkable features of GeoGebra is the functional design of its tools (Hohenwarter & Fuchs, 2004; Nguyen, 2014). These tools allow users to carry out the desired operations, for example to draw a circle. The tools in GeoGebra are not just functional, but also multifunctional. It can draw a circle and show the midpoint. It can also calculate the area or the circumference instantaneously.

Another significant advantage is that GeoGebra allows for a double representation of objects (Nguyen, 2014). For example, it enables one to open an algebra as well as a geometry window at the same time.

It is also possible to fully manipulate on one window and observe the corresponding change in the other windows, for example one can drag the circle on the geometry window to change its radius with the mouse and observe the change of its equation and area in the algebra window



or one can change the equation of the circle in the algebra window and observe the change in the geometry window (Nguyen, 2014, p. 3).

This property makes the software quite powerful for exploration as one sees the impact of GeoGebra dynamic geometry software, and the process of teaching and learning becomes more effective. The pedagogy of discovery learning as propounded by Bruner was cited as the leading factor. By discovery learning, Bruner was not only referring to discoveries made by humankind but "rather include all forms of obtaining knowledge for oneself by the use of one's own mind" (Bruner, 1961). Bruner (1961) gave four reasons for using discovery learning:

- (i) To make an impulse of thought
- (ii) To instead develop inner motivation than outer motivation
- (iii) To learn the way of discovery
- (iv) To develop thought

Tran *et al.* (2014) researched discovery learning using the GeoGebra App in Ho Chi Minh City, Vietnam. This research involved 37 teachers and 282 learners in a secondary school. The findings of this research were that:

- "Discovery learning with the help of GeoGebra is suitable for the self-learning of students, and it improves the effectiveness of teaching and learning" (Tran, Nguyen, Bui, & Phan, 2014).
- The rate of the self-learning of students was high.
- This method made students pleasant and interested in learning mathematics (Tran, Nguyen, Bui, & Phan, 2014).
- The GeoGebra software guided the teacher in teaching mathematics.
- When they used this GeoGebra software, they become more creative by coming up with new problems and proving these problems.

After using GeoGebra in their research, they concluded that:

After students learned according to discovery learning, we realise that: Students write well, briefly. They also express mathematical languages coherently and fluently. This thing proves that the competence of the self-learning of students develops clearly. Students are interested in mathematical learning. They develop mathematical thought, specially to develop creative thought. Students also improve technology skills clearly

and like to research the knowledge of the GeoGebra software. The effectiveness of the new method is better than traditional methods. (Tran, Nguyen, Bui, & Phan, 2014, p. 56)

Budinski (2017) enthused about how GeoGebra could be used as a tool for Science Technology Engineering and Mathematics (STEM). “GeoGebra was used in the process of learning mathematics through real-life situations derived from materials science” (Budinski, 2017, p. 150). She found that GeoGebra can contribute to the “four aspects of mathematical education: multiple display options, experimenting, elementarisation, and connectivity” (Budinski, 2017, p. 150). She urged her learners to use GeoGebra to record data regarding material science experiments, and GeoGebra helped them in extrapolating their data. They could now infer whether their data was linear or exponential.

GeoGebra provided opportunities for students to examine data from real/materials science experiments. Mathematical models were used to explore the properties of mathematical functions such as linear or exponential functions. The features of GeoGebra provided a dynamic environment for exploring variable (Budinski, 2017).

By looking at these three studies, one can understand why this App has pedagogical value and why it is one of the top ten mathematics Apps in South Africa.

#### **2.10.4. iTooch App**

The iTooch Elementary App is a collection of educational activities, including mathematics, natural science, language and art (Bishop, 2015). The App can be downloaded as a whole grade or for specific knowledge areas. The grade five App, for example, has 54 curriculum related lessons (Bishop, 2015). It is, according to Lee (2018, p. 1), the “largest collection of educational activities based on the US National Common Core Standards on the App Store”. It has more than 18 000 fun-filled exercises for elementary schools (Lee, 2018). This App is used in the classroom for learners to work through worksheets and assessments. The downside of the App is that it takes learners directly into an assessment, and although the lesson is available, it is not so visible on the side of the screen (Bishop, 2015). The assessment also does not consider multiple variations of the correct answer. For instance, when one misspells an answer, it will be wrong, or if one writes "autumn" instead of "fall", it will also be marked incorrect.

The advantage of the App lies in its functionality. It loads and the game plays smoothly, without bugs (Bishop, 2015). The lessons are clearly and carefully written according to Bishop (2015), and Lee (2018) adds that it has a game-centre embedded in it for break times. The App has a free version with ten titles for testing before buying it. It is used by more than 300 000 learners, parents and teachers (Lee, 2018).

#### **2.10.5. Mathway App**

This App is best described by Kievlan:

Mathway is an App as well as a website that lets users plug in math equations and tap “Evaluate” to find solutions. The free version only gives the answers, but a subscription will give step-by-step solutions to problems in a wide variety of math types, including basic math, pre-algebra, algebra, geometry, trigonometry, and calculus. (Kievlan, 2013)

The App has been found to help learners cheat on their homework. The free version only shows the answer to problems, but the paid version gives the whole process of how to solve any exercise (Kievlan, 2013). If used for the right reasons, this App can become a supportive companion for mathematics learners as it has a feature for guided practice. Learners can construct their own worksheets and experiment with graphs of functions and relations. This App is excellent for learners who are struggling and who needs help to get up to the level of other learners in the class.

#### **2.10.6. Math Exponents App**

The Math Exponents App is no longer available. The researcher included it to show that the list of Apps on the government’s education site is not updated.

#### **2.10.7. Mathematics Formula List App**

The Mathematics Formula App is no longer available. There are other mathematics formula Apps available that give one all the mathematics formulae one is searching for. These Apps are useful when one needs to work out a mathematics problem where the factors are known. One substitutes it in the equation, and the App does the rest.

### **2.10.8. MultiplicationX25Square App**

The MultiplicationX25Square is not available on the Play Store platform anymore. The researcher included it to show that the list of Apps on the government's education site is not updated.

### **2.10.9. Trigonometry Mathematics App**

The Google Play Store describes this App as follows:

“...designed for beginners to learn the basics of trigonometry. This explains its mathematical and geometrical interpretation and physical significances thoroughly. It deals with trigonometric formulas and identities. Very helpful tutorials for students to solve mathematical problems under the category of heights and distances” (Learner's series, 2018).

This App is excellent for learners who are new to trigonometry. It provides all the necessary identities and graphs and helps learners to visualise the problems. The App has an 82% rating out of 960 users on Google Play (Learner's series, 2018).

Some of the positive reviews include its simplicity and its clear and concise explanations that make it easy to understand the concepts. The negative reviews include the fact that this is just another textbook. The App does not use the standardised trigonometry nomenclature, and this makes it confusing.

### **2.10.10. Viewer for Khan Academy App**

In 2004, Salman Kahn assisted his cousin Nadine by explaining mathematics to her over the phone. He started to make videos of his explanations and published them on YouTube for her to watch in Boston. This Khan Academy site became one of the world's most significant online educational sites (Khan, 2014). After Bill Gates took an interest in the videos and started to fund the site, the Khan Academy grew to a staff of over 60 teachers producing these online videos.

His idea was not to replace the teacher in the class but to offer additional classes for learners that needed assistance (Khan, 2014). Kelly and Rutherford (2017) were so keen on using these videos to enhance their lessons that they set out to do a study to see if learners learned more

effectively by watching the videos. Murphy, Gallagher, Krumm, Mislevy and Hafter (2014) examined the attitudes of learners and teachers of the Khan Academy as well as testing scores of learners using the Khan Academy. The test scores did not show any significance in achievement, but there was a real reduction in mathematics anxiety and an improvement in mathematics self-belief (Murphy, Gallagher, Krumm, Mislevy, & Hafter, 2014). Pierson and Light (2014) in their research on Chilean students found that the Khan Academy was “useful for improving the procedural skills but not necessarily at promoting deeper mathematics learning or teaching difficult concepts; face-to-face teachers are still the best at that” (Pierson & Light, 2014). This statement agreed with Khan's vision that his software should not replace the teacher in the classroom but should preferably be used in addition.

This is what Kelly and Rutherford (2017) did with 114 learners in North Carolina. All the grade 7 learners received mathematics from the same teacher. The teacher then substituted the content of the one class with only Khan Academy content for four weeks. At the end of the four weeks, everyone had to write an assessment on the topic.

On the question of whether the Khan Academy enhanced learning, the statistical analysis showed no significance with a probability factor of 0,596. Although there was no significant difference in test scores, there was a positive association between time spent on the Khan Academy and the topics covered.

Zengin (2017) claimed to have more success in his study involving 28 students learning double integration using the flipped classroom method. This will be discussed in Chapter 3 of this thesis in full. Zengin's study was done over nine weeks, and learners had to watch the Khan Academy videos for three weeks before they engaged with classwork. He administered a pre-test and post-test that were identical and used qualitative data through an open-ended survey to triangulate his findings.

According to the analysis of the research done by Zengin (2017):

The analysis of qualitative data demonstrated that students understood the concepts much better as a result of using the flipped classroom approach that was designed using the Khan Academy materials and mathematics software together. In addition, it was emphasised by the students that the approach helped them to visualise the concepts, promoted retention of knowledge, and fostered easier learning of the concepts.

Moreover, it was revealed that the approach helped students to come to the lesson prepared; it concretised the subject and made students like the subject. (Zengin, 2017)

Zengin applied treatment in the form of Khan Academy videos after the pre-test. He only had a treatment group. There was no control group to compare it with. After the treatment, the students knew and understood the work. Any other treatment or lessons might have had similar results.

He also gave them an identical test as a post-test. Learners will do better if they redo any test that they have seen before. Nevertheless, it was a good methodology to use the flipped classroom approach as learners came to the class prepared, and it fostered collaboration.

## **2.11 How these Apps are used in the mathematics classrooms**

On the question of how computer tablets are used in the mathematics classroom, the answer is two-fold. On the one hand, it refers to the methodology, and on the other hand, it refers to the pedagogy. The methodology refers to the storing and handling of computer tablets, maybe in a group or individually, and the pedagogy refers to the learning design.

As more primary schools see the need to integrate computer tablets within the classroom, less emphasis is placed on the pedagogy as the art of learning (Parmar, 2017). The Nesta report (Luckin, et al., 2012) argued that the reason why educational technology has not made a proven impact yet is that researchers are too often looking at the technology tool rather than viewing it in the context of pedagogy and learning design. The report also indicated that “technology can have an impact as a tool for certain learning styles, for example, learning from experts, collaborative learning, learning through inquiry and learning through making, and that more research should be directed towards assessing these” (Luckin *et al.*, 2012). The teacher can now increasingly support learners with knowledge acquisition and the critical research skills that are needed in the 21st century.

What makes it difficult for teachers is the overwhelming number of available Apps (Rajput, 2015; Cherner, Dix, & Lee, 2014). Most of these Apps are designed for drill and practice activities (Parmar, 2017). Parmar (2017) listed the four pedagogy styles followed by teachers as:

- Drill and practice

- Independent exploration
- Guided interaction, and
- Communication and collaboration

The drill and practice method is what most parents and teachers were used to when they were in school (Cherner, Dix, & Lee, 2014). App developers that are not educationists also think that this is good teaching; hence, almost 60% of Apps on the Appstore follow this method. This method unfortunately results in high levels of stress and anxiety behaviour (Parmar, 2017).

Parmar (2017) reported that a significant part of learning comes from exploration, from re-inventing the wheel and finding out for yourself. This kind of teaching is referred to as “independent exploration”. With this kind of App, teachers must ensure that the content is age-appropriate and that enough time is allocated for trial and error (Parmar, 2017). Cherner, Dix, and Lee (2014, p. 168) reported that about a third of educational Apps belong to this category.

With “guided interaction”, the role of the teacher becomes fundamental in developing an appropriate learning environment (Parmar, 2017). The teacher becomes the orchestrator, and the focus shifts to the learners engaging with the App while guided by the teacher. The teacher actively supports and enhances the learners' interactions with the technology (Parmar, 2017).

The last level of Parmar’s pedagogical styles is that of “communication and collaboration”. This style proves to be the most effective as it allows the learners to learn alongside the teacher. Collaboration leads to opportunities for co-construction of possible solutions (Parmar, 2017). The drawback is that only 4% of educational Apps are aligned with the construction category (Cherner, Dix, & Lee, 2014).

Johansson (2012, p11), as cited in Clarke and Svanaes (2014), agreed with Parmar (2017) that “the use of mobile technology in learning is gradually changing the role of the teacher”. Johansson proposed that the teacher become a facilitator, and the classroom becomes learner-centred. The role of the teacher now shifts from a provider of knowledge to becoming a “filter” for search engine results and available Apps. Teachers can even suggest some Apps and websites to be used, and the learners can explore. This methodology brings its own challenges. Bjerede and Bondi (2012) highlighted issues like “preventing pupils from engaging in cyberbullying, looking at indecent content, becoming distracted in lessons, and damaging the

devices”. These are not new challenges in schools, but computer tablets afford the opportunity of delivering these challenges in new ways ( Bjerede & Bondi, 2012).

Fullan and Donnelly (2013) also pointed out that the use of computer tablets in class can vastly reduce the teacher's workload. Teachers can build up a library of e-content, get Apps to mark assessments, and deliver content and results to learners quickly. Tablets can “provide feedback or support effective feedback for teachers to improve their pedagogy, and the system to monitor and improve student achievement” (Fullan & Donnelly, 2013).

Tablets lend themselves to new pedagogies like flipped learning (Clarke & Svanaes, 2014). Flipped learning replaces the traditional homework assignments with content that is available beforehand that learners can engage with. Learners come to class having pre-knowledge on the topic, and collaboration can take place in the classroom.

Cornelas from Duke University taught two classes in different ways. The one class did flipped learning, and the other class was taught using the traditional lecture style. The result was that the flipped learning class outscored the other class by 6% on average (Raths, 2015). This method of teaching has also been linked to greater autonomy and motivation to learn (van't Hooft, 2013).

Clarke and Svanaes (2015) reported that computer tablets promote collaboration amongst learners, enabling more creativity and supporting learners with disabilities to a high degree. This kind of teaching is very effective in smaller size classes (Clarke & Svanaes, 2015). However, it is imperative for every learner to have their own device. Clarke and Svanaes (2015) reported that personal ownership is the most crucial factor for the successful implementation of computer tablets.

Another factor that is crucial to the success of using computer tablets in the classroom is that teachers must make it compulsory to own one (Norris & Hossain, 2012). They must structure their lessons in such a way that having a computer tablet should not be optional but mandatory. It must become an integrated part of the lesson. Bjerede and Bondi (2012) stated that a technology-rich environment where learners have their own devices to explore, discover and develop their own learning is a powerful and effective model for the future of education.



## 2.12 Summary

Chapter 2 of this thesis reviewed the literature on the use of computer tablets in the classroom. It started by looking at how the computer tablet and Apps evolved to become the device of preference in education. After that, the researcher investigated how widespread computer tablet integration is. Successes and failures of computer tablet projects around the world were recorded and the advantages and disadvantages of having computer tablets in the classroom were listed.

The ten best Apps for use in mathematics were identified, and their suitability for the mathematics classroom was discussed. Research showed how the computer tablet's affordances make them suitable for integrating into the classroom. Lastly the researcher reviewed the pedagogical value that computer tablets bring to a lesson.

# Chapter 3

## Conceptual Framework

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### 3.1. Introduction

The researcher constructed a conceptual framework by blending activity theory as propounded by Engeström with modern computer-integrated learning models such as Technological Pedagogical Content Knowledge (TPACK), blended learning, flipped classroom, the Substitution, Augmentation, Modification, and Redefinition model (SAMR), and 21st Century Learning (Engeström, Miettinen, & Punamaki, 1999). The researcher will discuss these theories and models in detail below.

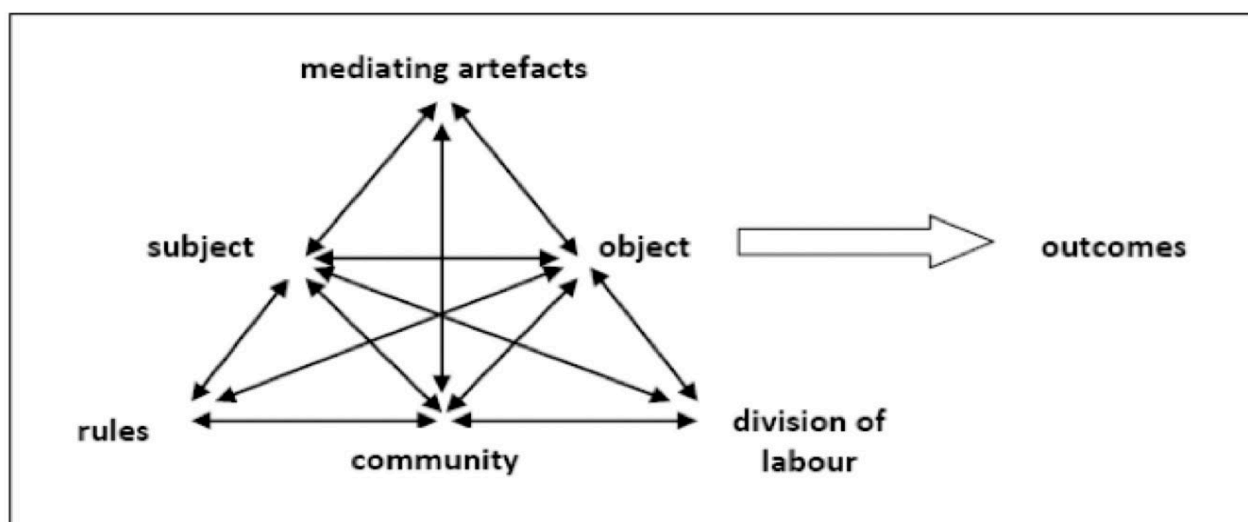
### 3.2. Activity Theory

“The fundamental basis of the activity theory comes from a Vygotskian understanding that all humans come into contact with their environment, recreate their environment and themselves through the actions that they engage in” (Mbekwa, 2002, p. 47). This is in contrast with theories that focus on the environment changing the individual and theories that focus on the individual changing the environment (Mbekwa, 2002).

Engeström suggested that “the evolution of activity theory could be seen in terms of three generations” as described below (Engeström, 2009). The activity theory found its roots in cultural-historical psychology, founded by Lev Vygotsky (Engeström, Miettinen, & Punamaki, 1999). This signified the first generation, and it emphasised the idea of mediation. Vygotsky introduced mediation as a special relationship between stimulus and response.

After his death, his colleague Leont’ev developed the activity theory further, and this marked the second generation. Leont’ev and Rubinstein searched for human activities beyond the paradigms of reflexology, as in the case of Ivan Pavlov’s dogs or the teachings of Vladimir Bekherev (AIU, 2016). This second generation of development involved other Russian scientists including Anokhin, Bernshtein and Rubinstein. Their work mainly resulted in the systemic-structural activity theory.

The Scandinavian Activity theory, as a third-generation theory, sought to merge the traditional Vygotskian socio-cultural beliefs with western intellectual developments such as Cognitive Science and Constructivism (AIU, 2016; Mbekwa, 2002). What made Engeström's theory different from that of Leont'ev was that Engeström considered three interacting entities, the individual, the object and the community, whereas Leont'ev only focused on the individual and the object (Mbekwa, 2002). When Leont'ev referred to a joint labour activity, he referred only to individuals as the subjects, while the Scandinavian theory includes groups as subjects as well. Other notions were also introduced, such as the notion of rules, which was not found in the traditional Russian theory. The diagram in Figure 3.1 shows the interaction between the different entities within the activity theory model, as explained by Engeström.



**Figure 3.1 Engeström's model (Engeström, 2009)**

According to Engeström's model above, a wide range of factors influences an activity. The subject comprises the actors involved in the activities, while the artefacts are the tools used by the actors in the system. To reach the desired outcome, specific objectives need to be reached, and the object refers to the objective of the activity system. This system is guided by rules and conventions regulating the activity, taking into consideration the community or all the actors involved in the system and dividing the labour or tasks amongst the actors in the system (Mbekwa, 2002).

The desired outcome of this computer tablet project is that enhanced learning must take place. The process is driven by the subject, and in this case, it is the learners and the teacher. This

human activity is mediated by artefacts. The mediating artefact in this case is the computer tablets, which are used by teachers and learners to attain the objectives of the activity.

This whole activity is guided by what Engeström calls a community. This community is the school, the learners, the teachers and the parents, and they all impart certain responsibilities to this activity. Engeström referred to these responsibilities as the “rules” of the activity. The parents are paying for computer tablets and need to see that the learners have Internet at home. They certainly have the right to be role players in the process. Together all the role players need to get to the objective. This typically calls for a division of labour or effort.

In the case of the computer tablet process, the teachers are using e-books to teach, the learners summarise and get actively involved with the learning material, and the parents support the learners in making sure that they have a working computer tablet and that it is charged.

Table 3.1 is how Mbekwa (2002) depicted the Engeströmian activity system for technology-driven mathematics.

**Table 3.1 Modified table of element of the Engeströmian activity theory (from Julie 2001 cited in Mbekwa (2002))**

Subjects	Grade 9 mathematics learners and teacher
Object	Exploration of mathematics with a computer tablet computer Mathematical understanding
Outcomes	Enhanced learning
Tools	Tablet computers, pens, books, data projector, speakers, screencast dongles, Wifi, Internet, server
Community	Learners, the facilitating teacher, the parents of these learners
Division of labour	Training of one teacher Teacher facilitating classes Learners to participate as normally as possible Parents providing computer tablets and Internet at home
Rules	Tablets need to be charged Wifi and Internet need to be functional

	<p>The teacher needs to project from a computer tablet</p> <p>Teacher teaching the same topic</p> <p>Different ways of working</p>
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The researcher is using the activity theory because it simplifies the given activity. Figure 3.2 below reinforces the reasoning process.

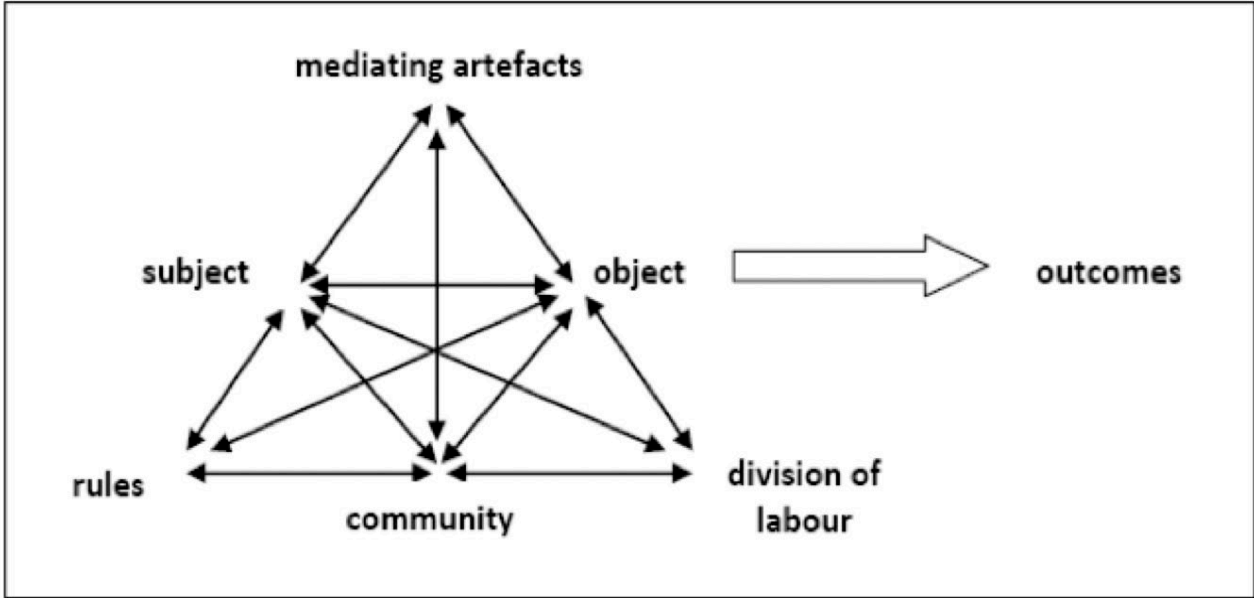


Figure 3.2 The interactive activities of the Engeström triangle (Engeström, Miettenin, & Punamaki, 1999)

Although the main activity revolves around the Subject-Artefact-Object triangle, there are several other interactive triangles. The whole activity can be simplified into smaller triangles, for instance the interaction between Subject, the Rules and the Community can be isolated and studied separately, as in Figure 3.3 below.

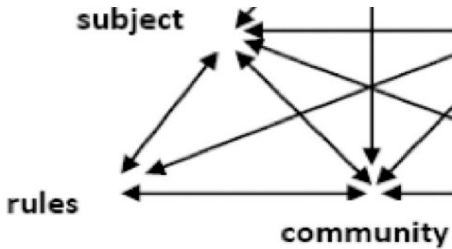


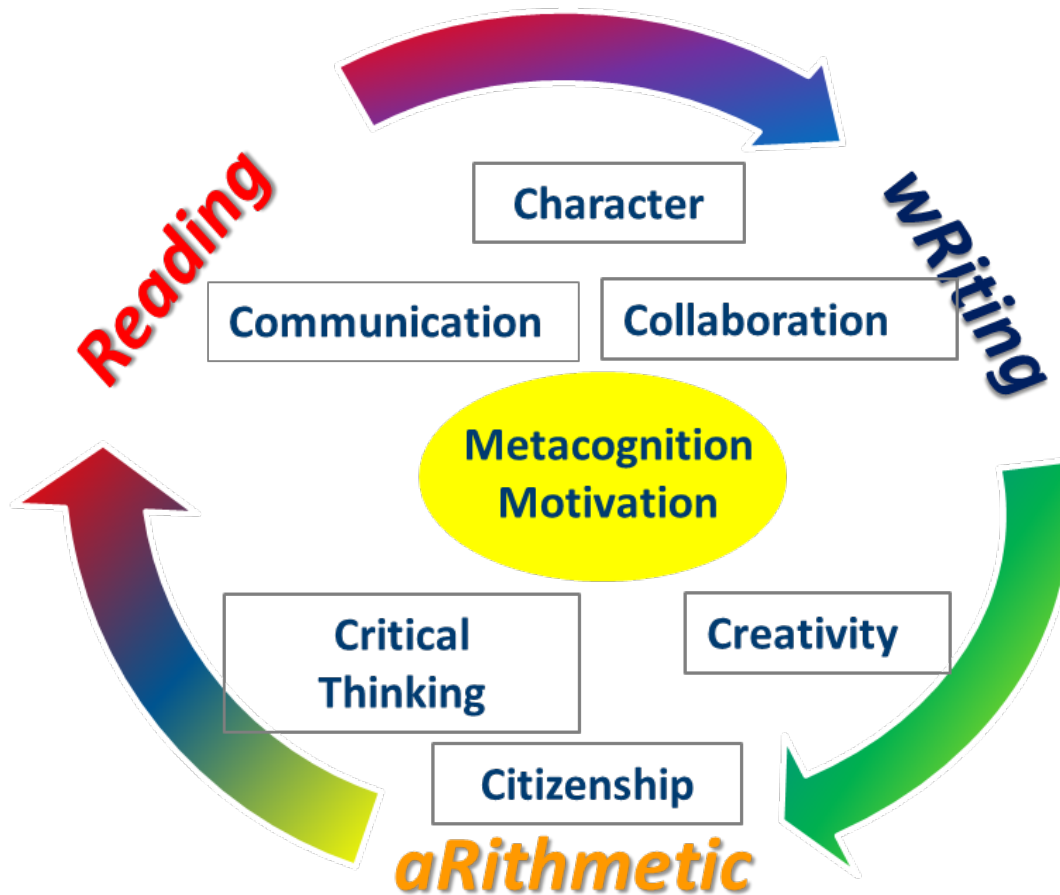
Figure 3.3 A portion of the Engeström triangle

The lines in the triangles have arrows going both ways, which signifies that there is a two-way interaction between these entities.

For this research, the “Subject” refers to the teachers in the first three questions and 40 learners in question four. To answer questions one to three, the researcher sent a survey to teachers to inquire what Apps they were using in the mathematics classroom, as well as why and how they were using these Apps. For these three questions, the teachers became the subject. For the last question, the researcher engaged learners to write a pre-test and a post-test. The “Subjects” or participants here were the 40 learners who took the tests as well as the teacher who facilitated these classes. The “Artefacts” in the study were mainly the computer tablets. Other “Artefacts” used as tools were the Apps, the data projector, speakers, the Internet, Wi-Fi, the whiteboard and the teacher’s laptop. The “Object” in this case was to explore mathematics with the use of computer tablets and the “Outcome” was enhanced learning. The “Rules” in this study had to be followed closely. The lessons were taught by the same mathematics teacher to two different classes. The one class used the “Artefacts” as explained above and the other class engaged in traditional teaching methods. Both classes spent the same amount of learning time and they covered the same amount of work. Seven periods of fifty minutes each were set aside for this intervention. All computer tablets had to be charged daily and all the learners had access to the Apps used in this study. All the “Artefacts” had to work properly so as not to hinder or buffer the process. The “Community” in this research comprised of the 40 learners who took part in the tests, the teacher who administered both classes, the parents of these learners who had to make sure that all the learners had a computer tablet, the school staff who allowed the researcher on the premises and the IT support team at the school. The “Division of Labour” was an important factor as every one of the “Community” had to know and understand their role in this research. The learners only needed to learn as normally as possible. They needed to learn how to use these Apps before the project began. The teacher had to be familiar with the Apps and how to use them. She also had to prepare herself to teach with the content provided to her from the researcher. The parents and the school staff had to give permission for this intervention to take place.

### 3.3. 21st Century Learning

The 21st Century skills were identified via a study where 250 academics from 60 different academic institutions in Australia, Singapore, Finland, and the USA identified specific skills as crucial for current learners to be ready for life after school (ATC21S, 2011). This included skills such as communication, creativity, collaboration, critical thinking, character building, citizenship, motivation and metacognition. These are summarised in Figure 3.4 below.



**Figure 3.4 21st Century learning**

The outer circle represents the traditional 3Rs of teaching: **R**eading, **w**RIting, and **a**Rithmetic. The six inner blocks represent the skills acquired in the 21st century, namely communication, collaboration, character building, critical thinking, creativity and citizenship. These skills are also known as the 6Cs. The inner circle depicts an attitude of motivation and metacognition. These attitudes are referred to as the 2Ms. Together they make up the 3Rs, 6Cs and 2Ms of the 21st century (21st Century Schools, 2008).

Tablets fits well with 21st Century learning as they can enhance the 3Rs, 6Cs and 2Ms of the 21st Century learning. Tablets can assist learners to read and write well. Adobe and Microsoft have created immersive readers that “use proven techniques to improve reading for people regardless of their age or ability (Shapiro, 2016). Shapiro adds that “Microsoft has imagined a technology that can truly make learning reading, writing, and comprehension easier for everyone” (Shapiro, 2016, p. 1). Numerous Apps focus on programmes that enhance the six skills. Hayes (2016) in his study called, “Mobile Apps for 21st Century Skills” showed that most educational Apps enhance the skills and attitudes needed in the 21st century.

### 3.4. Blended Learning

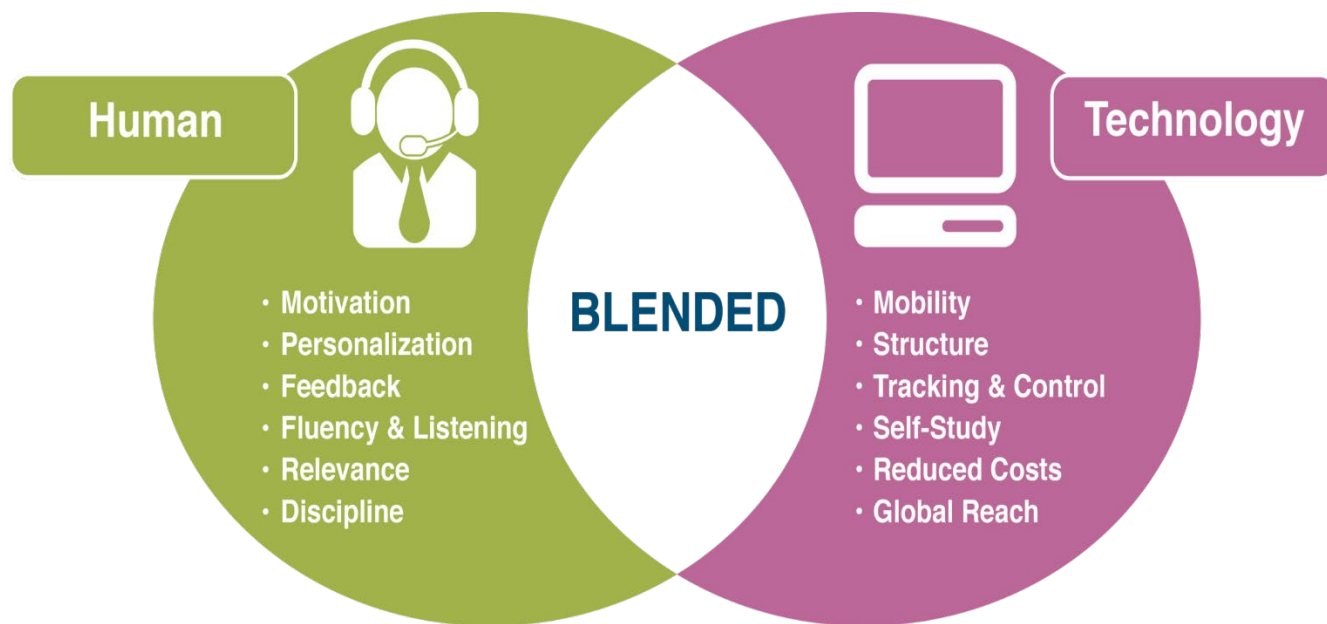


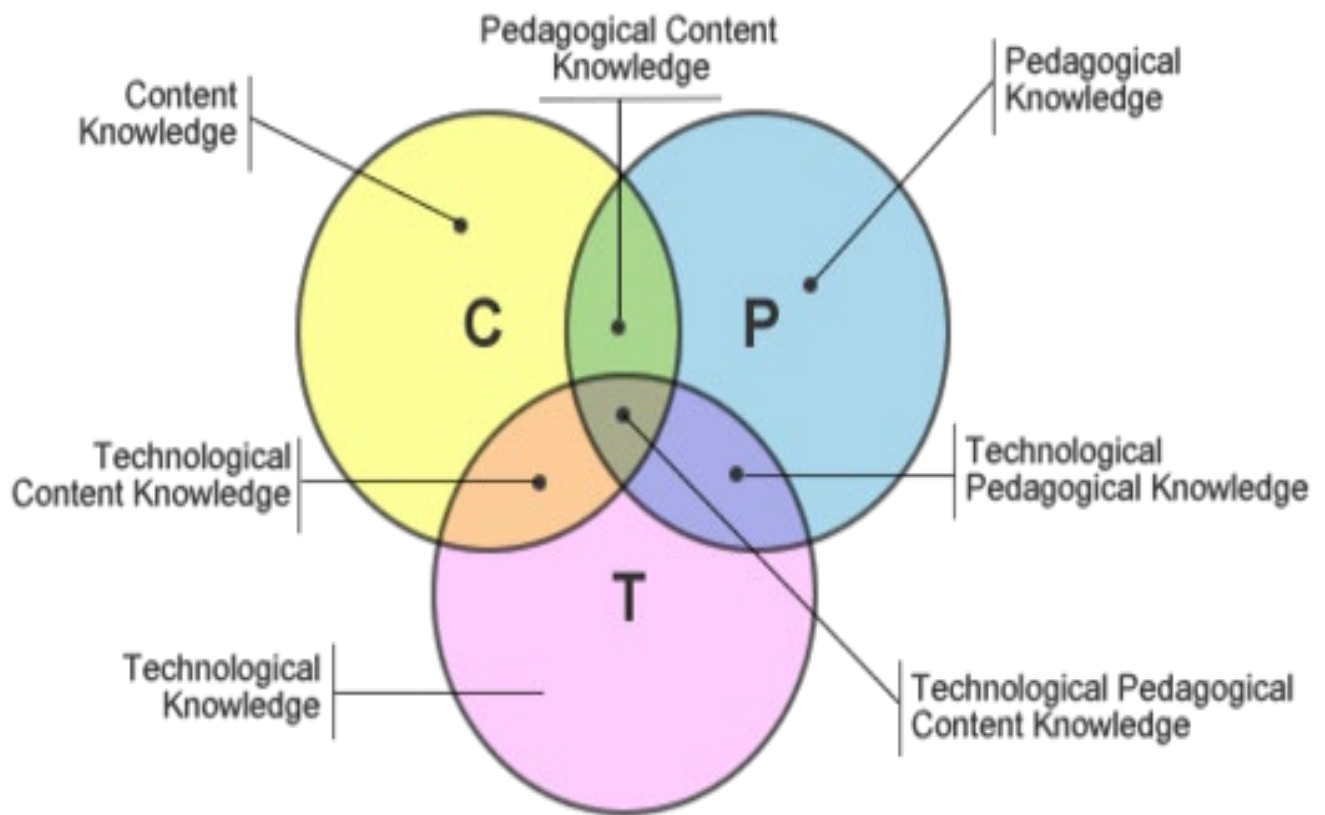
Figure 3.5 An image of blended learning (Peek, 2014)

Blended learning is “a term increasingly used to describe the way e-learning is being combined with traditional classroom methods and independent study to create a new, hybrid teaching methodology” (Mindflash, 2012). It is more than just adding computers to the classroom as it is accompanied by a change in pedagogy. It constitutes a fundamental change in the way teachers and students engage in the learning experience. It already has a few variations, of which the flipped classroom is one approach.



The flipped classroom model according to the Rochester Institute of Technology (RIT, 2013) is one in which traditional in-class teaching is delivered outside of the classroom with the aid of videotaped lessons and online resources. Classroom time can now be used for collaboration, problem-solving and to clarify misconceptions. Traditionally a lesson was taught, and homework was given afterward. Now the learners receive the video or notes before the time, watch and study them, and then participate in classroom discussions during the lesson.

### 3.5. TPACK



**Figure 3.6 TPACK model for computer tablet integration (Koehler & Mishra, 2009)**

TPACK stands for Technological Pedagogical And Content Knowledge (Koehler & Mishra, 2009). It is represented by three circles: Technological Knowledge, Content Knowledge and Pedagogical Knowledge. Koehler and Mishra (2009) described Content knowledge (CK) as “knowledge about the actual subject matter that is to be learned or taught”. Pedagogical knowledge (PK) was described as the “deep knowledge about the processes and practices or

methods of teaching and learning and how it encompasses, among other things, overall educational purposes, values and aims” (Koehler & Mishra, 2009, p. 1026). Technology knowledge (TK) was described as “the knowledge about the technology used” and, in this case, the computer tablet. This involves having the skills to operate the computer tablet as well as the Apps that used in the study.

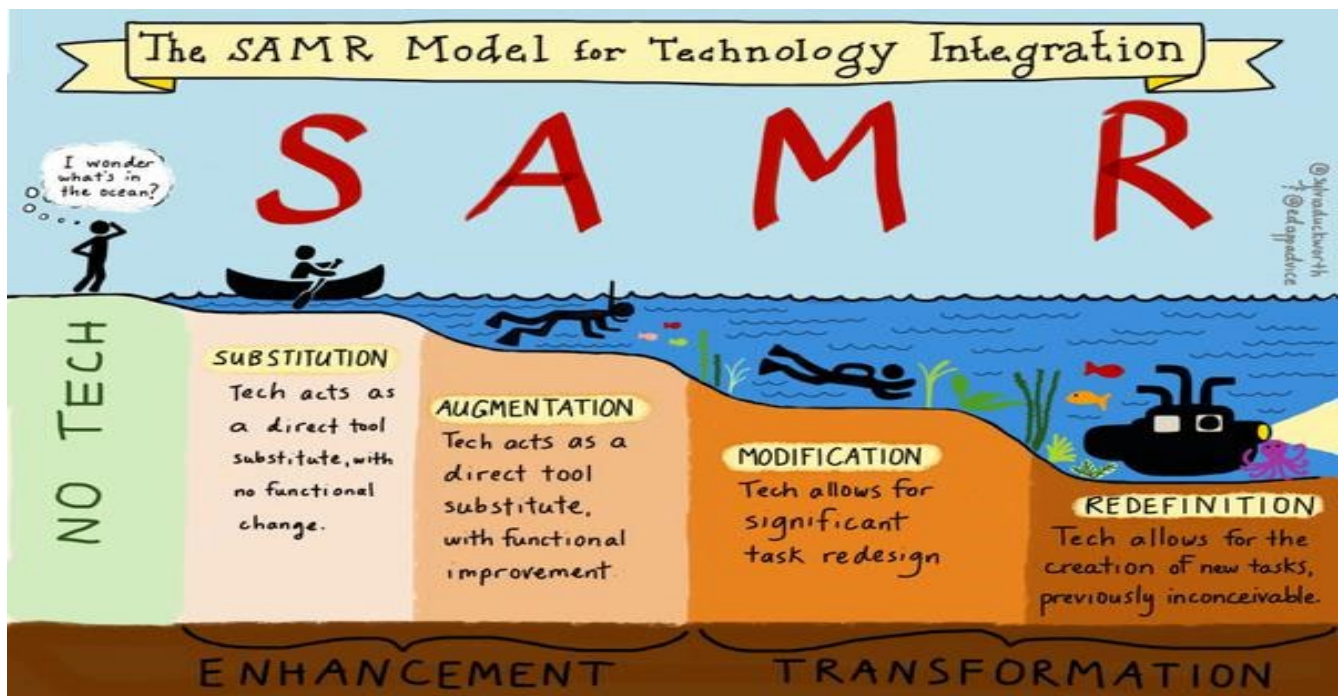
These Knowledge circles, however, do not operate in isolation. The power of the TPACK model lies in the integration or the overlapping of these circles.

Koehler and Mishra (2009) divided TPACK into seven sub-knowledge categories: Technology Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), Pedagogical Content Knowledge (PCK), and Technological Pedagogical Content Knowledge (TPACK). (Yildiz & Kirikcilar, 2018, p. 101)

TPACK comes from all three circles overlapping or working together to form the technological pedagogical content knowledge. This centrepiece is also called the ‘sweet spot’ where all knowledge areas work together to optimise computer tablet integrated learning.

### **3.6. SAMR**

SAMR is an acronym for Substitution, Augmentation, Modification, and Redefinition (Puentedura, 2016). This model describes the level of transformation of technology on learning. It is used to determine whether the application is enhancing or transforming learning. The first two levels of the SAMR depict how technology is enhancing the learning experience, and the top two levels address transformation.



**Figure 3.7 The SAMR model for computer tablet integrated teaching (Puentedura, 2016)**

With substitution, the computer tablet can be used to write an essay, for example. The computer tablet is only substituting the writing pad, and with augmentation the substitution is functionally improved. This essay is then placed on a shared drive where classmates can have input and leave comments as well as give room for modifications. This is the modification stage. The document is then placed on a blog and other learners can add and publish their own versions. The essay has become an article that travels around the world. The essay could redefine people's opinions as well as create new tasks when people make podcasts and videos of it, or when it gets discussed on forums. This depicts the redefinition stage. This is no longer an essay on a piece of paper.

### 3.7. Summary

Activity theory is widely known for "its triangular diagram made of six interrelated elements that allow for multiple networks of descriptions and interpretations of a dynamic situation" (Zahedi, Tessier, & Hawey, 2017). The six interrelated elements interact with each other, simplifying a complex situation that accounts for "historical context, culture, role of instruments and

motivations of people (subjects) in order to attain the object (outcome)” (Zahedi, Tessier, & Hawey, 2017).

This chapter explained different models in the conceptual framework. These models are not isolated from each other. The underlying theory is the activity theory as propounded by Engeström and the Western models that are integrated to enhance learning. The teacher and the learners who are the subjects use the computer tablets, which are the artefacts, to reach an objective. The 21st Century, the TPACK, the SAMR and the blended learning models represent the methodology of teaching and learning. The teacher finds his level of technology interaction as set out in SAMR, guided by the 21st Century model learning content, skills and attitude. The TPACK circles are used to find the sweet spot where technology, pedagogy and content meet. The teacher uses the technology only when and where it is appropriate. This mixing of computer tablet integration and traditional methods of teaching depicts blended learning.

# Chapter 4

## Research Design Sampling and Method of Data Collection

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### 4.1. Introduction

This chapter discusses the research design, including the critical questions, the approach, the paradigm, the ethical considerations, the validity of the research, the reliability of the study and the selection of the research instruments used to obtain data. The research instruments were a survey, observations, a pre-test and a post-test. The chapter also addresses the sampling of the target group and the research plan.

### 4.2. Research Questions

As stated in chapter 1, the researcher investigated the use of computer tablets in the mathematics classroom. To get a sense of how feasible this computer tablet project was, the researcher posed the following questions:

- i. What are the computer tablet applications (Apps) that mathematics teachers use in mathematics classrooms in South Africa?
- ii. Why are these mathematics teachers using these specific Apps?
- iii. How are these mathematics teachers using these specific Apps?
- iv. How effective is the use of computer tablets in a mathematics classroom compared to the traditional way of teaching?

### 4.3. The Research Approach

This study employed a mixed methods approach (Creswell & Creswell, 2017) to explore the use of computer tablets in the mathematics classroom. The mixed methods approach was defined by Johnson and Onwuegbuzie (2004) as “the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study”. May (2017) explained it as a continuum where the qualitative approach is on the left side and the quantitative approach is on the right side, with the mixed methods approach somewhere in-between. Creswell (2014, p. 32) agrees with May’s

explanation, but notes that it should not be viewed as “rigid, distinct categories, polar opposites, or dichotomies”, but that it sometimes overlap in a manner that one can refer to a study as more quantitative than qualitative or vice versa. Creswell (2014, p. 32) defines the use of mixed methods as an approach to inquiry “involving collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks”. The researcher chose the exploratory sequential mixed methods design.

The qualitative approach is described by Creswell (2014) as a researcher seeking to establish meaning of a phenomenon from the views of participants. This process can be very subjective as it depends on the experiences of the participants. Choy (2014) characterises the qualitative approach by the nature of the data collected. The qualitative approach gathers “soft data, in the form of impressions, words, sentences, photos, symbols and so forth (Choy, 2014). The strength of the qualitative approach is that it explore the views of people and unpack the different perspectives within a community (Choy, 2014). The qualitative researcher probes for underlying values, beliefs and assumptions to understand what is driving peoples’ behaviour (Choy, 2014). The weakness of this approach is that it is time consuming and important issues get easily overlooked (Choy, 2014; Creswell & Creswell, 2017).

Creswell (2014) describes the quantitative approach as a researcher testing a theory by specifying a hypothesis by collecting data to support or refute the hypothesis. An experimental design is used to assess before and after a treatment is applied (Creswell & Creswell, 2017). Choy (2014) characterises the quantitative approach as gathering data mostly in the form of numbers that can be transferred into a computer-readable format. The strength of this approach according to Choy (2014) is that it is a quick process to administer and it can be evaluated quickly. It is also easy to draw comparisons based on the data received (Choy, 2014). The weakness of this approach is that important characteristics and beliefs cannot always be reduced to numbers or cannot be adequately understood apart from it context (Choy, 2014).

The researcher applied the mixed methods approach in answering the research questions. The core assumption was that the combination of qualitative and quantitative approaches provide a more complete understanding of the research problem than only one of the two approaches (Creswell & Creswell, 2017).

Creswell (2014) identifies three basic mixed methods designs, namely: the convergent parallel mixed methods, the explanatory sequential mixed methods and the exploratory sequential mixed methods design.

- The convergent parallel mixed methods design involves a researcher who collects both quantitative and qualitative data, analyses them separately, and then compares the results to see if the findings confirm or disconfirm each other.
- The explanatory sequential mixed methods design involves a two-phase project in which the researcher collects quantitative data in the first phase, analyzes the results, and then uses the results to plan the second, qualitative phase.
- The exploratory sequential mixed methods design is a design in which the researcher first begins by exploring with qualitative data and analysis, and then uses the findings in a second quantitative phase.

This study employed an exploratory sequential mixed methods design in answering the first three research questions as the researcher first collected qualitative data using a survey, compiled it, sorted it and then represented it on a graph in a statistical format ranging from the most frequent to the least.

The researcher made use of quantizing qualitative data in answering the first research question. Quantizing is commonly understood as the numerical translation or conversion of qualitative data (Sandelowski, Voils, & Knafl, 2009). The respondents had to inform the researcher what Apps they were using. The researcher counted the Apps that were most frequently used and focused the research on the most used Apps.

The second and third research questions of the research start with a qualitative approach, as questions were posed as a survey and the teachers' answers were quite subjective with respect to their experiences. The teachers responded on why and how they were using these Apps and their reasons were quite diverse. The researcher then analysed their responses, rated their answers and grouped similar responses. The researcher drew a pivot table and graphed their responses from the most common to the least frequent. Once again, the researcher is quantizing the qualitative data. These steps constitute the exploratory sequential mixed method design as proposed by Creswell (2014) as the survey was a questionnaire on computer tablet usage in the teacher's classroom where after the researcher made quantitative interpretations for reporting purposes.

With the last research question, the researcher took a quantitative approach in order to test the objective theory that computer tablet interaction would enhance learning (Creswell & Creswell, 2017). The researcher used a pre-test and post-test to determine the learning gains. Creswell (2003) described the quantitative approach as testing a theory, setting a narrow hypothesis, and collecting data to either support or refute the hypothesis. In this study, the null hypothesis for question four was that there would be no difference in teaching with or without computer tablets. A significant difference in the results would then refute the null hypothesis and an alternative hypothesis would prevail. The alternative hypothesis would then be that the implementation of computer tablets does make a difference.

Considering all four questions, this study was carried out using a mixed method approach using both qualitative and quantitative data. This data was captured sequentially as the survey's qualitative data of questions two and three were used to inform the last question. The reason for the qualitative data in questions two and three were to supplement the primary quantitative data (Zengin, 2017). The quantitative section in question four was designed using four groups of learners where two groups wrote a pre-test, while all four groups wrote a post-test. This Solomon four-group design will be explained again in section 4.10.

#### **4.4. Research Paradigm**

A preferred paradigm for mixed methods research is the critical paradigm (Elshafie, 2013; Creswell & Creswell, 2017). Hussain et al (2013) believes that critical research aims at emancipating people by transforming their social context. In the case of this research, the way in which learners are taught might be transformed. Yet, the researcher has adopted the positivist paradigm because the mixed methods approach used, is not parallel, but sequential. The answers to the second and third questions were interpretive at first but sequentially changed to a positivist paradigm. The responses to questions one and four were positivistic in nature.

The research process sometimes requires the researcher to make multi-layered decisions (May, 2017). Creswell (2003) believed that these decisions were informed by the different questions that the researcher attempted to answer. For this research, the researcher posed four questions. The first three questions were part of a survey questionnaire where the teachers had to declare what Apps they were using, why they were using it and how they were using it.



The answers to questions two and three were subjective to the teachers' experiences and one might conclude that this research is located in an interpretive paradigm (Hussain, Elyas, & Nasseef, 2013). "Interpretivism seeks to understand the researched phenomena from the point of views of the people involved" (Elshafie, 2013), yet the analysis to these questions are located in the positivist paradigm.

The fourth question, however, investigated whether the computer tablet intervention could enhance learning and the researcher used the first three questions to determine what Apps to use in the study. To answer this question, the researcher made use of a pre-test and post-test, thus using a positivist paradigm. As this was the main question to determine the effectiveness of computer tablets in the classroom, the researcher decided to locate this study in the positivist paradigm. The ontology of the researcher was that this question could be "studied objectively without any interference from the researcher or observer" (Hussain, Elyas, & Nasseef, 2013, p. 2378). The study on effectiveness of the computer tablet project was tangible and existed "out there", and could be studied independently with prediction and control (Elshafie, 2013). The epistemological stance of the researcher was that of an objectivist as it is believed that objects respond "mechanically to their environment and have an identifiable existence independent of the knower or the inquirer" (Elshafie, 2013, p. 2378).

#### **4.5. Research Design**

The researcher started with a teacher survey to answer the first three research questions on what, why, and how the Apps were currently being integrated into their mathematics lessons. The first question was quantitative in nature as the researcher compiled the responses and sorted it from the most frequently used App to the least. The response to the second and third questions of the research were qualitative as the respondents gave input on how they were using these Apps and what their various reasons were for the use of these Apps. This open-ended survey was sent to 27 schools in various provinces that were using computer tablets in their classrooms. The researcher analysed these responses and treated it quantitatively.

The results of this survey guided the researcher to select five of these Apps to test in a mathematics classroom. The fourth research question was quantitative, as the researcher made use of the Solomon four-group design. For this a pre-test post-test design with four groups was devised to overcome the problem of pre-test sensitisation (Navarro & Siegel, 2018).

The central feature of the Solomon four-group design is that participants are randomly assigned to either receive or not to receive a pre-test and then randomly assigned to either a treatment or a comparison group. All participants then receive a post-test. This approach enables researchers to acquire the benefits of using a pre-test while also allowing an assessment of pretest sensitisation. (Navarro & Siegel, 2018)

The significance of the Solomon four-group design was determined by using William Gossett's t-test calculation, also known as the Student's t-test (Glen, T Test (Student's T-Test): Definition and Examples, 2019). The t-test determines whether the difference in the outcome in the different groups is significant or not, or whether it could have happened by chance (Glen, T Test (Student's T-Test): Definition and Examples, 2019). The t-test for a one sample case is:

$$t = \frac{\bar{X} - \mu}{s/\sqrt{n}}$$

where  $\bar{X}$  is the sample mean,  $\mu$  is the mean specified in the null hypothesis,  $s$  is the sample standard deviation, and  $n$  is the number of observations on which  $\bar{X}$  is based" (Coladarci, 2010, p. 1). For a two-sample case, the Student's t-test becomes:

$$t = \frac{X_1 - X_2}{\sqrt{\left( \frac{\sum_{i=1}^{n_1} (X_i - \bar{X}_1)^2 + \sum_{i=1}^{n_2} (X_i - \bar{X}_2)^2}{n_1 + n_2 - 2} \right) \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}}$$

When the t-score is large, it means that there is a big difference between the groups while a small t-score means that the groups are similar (Glen, T Test (Student's T-Test): Definition and Examples, 2019). The question is: how big must the t-value be for the difference to be significant. Glen (2019) explained that every t-value has a p-value attach to it. The p-value is the probability value. It shows the probability that the results from the sample data occurred by chance (Glen, T Test (Student's T-Test): Definition and Examples, 2019). A high t-value corresponds with a low p-value. P-values ranges from 0% to 100%. A p-value of 0.02 means there was a 2% probability that the results from an experiment happened by chance. The researcher chose 0.05 as a critical value for this research. A p-value of less than 0.05 (5%) is accepted to mean that the data is valid and the difference is significant.

The disadvantage of using the Solomon four-group design is that it is very costly, and double the number of participants is needed, as it is necessary to involve two groups that are similar. As the researcher was working with a school, and the participants were not paid, it was possible to make use of this design without incurring any cost. The school also had enough learners to select more than one group for investigation.

The researcher also calculated the effect size using the Cohen's d test to indicate the standard difference between the means of the pre-test and the post-test. "An effect size is how large an effect of something is" (Glen, 2016). The formula for Cohen's d is:

$$\text{Cohen's } d = (M_2 - M_1) / SD_{\text{pooled}}$$

where

$$SD_{\text{pooled}} = \sqrt{((SD_1^2 + SD_2^2) / 2)}$$

M1 and M2 are the means of the two groups and SD is the standard deviation for the two groups. The rule of thumb for Cohen's d is that a number close to 0.2 shows a small effect, anything close to 0.5 shows a medium effect and any number greater than 0.8 indicates a large effect (Glen, 2016).

Lastly, the researcher recorded all the activities except the tests on video, and these observations were used to triangulate the findings.

## 4.6. The Research Plan

The researcher firstly designed a survey which was sent to mathematics teachers at 27 schools. The researcher used the private school's database to get email addresses of the grade 9 mathematics teachers of these 27 schools. When they submitted their answers, the findings were analysed immediately. Of these schools, 25 responded that they are using computer tablets in the mathematics classroom. From this survey, the researcher was able to ascertain what the most popular Apps were that were being used in the mathematics classroom and why and how the teachers were using these Apps to foster learning. The findings of this survey will be presented in the next chapter.

The researcher took the five most popular Apps as indicated by the survey and assessed whether they could be used in the research. The researcher used the software assessment rubrics by Hannifin and Peck (1988) to assess whether these Apps were adequate to use as an educational resource. The criteria for this assessment are included as Appendix I. The grade 9 mathematics teacher of one school was then trained on how to use these Apps confidently in class.

The researcher looked at the mathematics curriculum and chose the topic “The Geometry of 3D Objects” for the research. The topic was scheduled over seven periods as follows:

- Lesson 1: Pre-test on 3D objects
- Lesson 2: Platonic solids and Euler’s formula
- Lesson 3: Properties of spheres and cylinders
- Lesson 4: Surface area and volume of prisms and cylinders
- Lesson 5: Nets on 3D objects
- Lesson 6: Consolidation
- Lesson 7: Post-test on 3D objects

The researcher used purposive sampling and selected two grade 9 classes that received mathematics tuition by the same teacher. The grade 9B class used computer tablets and Apps for learning, and the grade 9C class received hard copy and chalkboard tuition.

Only half of the grade 9Bs and half of the grade 9Cs wrote the pre-test, but all wrote the post-test. During lesson 2 to lesson 6, the teacher taught the grade 9Bs using the Apps that were selected, and the grade 9Cs received traditional teaching on the whiteboard.

The findings will be presented in the next chapter. Table 4.1 below is a summary of how data were captured.

**Table 4.1 Data capturing table**

<b>Q</b>	<b>Research Questions</b>	<b>Sources of Data</b>	<b>Data Collection</b>	<b>Data Analysis</b>
<b>1</b>	What are the computer tablet applications (Apps) that mathematics teachers are using	Teachers at 25 different schools	Survey to schools	Quantitative – Identifying and prioritising the Apps that are currently

	in the mathematics classrooms in schooling in South Africa?			used by teachers in order of popularity
2	Why are these mathematics teachers using these specific Apps?	Teachers at 25 different schools	Survey to schools	Qualitative at first with quantitative analysis. Sorting the reasons on a pivot table to prioritize
3	How are these mathematics teachers using these specific Apps?	Teachers at 25 different schools	Survey to schools	Qualitative at first with quantitative analysis. Sorting the reasons on a pivot table to prioritise
4	How effective is the use of computer tablets in the mathematics classroom compared to the traditional non-computer mathematics classrooms?	Learners of two grade 9 classes at the same school with the same teacher	Pre- and Post-test Observation	Quantitative – Comparing the marks of learners in the pre-test to the marks in the post-test looking for patterns. Using the video footage to justify the research.

## 4.7. Study Population

The results of the ANA test for 2014 show the following pattern of pass rate:

- Grade 1 – 68.4%
- Grade 2 – 61.8%
- Grade 3 – 55.4%
- Grade 4 – 37.3%
- Grade 5 – 37.3%
- Grade 6 – 43%
- Grade 9 – 10.8%

One can clearly see that there is a crisis in grade 9. All the other grades achieved more than 35% except grade 9, which only achieved 10.8%.

The research population for answering the first three research questions comprised of the grade 9 mathematics teachers of the 25 schools who answered the survey on the use of computer tablets in the classroom. The research population in the fourth research question then shifted to grade 9 learners of both genders, including all cultures, who were studying mathematics at the school. These learners were asked to do a pre-test and post-test to determine their progress.

#### **4.8. Study Sample and Sampling Techniques**

The private school group had 50 schools distributed all over South Africa. The researcher sent the survey to all of these schools, of which 27 responded. Two schools responded that they could not be of help. The other 25 schools were able to assist in the survey by answering research questions one to three.

For the last research question, the researcher made use of purposive sampling to select the institution and the learners. The researcher handpicked “the cases to be included in the sample on the basis of the judgment of their typicality” (Cohen, Manion, & Morrison, 2002, p103). For assessing the role of computer tablets in a mathematics class, the researcher worked with a school in the Western Cape that was implementing the computer tablet project for the first time. The researcher selected two classes of mathematics learners in grade 9 with the same average marks.

#### **4.9. Data Collection Techniques**

##### **4.9.1. Teacher survey**

Surveys are ideal for gathering data at a particular point in time with the intention of “describing the nature of existing conditions or identifying standards against which existing conditions can be compared, or determining the relationships that exist between specific events” (Cohen, Manion, & Morrison, 2002).

The benefit of using a survey is that it is a powerful tool for gathering data, yet it is cost-effective, extensive, flexible and dependable (DeFranzo, 2012). The researcher compiled an online survey with open-ended questions (Appendix M). This survey was emailed to mathematics teachers of 50 schools. These teachers needed to go online using a Uniform Resource Locator (Url) and complete the survey without using their own name. Being anonymous helped the teachers to give a true reflection without the fear to be judged. Using a survey was the most cost-effective way of distribution and receiving the responses back. It was an extensive survey as the researcher was able to reach all the mathematics teachers in this school group across South Africa at the same time. This medium was highly flexible as the researcher had a choice of conducting the survey telephonically, on social media, by email, face-to-face, by mobile or online. The researcher opted for an online survey where the answers were submitted, and the responses were compiled and logged for the researcher to analyse. The anonymity of the survey contributed to making it dependable. Teachers could be candid and honest in answering the questionnaire without fear of being exposed.

The researcher designed a survey to find out what Apps were being used currently in the mathematics classroom. The survey consisted of four questions, and teachers had to complete it online. It enquired what Apps were being used in the mathematics classroom and teachers needed to elaborate on why they were using those specific Apps. They also needed to discuss how and when they were using the Apps. A screenshot of the survey is shown in Figure 4.1.

**Tablets in the Mathematics Classroom**

1. Are you as a Mathematics teacher integrating tablets in the mathematics Classroom?

2. What are the Apps that you are using in the Mathematics classroom?

3. Please elaborate on why you are using these specific Apps.

4. Please describe how and when are you using the Apps mentioned above.

**Done**

**Figure 4.1 Screenshot of the teacher survey**

#### **4.9.2. Pre-tests and post-tests**

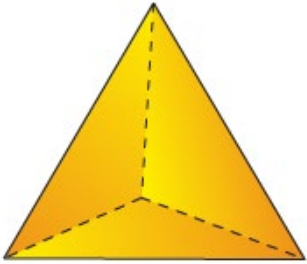
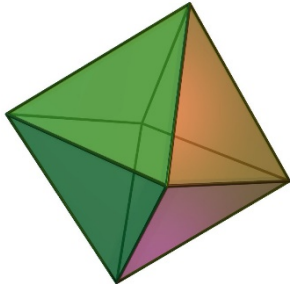
The construction of a pre-test and post-test was an essential part of the quantitative approach. Both the control group and the experimental groups wrote the same tests in the same timeframe. Guided by Cohen, Manion & Morrison (2002), the test adhered to the following conditions:

- It differed in form or wording, but tested the same content
- The tests were the same for both the control and the experimental groups
- Care was taken not to make the completing of these tests easier for the one group than for the other
- The level of difficulty was the same for both groups

The pre-test and post-test were compiled on the topic of 3D objects. They were designed to be similar, but not identical. They needed to test the same skill set and yet be different so that learners did not recall any of the answers. An example of these tests is given in the comparison below in Table 4.2 to illustrate the similarity. The full tests are attached as Appendix C and Appendix D.



**Table 4.2 An example of the pre-test and post-test**

Pre-test	Post-test
<div style="text-align: center;">  </div> <p>1. What is the name of this shape?</p> <p>a. Cube b. Tetrahedron c. Octagonal prism d. Square pyramid</p>	<div style="text-align: center;">  </div> <p>1. What is the name of this shape?</p> <p>a. Cube b. Tetrahedron c. Octagonal prism d. Square pyramid</p>

The researcher selected the Solomon Four-Group design to overcome the external validity challenge where learners writing the pre-test and post-test would attain better results than learners who only wrote the post-test.

**Table 4.3 Solomon Four-Group design**

Group	Pre-test	Treatment	Post-test
<i>10 Grade 9B using tablets</i>	O	X	O
<i>10 Grade 9C without tablets</i>	O		O
<i>10 Grade 9B using tablets</i>		X	O
<i>10 Grade 9C without tablets</i>			O

With the Four-Group design, both classes were divided into two. Everyone wrote the post-test but only half of the two classes wrote the pre-test. With this methodology it is possible to determine whether participation in the pre-test influenced the data when those learners wrote the post-test.

### 4.9.3. Observation

As the researcher opted for a mixed methods approach, observation was included as a resource method. The researcher made use of a quantitative approach in answering the fourth

research question and only used observation, although it was qualitative, for triangulation. In social research, the term triangulation is used when data on a specific topic is gathered from at least two different points. In this case, the researcher collected data mainly from the pre-test and post-test, but used observation as a strategy for the validation of the study (Flick, von Kardoff, & Steinke, 2004).

Participant observation was defined by Becker and Geer (1970) as “that method in which the observer participates in the daily life of the people under study, either openly in the role of researcher or covertly in some disguised role, observing things that happen, listening to what is said, and questioning people, over some length of time” (Becker & Geer, 1970, p. 28). Baker (2006) distinguished between “four roles researchers can play in their efforts to study and develop relationships with insiders, including complete observer, observer-as-participant, participant-as-observer, and complete participant” (Baker, 2006, p. 173). These levels determine the level of involvement by the observer. The researcher chose to be a complete participant but unobtrusive and passive (Baker, 2006). This role allowed the researcher to listen and observe. The advantage was that the researcher was completely detached from the group, but the disadvantage was that the researcher could not ask questions to qualify what was being said or done (Baker, 2006). For this reason, the researcher also recorded video footage to replay if needed.

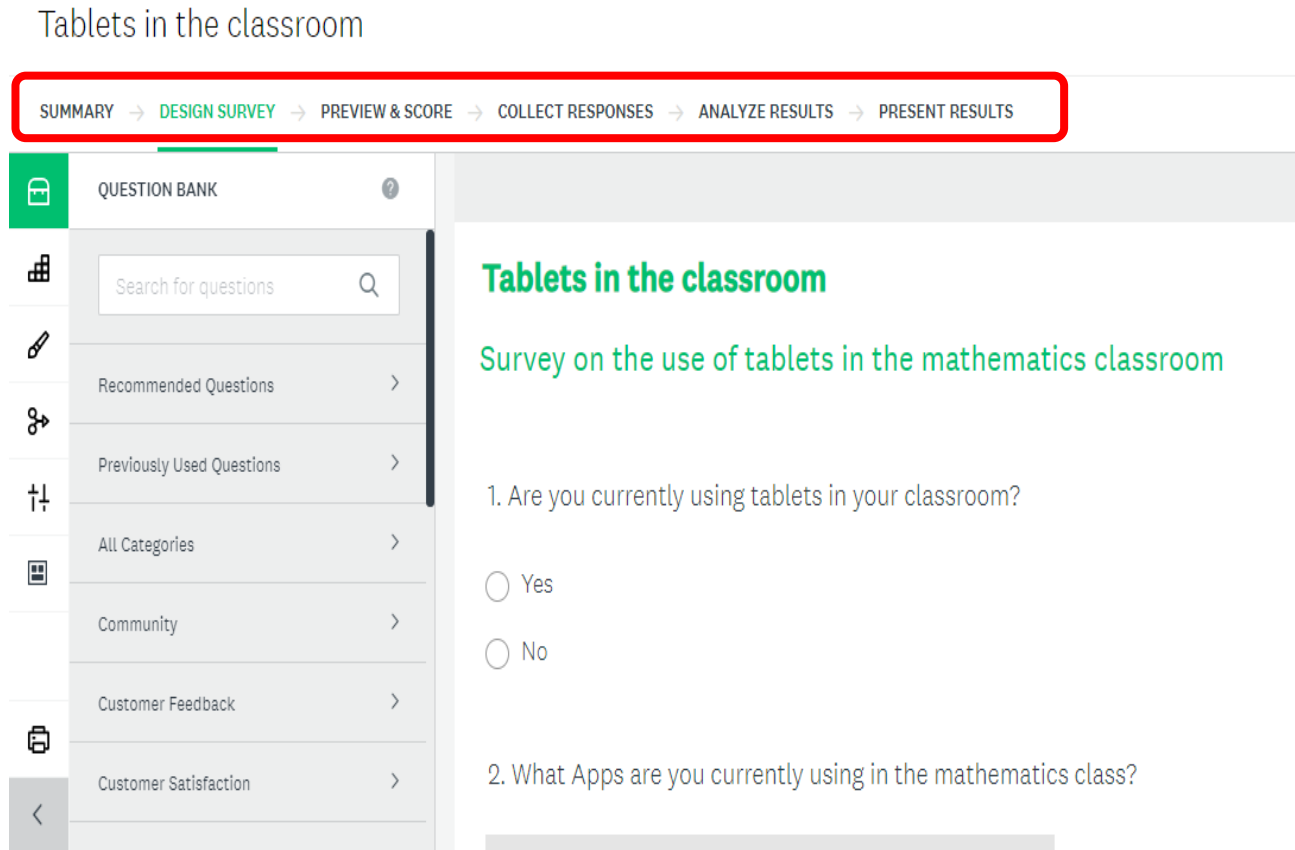
The advantage of doing observations was that the researcher had the opportunity to look at “what is taking place in situ rather than at second hand” (Cohen, Manion, & Morrison, 2002). The researcher was guided by Cohen, Manion, & Morrison (2002) and observed the following:

- (i) Physical setting (physical environment)
- (ii) Human setting (organisation of people and characteristics)
- (iii) Interactional setting (the interactions in the class)
- (iv) Programme setting (the resources, the pedagogy, the curriculum, etc.)

The researcher sat at the back of the class to observe the process. A wide-lens video was also recorded to capture the whole class and to be used for validating the observation.

## 4.10. Data Analysis Procedure

The researcher used the software programme Survey Monkey for the first three research questions. This software gathered the responses of the teachers, analysed the data, and presented it in the desired format. See Figure 4.2.



**Figure 4.2 Screenshot from the programme Survey Monkey that was used to analyse questions**

In order to answer the fourth question, which constituted the quantitative part, the researcher made use of the Solomon Four Group Design (Navarro & Siegel, 2018). The two grade 9 classes were divided into four groups, where one group from each class wrote a pre-test. All the learners wrote a post-test. However only one class received the computer tablet intervention. Figure 4.3 below explains the procedure.

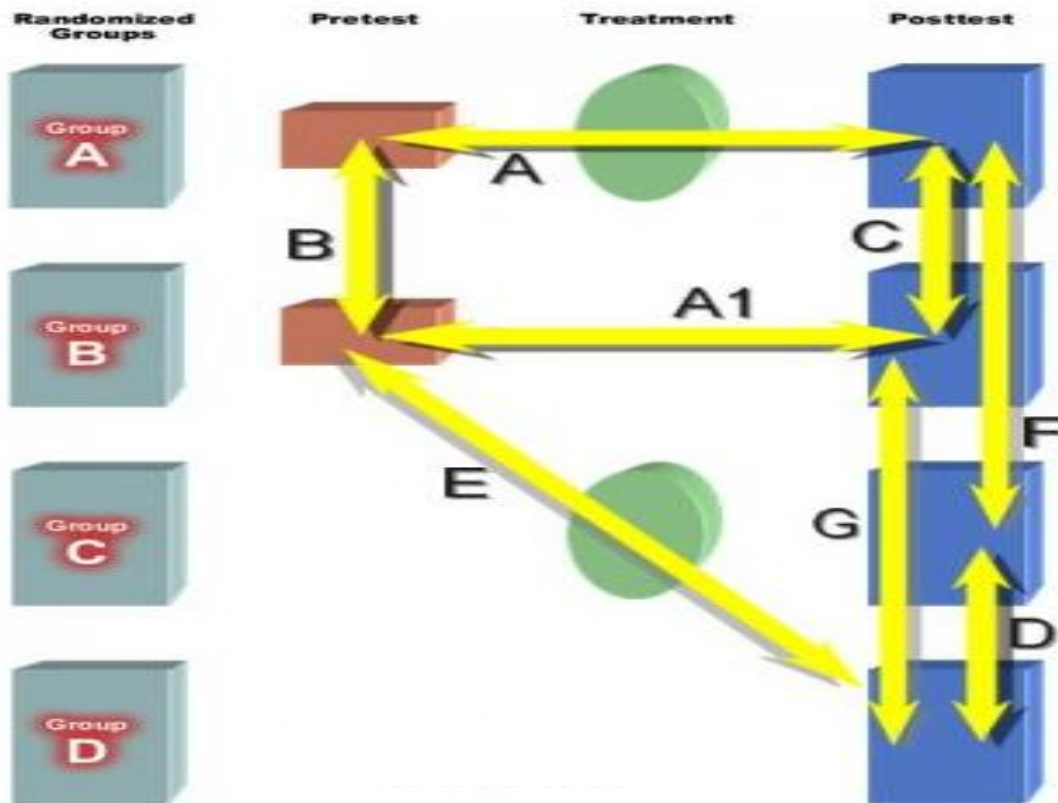


Figure 4.3 The Solomon Four Group Design explained (Shuttleworth, 2009)

The first two groups, group A and group B in the Solomon four-group design, were designed and interpreted in precisely the same way as the normal pre-test and post-test design. The comparison in the results of group A and group B determined whether significant learning had taken place.

Group C and group D did not write the pre-test. When the results of group C and group D were compared with the results of group A and group B, it was possible to determine whether the pre-test influenced the results. This Solomon Four-Group Design was effective in establishing the internal validity of the research.

#### 4.11. Presentation of Results

With respect to the question whether the teachers were using Apps in the mathematics classroom, the Survey Monkey software generated a graph indicating the results. This was generated as a bar graph and will be displayed in the next chapter.

It analysed the answers to the second research question in the same manner, and this was also presented in a table. On the question of why and how the teachers were using these Apps, the software programme summarised the responses. These responses will be discussed in the next chapter. The last question was presented as the results of the pre-test and post-test.

#### **4.12. Ethical considerations**

The contrast between the “right to know” and the “right to privacy” is defined in the *Ethical Guidelines for the Institutional Review Committee for Research with Human Subjects* as that which “extends to all information relating to a person’s physical and mental condition, personal circumstances and social relationships which is not already in the public domain” (Cohen, Manion, & Morrison, 2002, p. 51). The researcher pledged to protect the research participants concerning anonymity and confidentiality.

Strike (1990) and Cohen, Manion & Morrison (2002) listed ethical principles that educational research should adhere to. The researcher incorporated Strike's guidelines in the code of ethics that follows.

The researcher protected the participants from unwarranted interference in their affairs. The evaluation only pertained to those aspects of the teacher’s activities that were job-related. The researcher refrained from making decisions based on race, religion, gender, ethnicity or sexual orientation. On public perspicuity, the researcher pledged openness concerning evaluation procedures, their purposes and the results. The researcher acted in a humane manner considering the feelings and sensitivities of those participating in the study. On the matter of client benefit, the researcher ensured the participants that decisions were made in a way that respected the interest of the learners, the teacher and the school involved. The researcher tried to maintain the academic freedom that is the norm of the class. Lastly, the researcher practiced respect for autonomy. The teacher was not restricted in discretion and judgment in making decisions in the classroom. The researcher has included a letter of ethical clearance as addendum B.

### **4.13. Validity and Reliability**

To improve the validity of this quantitative research, the researcher exercised care in the selection of the participants and utilised the appropriate instruments to treat the data. An independent statistician was asked to assist with the results. To improve validity, the researcher made use of triangulation by employing observation. Triangulation was defined by Cohen, Manion, & Morrison (2002) as the use of two or more methods of data collection in the study of some aspect of human behaviour.

To further add to the validity of this research, the researcher tried to minimise the Hawthorne Effect. This is the “tendency, particularly in social experiments, for people to modify their behaviour because they know they are being studied, and so to distort (usually unwittingly) the research findings” (Payne & Payne, 2004, p. 1). The researcher was a “fly on the wall” and disrupted the lesson as little as possible.

Reliability, according to Cohen, Manion, & Morrison (2002, p. 117) is synonymous with consistency and replicability over time. The researcher limited contact time to one period a day, but studied the unit of analysis for the duration of a particular topic. This method helped to make the observations more reliable. The researcher also refrained from seeking answers to any preconceived notions and hence made this study more valid and reliable.

Validity and reliability in the quantitative research paradigm is replaced with four criteria of trustworthiness and authenticity in the qualitative research paradigm, namely; credibility, dependability, conformability and transferability. (Kivunja & Kuyini, 2017). The criteria of credibility is met due to the survey being anonymous. The teachers had no obligation to take part in the survey and no judgement could have been passed as the researcher did not know who submitted the form. The survey focused on the use of Apps. The answers are clear-cut answers. You either use the App or not, or you use a different App. Although it is in the interpretist paradigm, it is not so much subjective. The researcher would have gotten a similar result should the survey be given again. One can therefore state that the criteria of dependability is met. The App that was used by all teachers, was the miEbooks App. This App tracks the activity of all the teachers which means that the researcher can confirm the teachers activity by compiling a report of the schools in the study. The teachers in the study are fully aware that I

can confirm their answers. The criteria of conformibility also contributes to the level of trustworthiness and authenticity of the study.

#### **4.14. Summary**

This chapter documented the research design, which included ethical considerations, validity, reliability and the research approach. Following a mixed methods approach, the researcher made use of a survey to find the most popular mathematics Apps that teachers were using. The survey also reported on the reasons why these teachers were using each App, as well as the methodology and the pedagogy that they were following. Furthermore, learners engaged in a pre-test and post-test, and the researcher triangulated the findings with observation. These research instruments were also discussed in this chapter. The following chapter will present and analyse the research data. The data is sequenced according to the research questions.

# Chapter 5

## Data Presentation, Analysis and Findings

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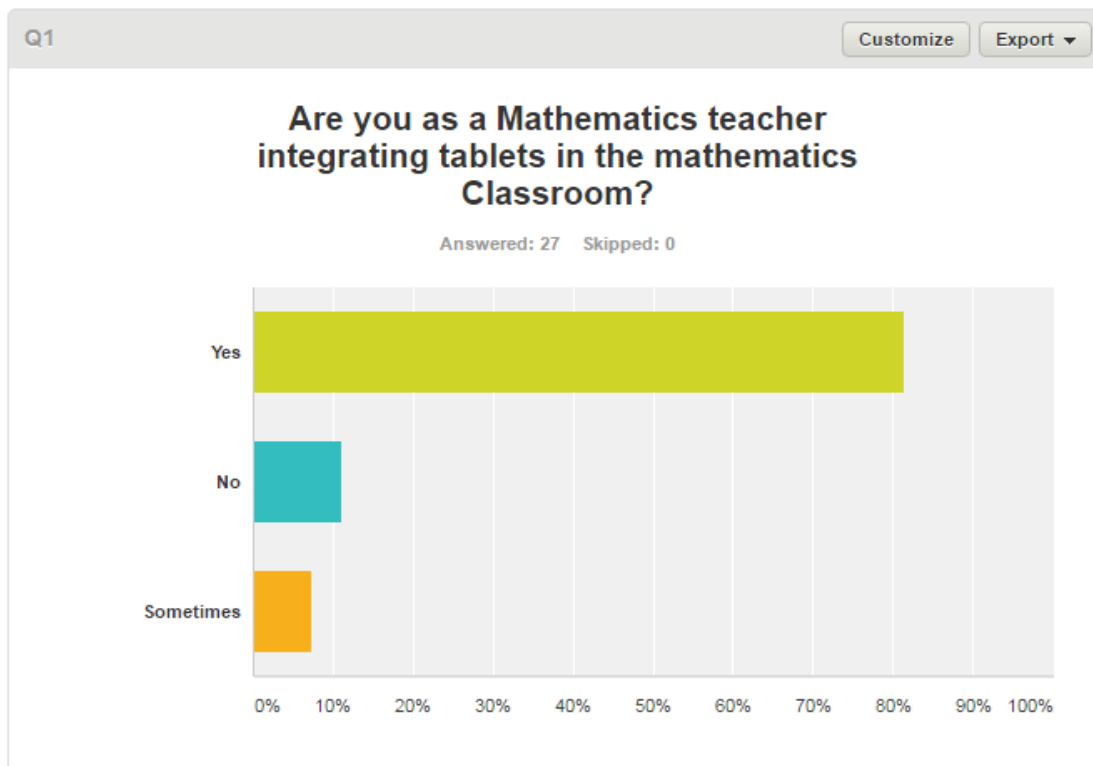
### 5.1. Introduction

This research questioned what, why, and how Apps and computer tablets are used in the mathematics classroom, and how effective they are. The first part of the question was carried out by sending a survey to schools to find out what Apps they were using. The survey also questioned why, and how they were using the specific Apps that they selected to use in the mathematics classroom. For the last part of the investigation, the researcher compiled a pre-test and post-test to determine whether learning had taken place. The researcher also visited these classes to observe and capture video footage. The findings will be presented and analysed in this chapter.

### 5.2. The computer tablet applications (Apps) that mathematics teachers use in the mathematics classrooms in South Africa

The researcher sent a survey to schools to find out whether the mathematics teachers were using computer tablets in their teaching. The response is shown in Figure 5.1 below:

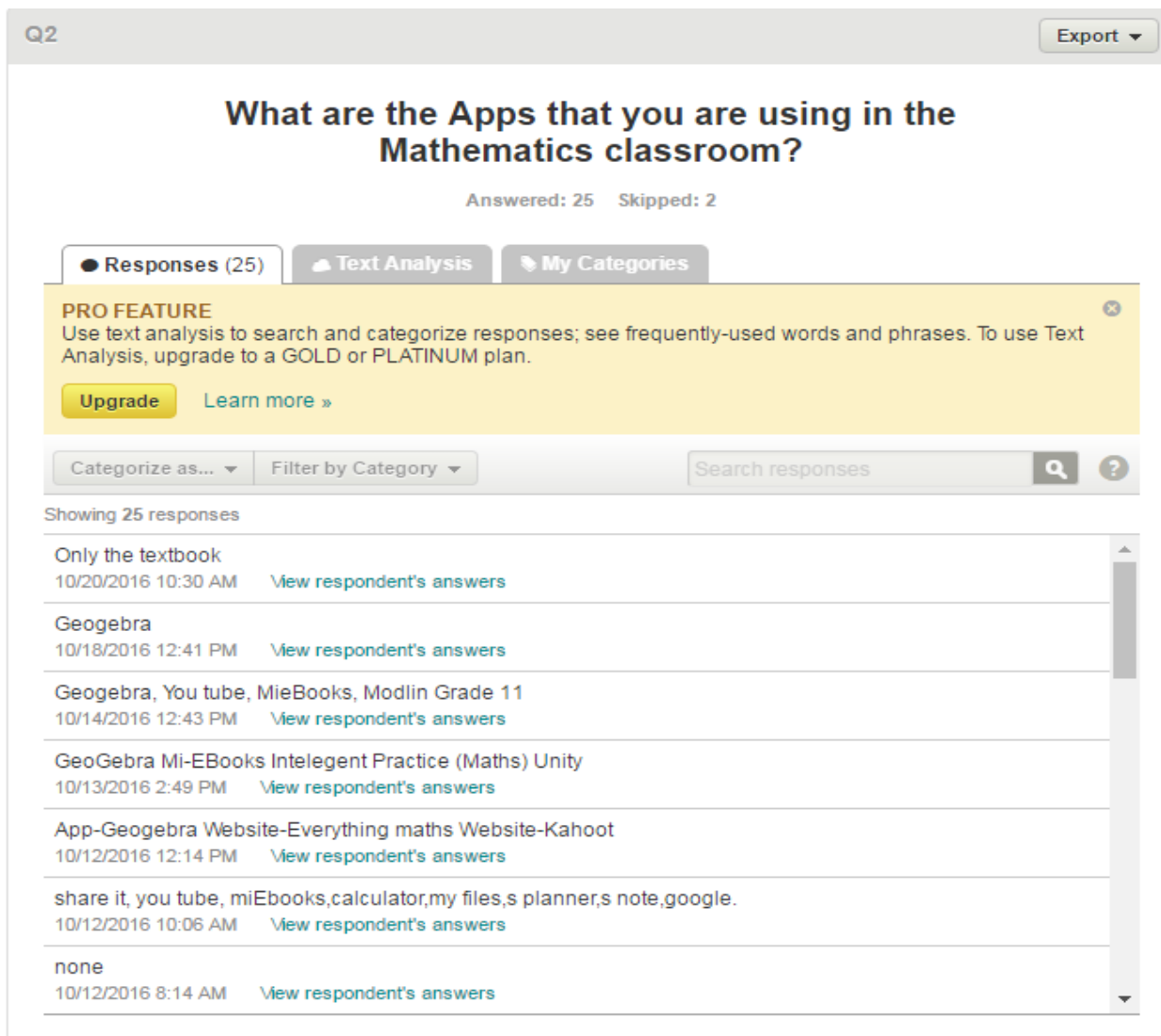




**Figure 5.1 Teachers using computer tablets in the mathematics class**

Of the questionnaires that were distributed, 27 teachers responded. Twenty-five teachers replied that they were integrating computer tablets in the mathematics classrooms. Only two of the 27 responses were not making use of computer tablets. The researcher therefore had a choice of 25 schools to conduct the research in. Of these teachers, 22 were using their computer tablets frequently, and three teachers were only using it occasionally. This equated to 81.48% of teachers integrating computer tablets in the teaching of mathematics. The researcher selected a school in Durbanville as the location for the research. The school is close to the workplace of the researcher which made it convenient to visit.

Another question in the survey addressed the question of what the Apps were that teachers were using in the mathematics classroom. The researcher made use of a software programme called Survey Monkey, which allowed teachers to enter data and submit the form online. This data was collated and presented as a graph. Figure 5.2 below is a screenshot of one page of responses.



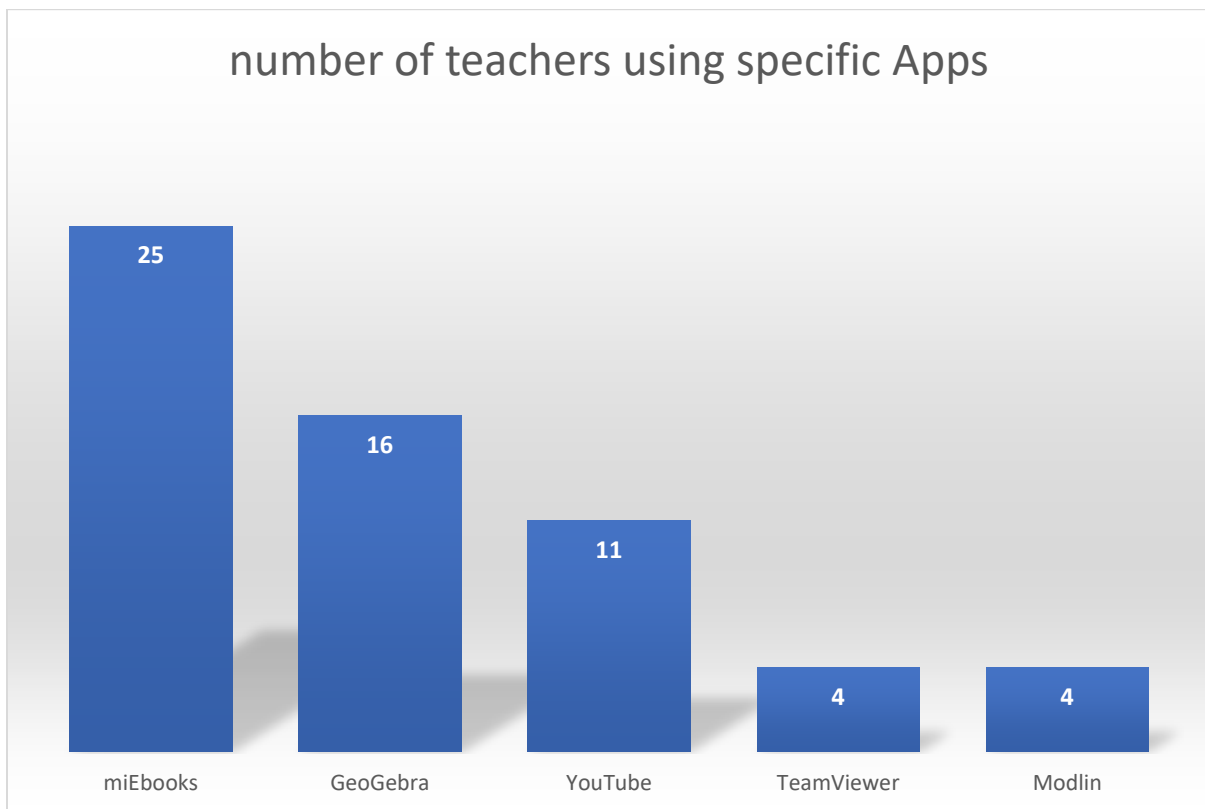
**Figure 3** A screenshot of some of the Apps that teachers are using in the mathematics classroom

The researcher collated the Apps that were being used in the grade 9 classroom at the 25 schools and selected the five most popular ones to use in the research. Table 5.1 below shows the responses from the mathematics teachers at the 25 different schools.

**Table 5.1 Mathematics Apps that were used in the classroom**

	<b>Apps that Mathematics teachers are using in class</b>									
	Geo= Gebra	miEbooks	Modlin	Intelligent practice	Everything Maths	Kahoot	Share it	Excel	You= Tube	Team Viewer
School 1	1	1							1	
School 2	1	1	1						1	1
School 3	1	1		1						
School 4	1	1			1					
School 5		1					1		1	
School 6		1	1						1	
School 7	1	1						1		
School 8		1							1	
School 9	1	1								
School 10	1	1						1		
School 11	1	1								
School 12	1	1							1	1
School 13	1	1				1				
School 14	1	1							1	
School 15	1	1								
School 16		1	1							
School 17	1	1								
School 18		1			1				1	
School 19		1				1				
School 20	1	1							1	
School 21	1	1								1
School 22		1							1	
School 23	1	1								
School 24		1								
School 25		1	1						1	1
<b>Total</b>	<b>16</b>	<b>25</b>	<b>4</b>	<b>1</b>	<b>2</b>	<b>2</b>	<b>1</b>	<b>2</b>	<b>11</b>	<b>4</b>

The most popular App that was used in the mathematics classroom was miEbooks, and all 25 schools were using it. Sixteen schools were using GeoGebra, eleven schools made use of YouTube videos, and four schools used Modlin and Team Viewer respectively.



**Figure 4 The Apps that teachers used most in descending order**

The top five Apps were arranged in descending order of popularity. None of these five Apps were on the global list of the top ten mathematics Apps according to the Educational Appstore (2018). From the literature, the best ten mathematics Apps, according to the Educational Appstore (2018), are listed and discussed below in rank order as a reminder to the reader:

1. Komodo Maths
2. Rocket Maths
3. DoodleMaths
4. IXL Maths
5. Math Facts Mahjong game
6. Fun Expected Maths
7. Splash Maths
8. TimeLand
9. Elephant Learning
10. Division with IbbleObble

All the global top ten Apps except for IXL, focused on primary school learners. The Komodo Math App, for instance, aims to build a foundation for learners from 5 to 11 years old (Educational App Store, 2018). The target audience for this study was grade 9 learners with an average age of 15 to 16 years. These learners were using Windows 2-in-1 devices with a Windows operating system and the Komodo App was only available on iOS and Android. Rocket Math focuses on math facts and is aimed at primary school learners. It is also only available on iOS and Android and not the Microsoft Store of Windows. The target audience for DoodleMaths is 4 to 14 years old, and it is not found in the Microsoft store. IXL Math provides a comprehensive, CAPS curriculum-aligned mathematics platform from grade 1 to grade 12. It would have been the ideal App to use in the classroom, but it is not available in the Microsoft Store, only on iOS and Android. The Math Facts Mahjong Game is also focused on younger learners and is not available in the Microsoft Store. Fun Expected Math is only available on iOS and Splash Math is suitable for learners up to grade 5. Splash Math is only available on iOS and Android. Timeland only focuses on a clock and a calendar and has very limited content, and is, once again, only on iOS and Android platforms. Elephant Learning is aimed at kindergarden learners with its colours and sound, and is not on the Microsoft Store platform. Division with Ibbleobble is only available on iOS. It is evidently clear that by choosing the Windows 2-in-1 device as a learning tool, the schools excluded themselves from a vast number of Apps, which were only available on iOS and Android.

The Apps that the South African Department of Basic Education (DBE) recommended for the government schools in 2017, were:

- Complete Mathematics
- Financial Calculator
- GeoGebra
- iTooch
- Mathway
- Math Exponents
- Mathematics Formula list
- MultiplicationX25Square
- Trigonometry Mathematics
- Viewer for Khan Academy

When the researcher investigated these Apps, it was observed that some of them were not available on any platform and yet were on the DBE's recommended list, thus suggesting that this list was outdated. Whoever drew up the list did not have an adequate knowledge of the functionality of the Apps. Most of them were international Apps and the language was not suitable for South African learners struggling with English as a second or third language, for example "Colours" is spelled as "Colors" and there are many other words that follow this trend. Then there is the "Z" instead of the "S" in words like "utilization" instead of "utilisation", "organization" instead of "organisation", etc. These differences can cause confusion for learners who are struggling to master a second language.

The most significant flaws were found in Apps like Trigonometry Mathematics, where the nomenclature was not conventional. It used "x" instead of "Theta" and "y" instead of "Sigma", etc (Learner's series, 2018). It appears as if person compiling the list for the DBE might not have been an expert in mathematics. The free Mathway App only solved equations without explaining any steps and this was pedagogically of little value, unless used to check an answer.

Looking at the list that the Department of Basic Education (DBE, Department of Basic Education Appstore, 2017) prescribed for use in the mathematics classroom, only two Apps were found on the Microsoft Store platform. These were iTooch and Geogebra (Microsoft Store, 2019). The iTooch App was available at a cost of R85 per learner and the Geogebra App was free. This explains why these schools were using Geogebra as a mathematics App to assist learners to understand mathematics concepts. Another App mentioned in the survey by the teachers was the Kahn Academy. This was mentioned as part of the YouTube videos that the teachers referred to.

The five Apps that the teachers in the survey used most, had diverse functionality. Geogebra and Modlin are content-based. Team Viewer is an App that makes casting possible. MiEbooks is a content management App that has quite a lot of optimised features like adding enhancements and summarizing content, and Youtube is a streaming site. These Apps used together complemented the lessons well.

### 5.3. Why teachers are using these Apps

The second research question in this study investigated why teachers were using the Apps mentioned in the survey. Appendix J provides a summary of the responses of the teachers in table form. Figure 5.4 shows a screenshot of part of the responses to the survey that was done online. This is followed by a graph in Figure 5.5 summarising the responses of the teachers by ranking it from the most used answer to the least.

Q3 Export ▾

**Please elaborate on why you are using these specific Apps.**

Answered: 25 Skipped: 2

● Responses (25) ☁ Text Analysis 📁 My Categories

**PRO FEATURE** ✕

Use text analysis to search and categorize responses; see frequently-used words and phrases. To use Text Analysis, upgrade to a GOLD or PLATINUM plan.

Upgrade [Learn more »](#)

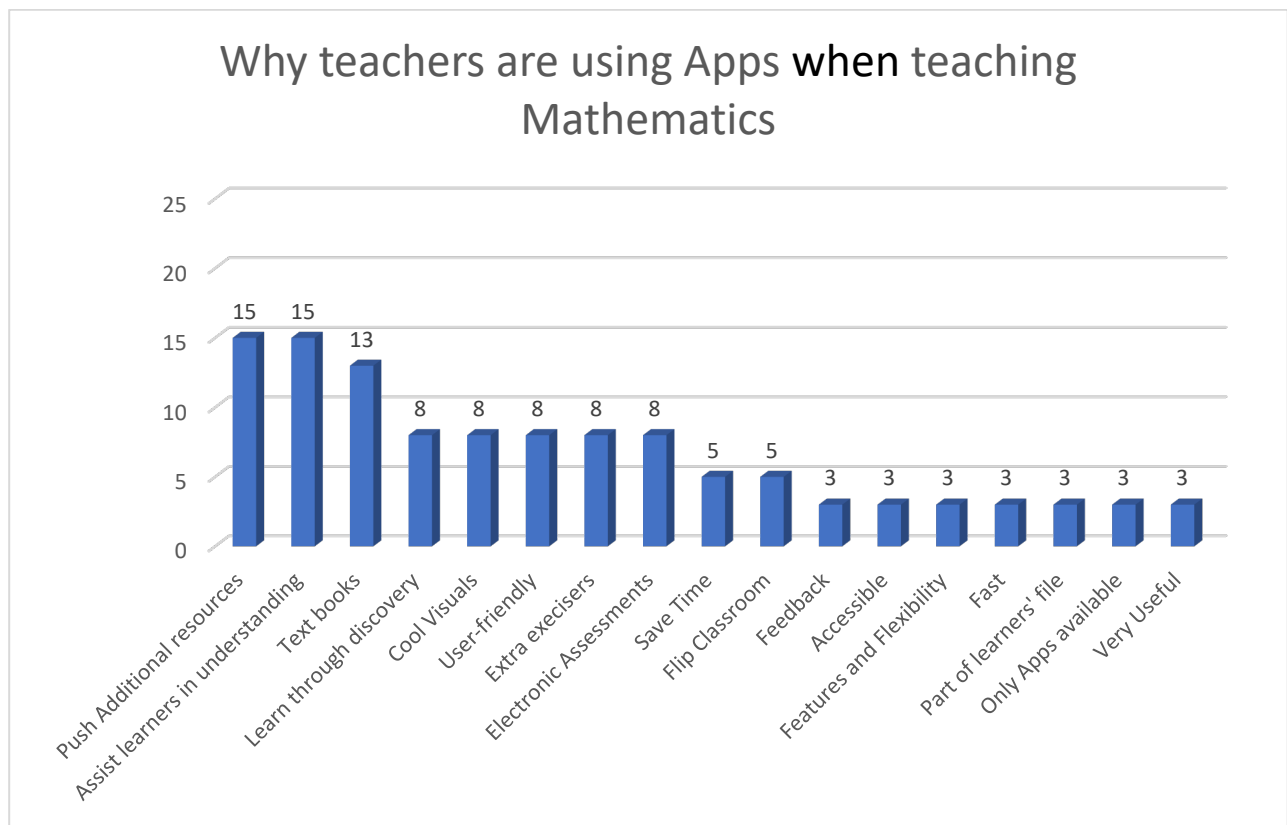
Categorize as... ▾ Filter by Category ▾ Search responses 🔍 ?

Showing 25 responses

N/A	10/20/2016 10:30 AM	<a href="#">View respondent's answers</a>
Very useful and fast, and has cool visuals	10/18/2016 12:41 PM	<a href="#">View respondent's answers</a>
User friendly, assist learners in understanding the work.	10/14/2016 12:43 PM	<a href="#">View respondent's answers</a>
CURRO workschedule Text books Additional resource Info pushed + text books + assessments + demarkations + memos + additional work and resources	10/13/2016 2:49 PM	<a href="#">View respondent's answers</a>
For learners to understand certain concepts better-through seeing everything. Interactive Fun & Interesting "Flip Classrooms"	10/12/2016 12:14 PM	<a href="#">View respondent's answers</a>
passing information homework,classwork to learners.	10/12/2016 10:06 AM	<a href="#">View respondent's answers</a>
N/A		

Figure 5 A screenshot of part of the survey on “why teachers are using these Apps”

This question received responses from 25 teachers and the Figure 5.5 shows the frequency of the results in decreasing order.



**Figure 6 Results on “Why teachers are using Apps in the mathematics classroom”**

In their responses, 60% of the teachers said that they valued the feature that additional resources could be added to the learners’ textbooks. Equally valued was the fact that some of the Apps helped the learners in understanding the mathematical concepts better. 52% of the teachers reported that they treasured the fact that text books could be included and 32% mentioned the cool visuals and the user-friendliness of these Apps. Equally valued was the fact that these Apps helped learners to learn through discovery. Eight teachers liked the electronic assessment features, which allowed for autonomous marking which saved time and gave instant feedback.

The researcher will now elaborate on the five Apps that were chosen for the research and why teachers valued it more than other Apps.



### 5.3.1. Why teachers are using the miEbooks App

As mentioned earlier all 25 schools used the miEbooks App. Figure 5.6 shows the different functions that is embedded in the miEbooks App. The red and yellow book in the picture represents the textbooks that can be loaded on the App. The paperclip in the graphic means that any attachment can be added. The yellow highlighter means that text can be highlighted and extracted as a summary. The page represents assessments and the symbol for the world map shows connectivity and Internet access.



**Figure 5.6** Graphic of the different features of MiEbooks (Liebenberg, 2016)

The miEbooks App is an e-book reader and was used in all 25 schools that responded, because it served as an alternative to the textbooks. This App allows learners to have all their textbooks on their computer tablet. Thirteen of the 25 responses in Figure 5.5 valued the fact that textbooks can be embedded in the MiEbooks App. The biggest advantage for the learners was that they did not have to carry their heavy textbooks with them anymore, they only needed to pack their computer tablet. The following responses are abstracts taken from the survey:

*Teacher 8:* All the learners' textbooks are on one tablet.

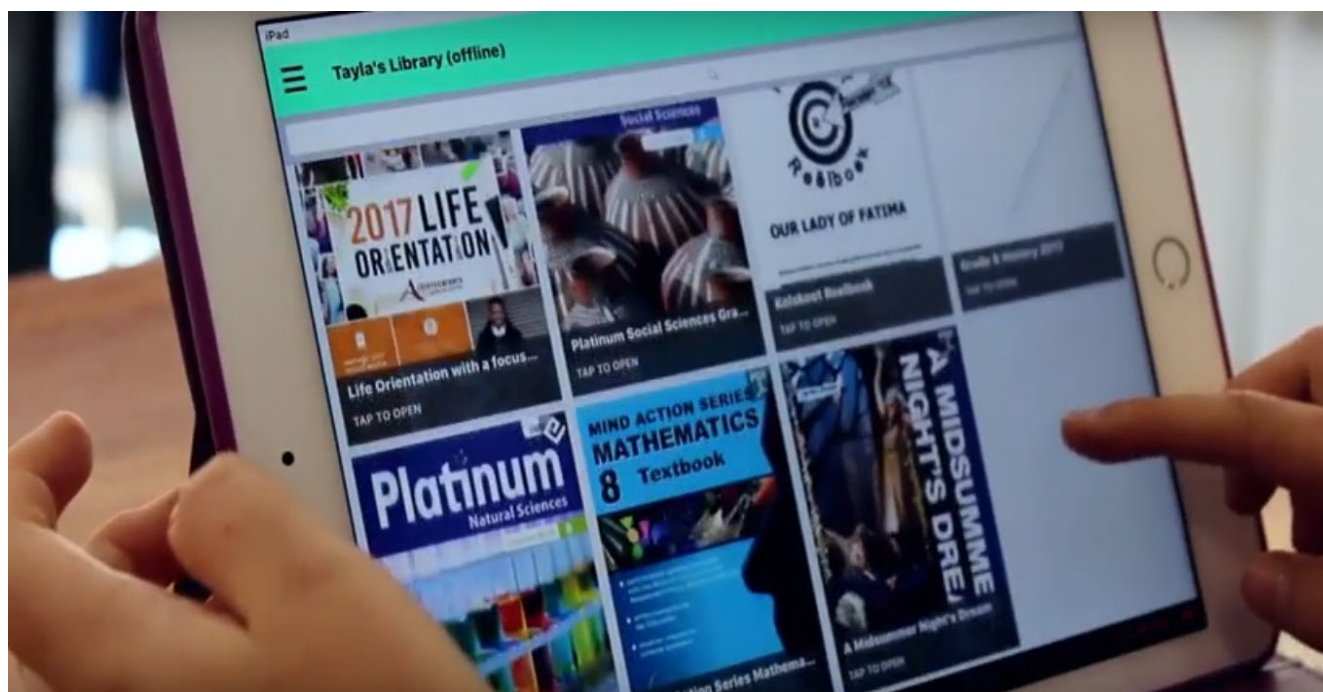
*Teacher 9:* Learners do not need to carry heavy textbooks.

*Teacher 19:* E-books are cheaper than hardcopy books.

Liebenberg (2017) calls it an optimised e-book as it does much more than just an e-book reader. Learners are given a unique login code that allows them to personalise their e-textbooks. They

can add notes to specific chapters of their e-textbook, they can highlight text, they can add freehand drawings, and generate summaries of the highlighted text to study (Liebenberg, 2017). These additions are called learning enhancements and can be placed in their e-book next to a relevant paragraph. The miEbooks App supports the following types of files: mp3 (Audio), mp4 (video), Google Drive link, Images, One Note links, PDF, Text, URLs, MS Excel, MS Word, MS Powerpoint, Assessments and Flashcard decks. All the learners' notes, drawings, and highlights can be stored on the computer tablet, with backup on the school's server. If anything happens to the computer tablet, the learners can simply download all their personalised content and highlights from the server onto another device. The summaries of their content can also be printed for those learners who like to study from hard copy. This was the only one of all the textbook Apps investigated that had this enhancement functionality.

Below is a picture in Figure 5.7 of a computer tablet with the miEbooks App running. What is visible is the set of textbooks available to the learner. The learner selects a book and browses through it to the desired page. When learners reach their selected topic, they also find all the learning enhancements that the teacher has added. The miEbooks App also allows learners to work offline.



**Figure 7** A picture of what the miEbooks App looks like (Liebenberg, 2016)

The fact that teachers could add these learning enhancements to the learners' books made it very convenient to gather all their resources in one place. They could add content to an individual computer tablet or to a whole grade at the press of a button. Learners gained access to their personal content, additional learning enhancements and their school curriculum resources in a single location. After accessing and completing the tests and quizzes that were pushed to their computer tablets, the results were automatically sent back to the teacher. The teachers could also add other textbooks in a portable document format (pdf) to their existing textbook. The App also allowed teachers to track their learners' progress. It reported on the time that learners spent on a specific topic and tracked their assessments. The Students tab gave a summary of engagement per learner, daily activity, hourly activity, annotations made, time spent in a book, and resources opened (Liebenberg, 2016). Fifteen of the 25 teachers that responded valued the feature that resources could be added to the textbook. Here are some extracts of those responses:

*Teacher 3:* Pushing resources. Electronic Assessments. Time saving. Extra exercisers.

*Teacher 15:* Flipped classroom. Videos can be sent to learners prior to the lesson for them to watch.

*Teacher 17:* Sharing enhanced resources in the textbook. No need to make copies for learners anymore.

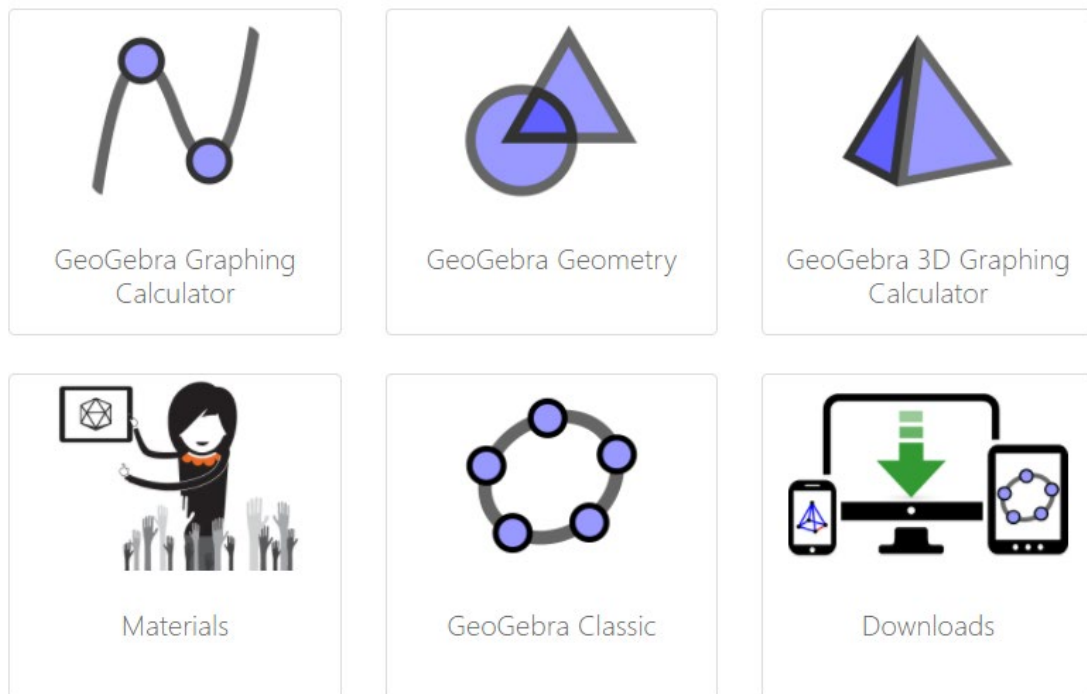
The miEbooks App has an integrated calendar that is used by teachers to post homework and share upcoming events with learners. Newsletters were shared with learners and parents, saving paper and print costs, and making "miEbooks a one-stop solution for all educational needs" (Bryant, 2018, p. 4). The researcher named this kind of App a content-management App.

### **5.3.2. Why teachers are using the GeoGebra App**

Figure 5.3 shows that the GeoGebra App was used by 16 of the 25 teachers that responded. The GeoGebra App is an instructional App and is "dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package" (Hohenwarter, 2017, p. 1).

## Discover Math with GeoGebra

Solve equations, graph functions, create constructions, analyze data, explore 3D math!



**Figure 5.8 Dashboard of the GeoGebra App (International GeoGebra Institute, 2014)**

The programme is not very user-friendly at first and it takes time to learn how to use it. Once mastered, the teachers found its pedagogical power. One way in which they used it in the classroom was as an exploration tool. GeoGebra allowed the learners to investigate different scenarios, for example, exploring a parabola. They could change the signs, the coefficients and the variables, and observed how the graph changed. GeoGebra allows for double representation of data, which means that one can have two screens representing the same function. The one screen can show the algebraic function while the next screen can show the geometric graph of the same function. Learners can change the variables on the algebraic screen and see the changes on the graph on the other screen. The learners learned while they explored. Tran, Nguyen, Bui, and Phan (2014) call this, discovery learning. They claim that discovery learning leads to better understanding. Budinski (2017) attributed the success of GeoGebra to a dynamic environment where learners could explore with different variables. It is suitable for learners at different levels as it is interactive, with features such as sliders and animation. One of the major advantages of this App is that it can run on almost any computer,

computer tablet and even cell phone. This feature makes it very accessible to learners. Some of the teachers' responses are:

*Teacher 7:* Geogebra on two screens helps learners with understanding.

*Teacher 18:* Discovery learning makes classes meaningful.

*Teacher 25:* GeoGebra runs quickly even on the Raspberry Pi computers.

### **5.3.3. Why teachers are using the YouTube App**

Youtube has an educational channel that covers almost every topic in the curriculum. These videos can be downloaded and used in the classroom. Visual learning is powerful. It engages more senses than just auditory learning (Mayer & Moreno, 2002). This fact makes videos more effective as a learning tool than only hearing or only seeing.

These videos can be transferred to the learners' devices a day before their lesson. This functionality allowed learners to watch the videos on 3D images at home, and then discussed them the next day in class. This teaching model is an example of the flipped classroom (Zengin, 2017). Learners watched the video and could then collaborate with one another and present their understanding to the whole class. This method allowed learners to learn at their own pace. Learners could repeat the video numerous times until they understood. Some of the teachers feedback is listed below:

*Teacher 8:* Flipped classroom helps with collaboration in class.

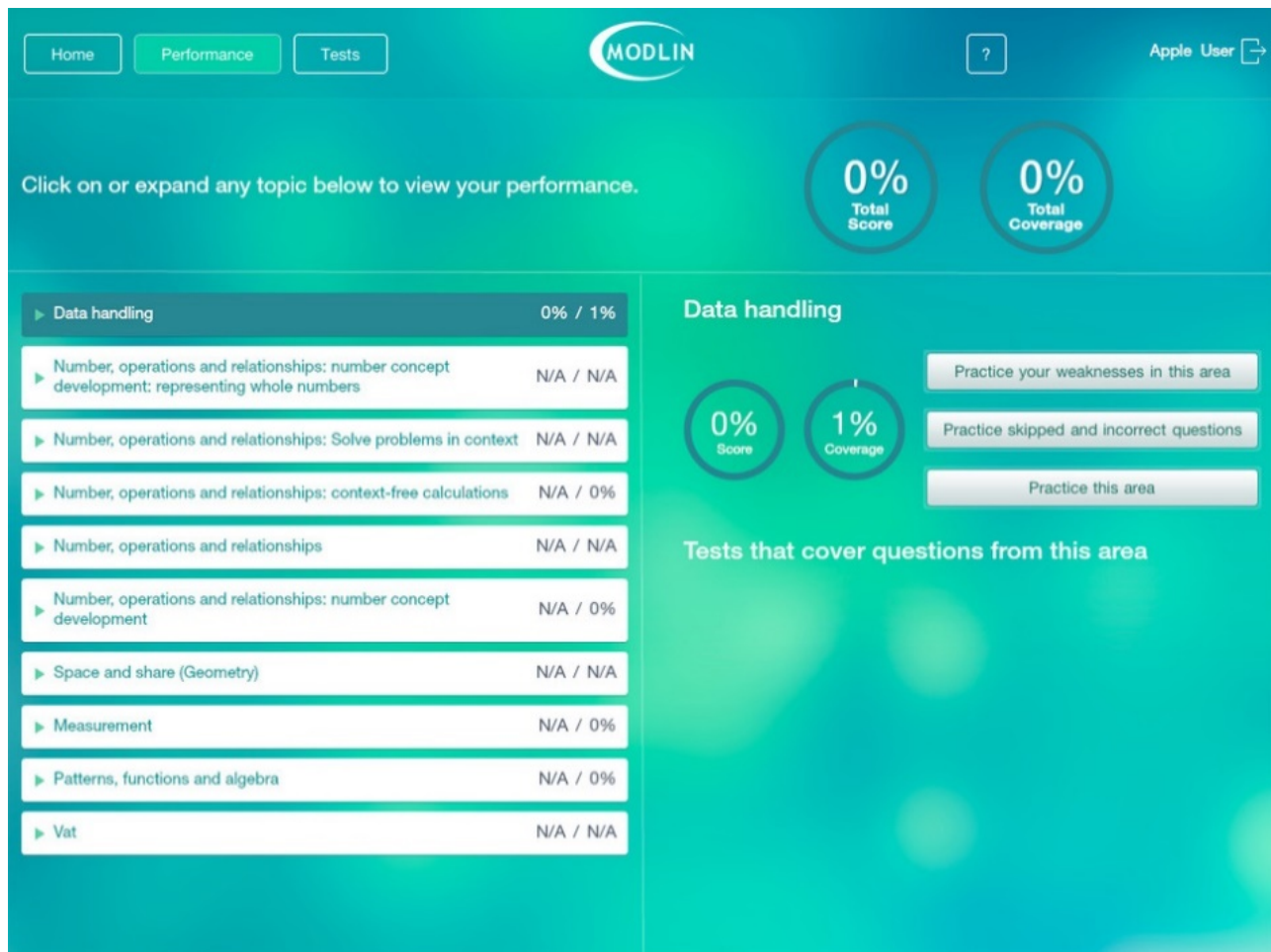
*Teacher 13:* Useful especially in watching educational videos. Learners can watch it repeatedly.

*Teacher 24:* YouTube teaches both learners and teachers.

### **5.3.4. Why teachers are using the Modlin App**

The Modlin app was used as a diagnostic app as it assessed a learner's progress and assigned more exercises depending on the learner's level. This App has a database that deals with

content, including an assessment section that tracks a learner's wrong answers and suggests more exercises on those topics. This function makes it an excellent remedial tool.



**Figure 5.9** Dashboard of the Modlin app (Modlin, 2017)

This App tracks learners' performances and their time-on-task and presents these as a Comma Separated Value (CSV) file that can be opened in Microsoft Excel for reporting purposes. The teacher can then see every learner's efforts and acts on it. The dashboard of the App in Figure 5.9, shows learners the whole curriculum and what percentage of the curriculum is covered during the learner's interaction. It also shows the learner's success rate and diagnoses the weak points of the learner. Some feedback from the teachers refer:

Teacher 10: Immediate feedback and tracking in Modlin helps the learners to assess themselves.

Teacher 22: Extra exercises with remedial function is great for hardworking students.

### 5.3.5. Why teachers are using the TeamViewer App

The TeamViewer App is a screencasting App as it allows teachers to mirror their computer tablet screen on their computers. This feature allowed the teacher to walk around with a computer tablet and still project the desktop on a whiteboard screen via the computer that was connected to a data projector.

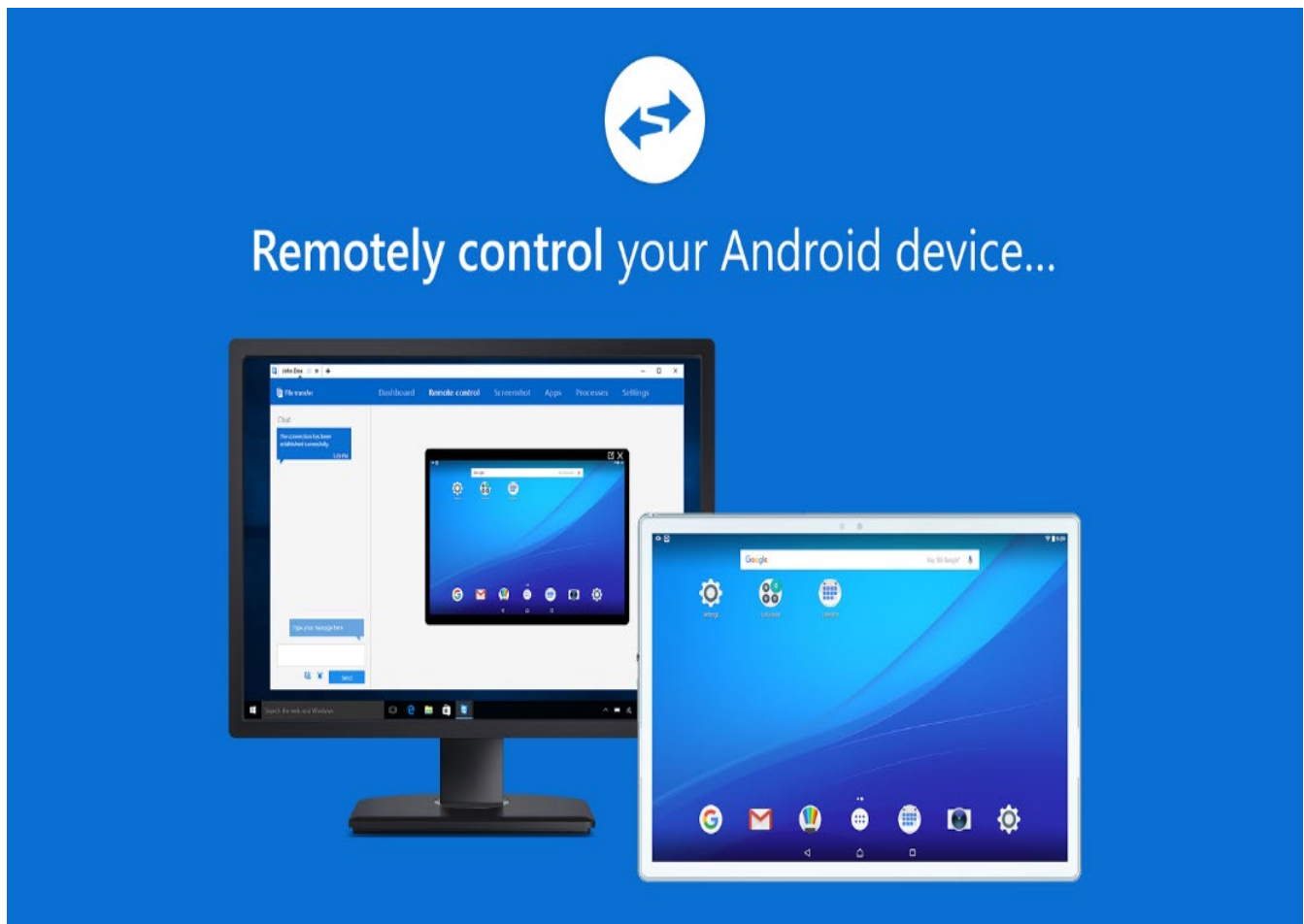


Figure 5.10 TeamViewer on an Android tablet (TeamViewer, 2017)

Some of the responses of the teachers are shown below:

*Teacher 11:* Learners can connect to one screen to make collaboration possible.

*Teacher 22:* Learners can even project on the screen from their computer tablets.

*Teacher 23:* TeamViewer makes it possible to project from my computer tablet.



## 5.4. How the teachers were using these Apps

Twenty-four teachers responded to this question. Appendix L is a summary of the responses on how teachers were using the computer tablets in the mathematics classroom. Figure 5.11 shows a screenshot of part of the survey on the question of how and when teachers were using the Apps.

Q4 Export ▾

**Please describe how and when are you using the Apps mentioned above.**

Answered: 24 Skipped: 3

● Responses (24)   Text Analysis   My Categories

**PRO FEATURE** ✕

Use text analysis to search and categorize responses; see frequently-used words and phrases. To use Text Analysis, upgrade to a GOLD or PLATINUM plan.

[Upgrade](#)   [Learn more »](#)

Categorize as... ▾   Filter by Category ▾   Search responses

Showing 24 responses

N/A	10/20/2016 10:30 AM	<a href="#">View respondent's answers</a>
For functions mainly	10/18/2016 12:41 PM	<a href="#">View respondent's answers</a>
Daily	10/14/2016 12:43 PM	<a href="#">View respondent's answers</a>
Some only during specific topic (Geogebra) Other (e-books and unity) every lesson	10/13/2016 2:49 PM	<a href="#">View respondent's answers</a>
Use app / website with textbook to explain concepts even better, and for learners to participate by doing things on their own (can test answers / graphs with geogebra)	10/12/2016 12:14 PM	<a href="#">View respondent's answers</a>
introduction, recapping, conclusion	10/12/2016 10:06 AM	<a href="#">View respondent's answers</a>

**Figure 5.11** A screenshot of part of the survey on “how teachers are using these Apps”

The researcher compiled the teachers' feedback, and it is presented below in no particular order.

- It supports independent learning
- Substituting the textbook is a huge advantage
- Learners' first do their own work and then verify their answers
- It helps learners with drawing graphs

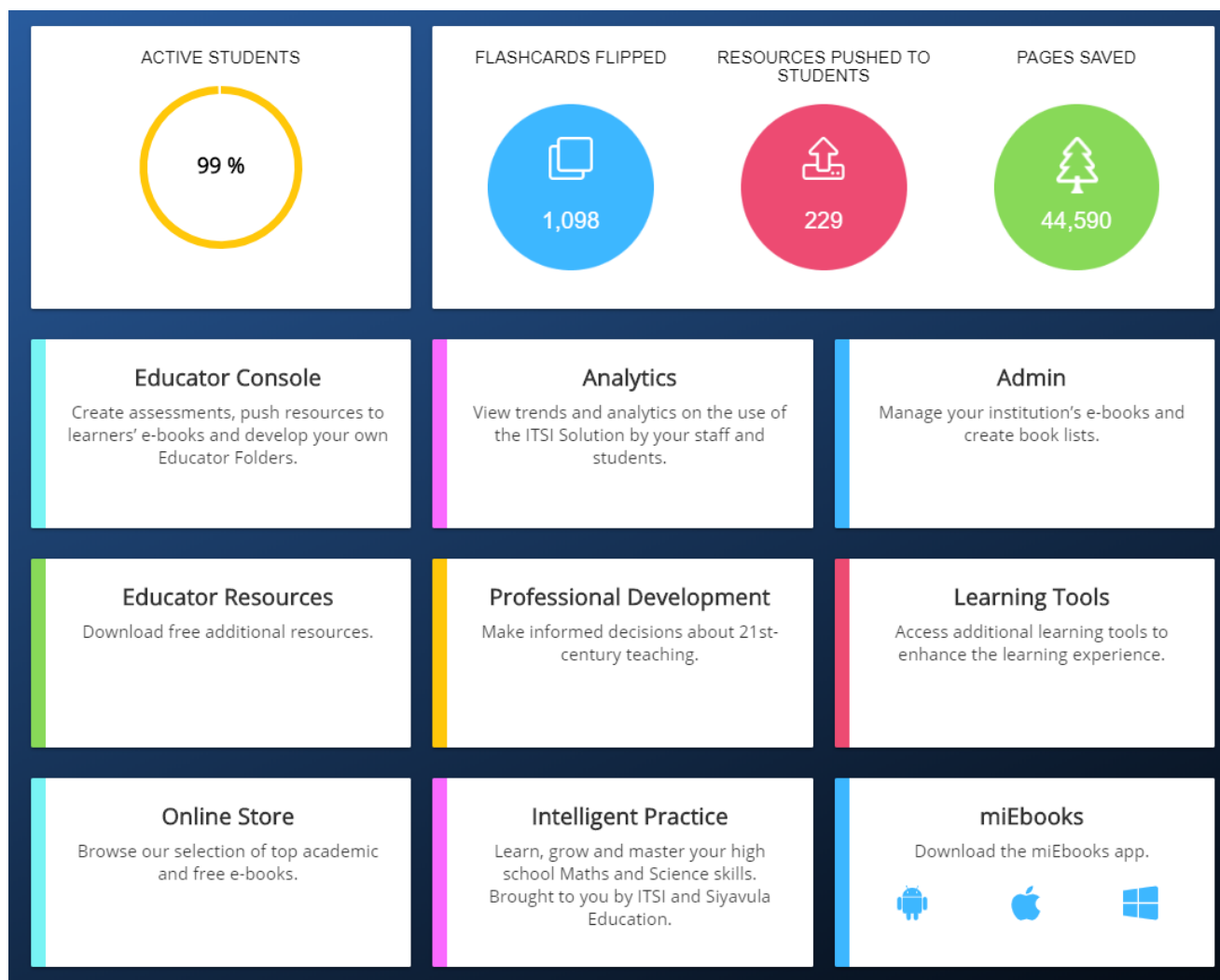


- Some teachers are only using computer tablets for specific topics, like
  - Geometry
  - Transformations
  - 3D Shapes
  - Measurement
- It better learners' understanding through visuals
- Some teachers use computer tablets when introducing new concepts
- To recap work
- To draw conclusions
- Learn by discovery through Apps
- For collaboration
- To watch simulations
- To do investigations
- To assess and revise topics and concepts
- To connect learners with each other.
- To cast the teacher's screen or the learners' screen onto the whiteboard.
- To use it as a video conferencing tool.
- To use as part of flipped classroom.

Where the feedback was unclear, the researcher confirmed with the particular teacher to ensure that data is precise. The researcher analysed the feedback and will discuss in depth how these five Apps were used in the mathematics classroom. The “how” refers, firstly to the methodology, and secondly to the pedagogy of integrating these Apps and not all the teachers were clear on the difference between the questions “why” and “how”. The next subsections will explain how the teachers used the 5 selected Apps to their advantage.

#### **5.4.1. How the teachers were using the miEbooks App**

IT School Innovation (ITSI) is the company that created and is hosting the miEbooks App. ITSI has a portal where teachers log on with a dashboard to make navigation easy. A screenshot of the portal can be seen in Figure 5.12.



**Figure 5.12 A screenshot of the ITSI dashboard (Liebenberg, 2017)**

On this dashboard, the teacher could see how many learners were on the Wi-Fi and engaging with the miEbooks App. These learners are displayed as “active students”. The dashboard allowed teachers to look for resources that were freely available in the Teacher Resource tab. The Professional Development tab gave teachers the opportunity to better their knowledge and skills regarding the 21st Century teaching. The Intelligent Practice tab was a tutorial programme where learners could engage with mathematics and science exercises. Although there were many features that teachers could use, the one tab that was most used, was the Teacher Console tab. This tab enabled teachers to project learning enhancement material to the learners’ textbooks. These pdf’s, video, images, documents, etc, appeared next to the topic in

the learners' miEbooks App for them to open and engage with. Some of the teachers' responses are:

*Teacher 12:* The MiEbooks App allows me to post work well before the time and the App releases it a day before the actual class.

*Teacher 14:* I use the Teacher Console tab as the back-end of MiEbooks to load videos onto the learners' tablets for them to watch at home the day before.

Another feature that was used often was that of Teacher Folders. Teachers created folders where administrative information was saved and where learners had access. In these folders, learners could find their marks, memos and any information that was not needed in the textbook. The Teacher Console also gave teachers the ability to share their worksheets and lesson plans with other teachers on the same domain. Some feedback of the teachers is recorded below:

*Teacher 13:* The assessment in MiEbooks displays differently on the learners' tablets as it is randomised. Learners sitting next to each other will have different questions in different order.

*Teacher 16:* Learners do assessments in the MiEbooks App. The tablet marks their results and post it in a log file where the learners have access to the marks.

Lastly, a feature that was used by a few teachers was calendar sharing. Some teachers planned their year and terms including dates for tests and exams and shared this information with their learners through the miEbooks App.

As for the pedagogical implementation of the miEbooks App, it was found that most teachers used the App for its textbook feature. The simplest form of using the miEbooks App would be for substitution (Puentedura, 2016). This was when a teacher merely substituted the textbook with a computer tablet. The learners read from the computer tablet as if it was a book. An added advantage was that e-books are much cheaper than the hard copy book. Some teachers in the study used it for augmentation. This means that although it was a textbook, the teacher added some functionality to it (Puentedura, 2016). They used a programme on their laptops to send videos on a topic to their learners a day prior to the lesson. The learners could watch the video at home and come to class with some background knowledge on the topic. They could also

collaborate with their peers to reach a greater understanding. This is what the Rochester Institute calls the flipped classroom (RIT, 2013). The teachers are now no longer the centre of the classroom but orchestrate their lessons by facilitation. The learners become the centre of learning and the teacher helps when needed. The picture below shows the different types of files that a teacher can project onto the learners' computer tablets through the miEbooks App.



**Figure 5.13** A diagram showing that teachers can transfer pdf's, videos, audio, pictures or web sites to the tablet (Liebenberg, 2016)

Some teachers even moved on to the modification stage of the SAMR (Puentedura, 2016). This step entailed redesigning their teaching. They set their assessments electronically and using miEbooks, they distributed the assessment to the class. The learners received this test in

different formats and the miEbooks App changed the numbering so that no two learners sitting next to each other had the same questions at the same number. The different formats included true-false questions, matching words, multiple choice and even open-ended questions. As the learners submitted their answers, the miEbooks App calculated the success rate and displayed it on the teacher's laptop. The miEbooks App also generated a report for each learner and exported it as a CSV file to open in Excel.

#### **5.4.2. How the teachers were using the GeoGebra App**

Most teachers indicated that GeoGebra assisted in the learners' understanding of a topic. The fact that you could draw a 3D image and rotate it so that learners could see the back of the image made it easier to understand. If the same image was on a piece of paper or in a book, the learner needed to think abstractly to be able to visualise the unseen.

Another teacher used GeoGebra for learners to verify their answers. They first needed to draw their graphs manually and afterwards punch in the formula in GeoGebra to see if their representation was correct. For this, the learners could open both the algebra and the geography screen side-by-side to see the effect immediately. This feature is what Nguyen (2014) calls double representation. It is a powerful learning tool as learners can explore changing the function in the one window and see the effect in the other window.

Teachers valued the fact that GeoGebra allowed learners to work independently. Learners could explore and observe the changes. They could draw conclusions from their experiments. This was an ideal tool for a constructivist lesson. Some of the teachers' responses are listed below:

*Teacher 6:* Learners would first do the functions manually in the workbooks and then go to GeoGebra and verify their results.

*Teacher 11:* To teach inductively and draw conclusions. Learners played around with variables and saw the changes in the graph on the second window. Learners could now detect patterns and conclude with a rule.

Important feedback from the survey showed that even though GeoGebra was an excellent pedagogical tool, teachers must be selective when to use it. GeoGebra is ideal for visualisation

and making a link between algebra and geometry, but there are topics which it is not suitable for. Teachers need to be selective about what topics to apply it to.

#### **5.4.3. How the teachers were using the YouTube App**

The YouTube App gave teachers access to numerous educational videos. Teachers downloaded these videos onto their laptops and then used the miEbooks App to transfer them to the learners' computer tablets. The learners downloaded them at school, and then watched at home without Internet access. They watched these videos in their own time and if they did not understand the topic the first time, they could replay it as many times as it took for them to grasp the concept. Watching videos involved visual and auditory sensors which made it easier for learners to understand. The first step in Gagne's conditions for learning is to capture the learner's attention, and letting learners watch a video is one strategy (Gagné, Briggs, & Wagner, 1992). This strategy also leads to flipped classroom learning (RIT, 2013). The learners come to class with pre-knowledge on a topic, which allows them to engage in collaboration with their peers. This methodology gives learners the opportunity to practice their 21st Century learning skills of communication and collaboration (ATC21S, 2011). Some of the teachers' responses are listed below:

*Teacher 19:* Learners would watch the coursework at home and collaborate the next morning in groups. This flipped classroom technique is quite powerful.

*Teacher 24:* Videos are power learning tools and learners can watch it over and over until they grasp the concept.

One study showed that some teachers using YouTube ventured to the redefinition stage of SAMR (Puentedura, 2016). These teachers allowed for the creation of new tasks previously inconceivable (Puentedura, 2016). Learners from some of these schools collaborated with a school in South Korea, building a 3D printer, a racing drone, programming in Arduino and learning how to write in Hangul via video conferencing and YouTube videos. The South Korean learners made video recordings for the South African learners and published them on YouTube for them to download. These learners arranged to communicate for one hour a day at a time convenient to them considering the time zones. The rest of the day the South African learners watched the videos and built accordingly. The one-hour video conferencing sessions were used

as question and answer sessions and to explain certain aspects that were not clear in the videos. The picture in Figure 5.14 below shows one of these contact sessions. The South African learner is standing in front of a camera so the Koreans can see him on their screens, They have a camera so that the South African learners can see them and the YouTube video is embedded in the video conferencing screen in case the learner wants to refer to it.



**Figure 5.14** A learner communicating with his peers in South Korea via video conferencing

It took the South African learners six days to complete the 3D printer, the drone, and the Arduino programming. This was done mainly with the guidance of YouTube videos. This constitutes the redefinition stage of the SAMR.

#### **5.4.4. How the teachers were using the Modlin App**

Most teachers indicated that they used Modlin as an extra-curricular App. Eight schools bought licenses for all their learners, but only four teachers according to the survey were using it at the time of this study. The Modlin App can be used as a remedial strategy. It covers all the content of the CAPS curriculum and boasts the most comprehensive number of assessment tasks. Learners do these assessments after school and the App calculates the level of difficulty that the learner should attempt next. If the learners were unsuccessful in a task, they are reassigned

to that same level and the App generates new but similar problems to work on. The App can be used for diagnostic tests as it gives a report on the learner's level of mathematics understanding. What made teachers excited was the fact that it tracked the learners' participation and reported back in a log file. The teacher could tell exactly when a learner engaged with the App, the duration, and the success rate. This App is excellent for self-study. Most teachers indicated that they used this App for learners to self-assess and to revise topics and concepts. Some of the teachers responded as follows:

*Teacher 10:* Learners can engage with the Modlin App at home as it is adjusting the exercises to the learners' level of understanding. If a learner is not successful, the App will give more of the same exercises until it is mastered.

*Teacher 21:* As a homework tool and for remedial purposes through Modlin.

#### **5.4.5. How the teachers were using the TeamViewer App**

TeamViewer is a screen casting App that allows one to share a computer tablet screen with a computer screen. Learners can share each other's screens and even cast their screen onto the teacher's laptop. The great advantage is that at this stage technology does not allow for projection from a computer tablet unless it is projected to a Wi-Fi enabled projector. The schools in the study all had projectors with Video Graphics Array (VGA) inputs. A laptop has a VGA output and therefore it can be casted from the computer tablet to the laptop and then projected onto a whiteboard or screen. Some teachers responded:

*Teacher 15:* After projecting images on the whiteboard, the teacher can manipulate the image by turning the image and inspect the back of it. Learners can now easily count the faces, the edges and vertices of a 3D image.

*Teacher 23:* To share screens of learners and project them on the whiteboard. Learners do not have to walk to the whiteboard to share their work with the rest of the class, they can simply connect remotely to the teacher's laptop and everyone can watch their work on the big screen.

TeamViewer allows a teacher to project any learner's computer tablet screen to the teacher's laptop, which is connected to the projector. Learners can then project their own work on the



whiteboard without going to the front of the class. They can explain to their peers their understanding of the work and show their contributions on the whiteboard. The picture in Figure 5.15 shows a learner working out the volume of a sphere and sharing it with the class. In this instance it was done on the teacher's computer tablet and this was connected to a laptop to save connection time. The teacher walked around in the classroom and whenever she wanted the learners to contribute, she gave them her computer tablet to do the work on. Everyone could then watch her work on the big screen in the front of the classroom. Figure 5.15 shows a learner explaining to the rest of the class using the teacher's computer tablet to notate on. Her screen is mirrored onto the teacher's laptop, which is connected to the data projector.

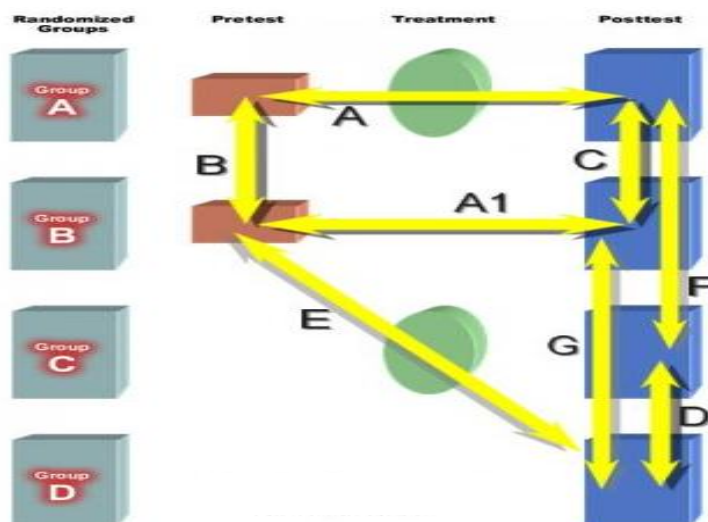


**Figure 5.15** Actual footage of a learner projecting her work onto the whiteboard by casting it to the teacher's laptop

## 5.5. The use of computer tablets in the mathematics classroom compared to the traditional mathematics classrooms

On the question of how effective the use of computer tablets was, the researcher made use of the Solomon four-group design for a pre-test and a post-test. The researcher used two grade 9 mathematics classes that were taught by the same teacher in one school. Both classes were taught about 3D images. The one class, the experimental group, used computer tablets extensively in its learning of the topic, and the other class, the control group, was using the traditional textbook and chalkboard way.

Figure 5.16 is revisited in order to explain how the 4 groups were formed.



**Figure 5.16** A representation of the Solomon four-group model (Shuttleworth, 2009)

Two grade 9 classes of 20 learners were selected to take part in the study. The grade 9B class was the experimental group, and the grade 9C class was the control. Both classes were divided in half to form four groups. The grade 9B class used computer tablets for the learning of the content and formed Group A and Group C. Half of the class wrote the pre-test and the post-test, and the other half only wrote the post-test. The pre-test is shown as a red brick in Figure 5.16. The green ball symbolises the computer tablet intervention and the blue cube represents the post-test. The grade 9C class, which acted as the control group, was also divided into two halves and formed group B and group D in Figure 5.16. Neither of the two groups received the computer tablet intervention, but half of the class wrote the pre-test. Both groups B and D wrote

the post-test. The reason for this is that if group B did significantly better than group D, then it is evident that the pre-test had an influence on the result. If there is no significant difference in the results of these two groups, then the pre-test did not influence the data and the internal validity is intact. The table below explains the intervention well.

**Table 5.2 A diagram of the four groups in the research design**

Grade 9B	Group A	Pre-test	Tablet Intervention	Post-test
Experimental group	Group C	No Pre-test	Tablet Intervention	Post-test
Grade 9C	Group B	Pre-test	No Tablet Intervention	Post-test
Control Group	Group D	No Pre-test	No Tablet Intervention	Post-test

The results from the two grades are given below with an interpretation thereof. The discussions will be dealt with in their respective groups.

Grade 9B was the experimental group that received computer tablet intervention where half the class wrote a pre-test, and everyone wrote the post-test. The results for Grade 9B are shown below in Table 5.3.

**Table 5.3 Results of the pre-tests and post-tests of the experimental group**

<b>Grade 9B - Experimental group</b>							
<b>Group A</b>				<b>Group C</b>			
<b>Learners</b>	<b>Pre-test</b>		<b>Post-test</b>	<b>Learners</b>	<b>Pre-test</b>		<b>Post-test</b>
Learner 1	42	Tablet Intervention	46	Learner 11	No Pre-test	Tablet Intervention	32
Learner 2	38		50	Learner 12			50
Learner 3	48		50	Learner 13			42
Learner 4	36		46	Learner 14			36
Learner 5	38		40	Learner 15			42
Learner 6	38		56	Learner 16			36
Learner 7	50		54	Learner 17			36
Learner 8	36		40	Learner 18			42
Learner 9	50		58	Learner 19			42
Learner 10	52		58	Learner 20			40
<b>Total Learners</b>	<b>10</b>		<b>10</b>	<b>Total Learners</b>			<b>10</b>
<b>Average Mark</b>	<b>42.8</b>		<b>49.8</b>	<b>Average Mark</b>			<b>39.8</b>
<b>Percentage</b>	<b>71.33</b>		<b>83.00</b>	<b>Percentage</b>			<b>66.33</b>

The same total of learners, namely 10, wrote the pre-test and the post-test. The average mark of the group that wrote both the pre-test and the post-test improved from 42.8 to 49.8. That is an improvement of 12.67%. The group that only wrote the pre-test scored 39.8 on average.

The grade 9C groups were taught the same topic without using computer tablets. This class was also divided in two where half wrote the pre-test and the post-test, and the other half only wrote the post-test. Both halves received computer tablet integrated mathematics lessons. The results are displayed in Table 5.4.

**Table 5.4 Results of the pre-tests and post-tests of the control group**

<b>Grade 9C - Control Group</b>							
<b>Group B</b>				<b>Group D</b>			
<b>Learners</b>	<b>Pre-test</b>		<b>Post-test</b>	<b>Learners</b>	<b>Pre-test</b>		<b>Post-test</b>
Learner 1	46	Traditional Teaching	48	Learner 11	No Pre-test	Traditional Teaching	38
Learner 2	44		46	Learner 12			12
Learner 3	42		36	Learner 13			46
Learner 4	30		36	Learner 14			40
Learner 5	40		40	Learner 15			46
Learner 6	42		36	Learner 16			50
Learner 7	58		40	Learner 17			38
Learner 8	40		28	Learner 18			44
Learner 9	38		38	Learner 19			34
Learner 10	44		40	Learner 20			44
<b>Total Learners</b>	<b>10</b>		<b>10</b>	<b>Total Learners</b>			<b>10</b>
<b>Average Mark</b>	<b>42.4</b>		<b>38.8</b>	<b>Average Mark</b>			<b>39.2</b>
<b>Percentage</b>	<b>70.67</b>		<b>64.67</b>	<b>Percentage</b>			<b>65.33</b>

The results were analysed using William Gosset's t-statistic on the Solomon four-group design. Table 5.5 shows a t-test of group A which entailed the pre-test and the post-test results of the experimental group.

**Table 5.5 Comparing the pre- and the post-test of Group A, the experiment group.**

<b>Group A</b>	<b>Pre-test</b>	<b>Post-test</b>
Mean	42.8	49.8
Variance	41.95555556	45.73333333
Observations	10	10
Pearson Correlation	0.704150977	
Standard deviation	6.144916598	6.415605973
Hypothesized Mean Difference	0	
df	9	
t Stat	4.341215711	
P(T<=t) one-tail	0.000937067	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.001874134	
t Critical two-tail	2.262157163	

The average mark of the experimental group of ten learners improved from 42.8 to 49.8 out of a possible 60 marks. This is an improvement of 7 marks on average. It shows a Pearson Correlation of more than 0.7 which represents a strong positive correlation. This means that for a high pre-test score, the post-test score was also high, even higher. It shows a t-statistic of about 4.3 which corresponds to a p-value of 0.0018. This p-value is less than 0.05 which makes this progress significant. The null hypothesis for this intervention was that there was no significant difference in results between the pre-test and the post-test. This p-value of 0.0018 which is far smaller than 0.05, shows strong evidence against such a hypothesis (Runkel, 2016). The alternative hypothesis is then true which states that there was a great significance in the progression from the pre-to the post-test. The two-tailed null hypothesis is: There is no difference. Hence our conclusion is that there is a significant difference between the pretest and post-test means. Since the post-test mean turns out to be higher it means it is significantly higher. The null hypothesis for the 1-tailed t-test says the post-test score is not higher than the pretest score. The result is that  $p < 0.05$  also. One can thus conclude that the post-test mean is significantly higher.

It shows that learners can learn a lot when computer tablets are used in teaching mathematics. Having stated this, the researcher also needed to look at the control groups before coming to such a conclusion.

Group B was one of the control groups. These ten learners were from grade 9C. They had the same mathematics teacher and were taught in the same language for the same amount of time as the grade 9B class. They wrote the same pre-test and the same post-test as the learners in the grade 9B group. The only difference in the design was that they did not use the computer tablets at all. Table 5.6 below shows the results for group B.

**Table 5.6 Comparison between the pre- and the post-test for the control group, Group B.**

<b>Group B</b>	<b>Pre-test</b>	<b>Post-test</b>
Mean	42.4	38.8
Variance	49.6	31.28889
Observations	10	10
Pearson Correlation	0.363276617	
Standard deviation	6.681317235	5.306599665
Hypothesized Mean Difference	0	
df	9	
t Stat	1.574671978	
P(T<=t) one-tail	0.07489233	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.14978466	
t Critical two-tail	2.262157163	

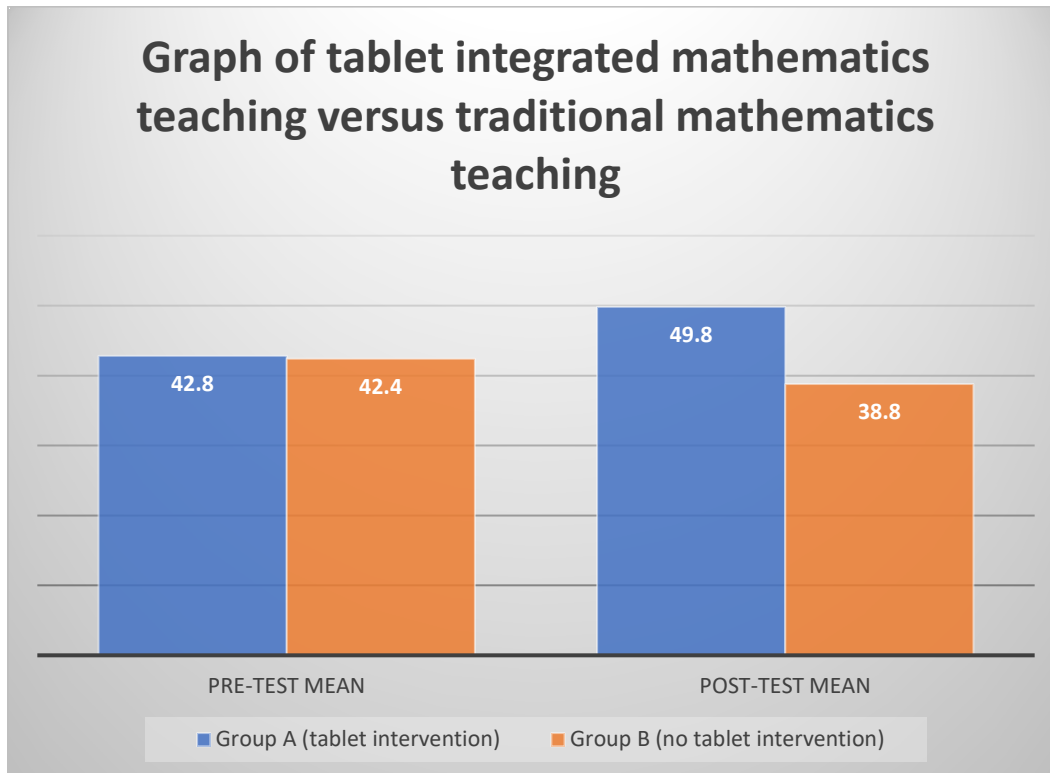
Their average mark in the control group B declined from 42.4 to 38.8. This might indicate that the post-test was more difficult than the pre-test. Their t-stat value was quite low, corresponding to a probability value of approximately 0.15. This p-value of 0.15 was much greater than 0.05 which indicated that the null hypothesis was true, and that no significant learning had taken place.

Table 5.7 draws a comparison between Group A and Group B. This comparison addresses the question of whether teaching with computer tablets resulted in significant progress compared to the traditional way of teaching mathematics.

**Table 5.7 Comparison between the two classes for pre- and post-tests**

Groups	Pre-test Mean	Post-test Mean
Group A (tablet intervention)	42.8	49.8
Group B (no tablet intervention)	42.4	38.8

The graph in Figure 5.17 is a visual representation of the Table 5.7.



**Figure 5.17 Graph of Group A vs Group B**

The learners in both group A and group B wrote the same pre-test and the same post-test. The only difference was that group A integrated computer tablets in the mathematics lessons whereas group B was taught without the use of computer tablets. From the graph one can deduce that both groups did equally well in the pre-test. This means that the prior knowledge of the two groups of learners was on the same level. There was a 0.4 difference in the average score of the two pre-tests. This relates to a p-value of approximately 0.9 which is greater than the threshold value of 0.05 and thus the null hypothesis, that both classes were on the same level, holds. There were no significant differences with regards to knowledge levels between these two groups. This is confirmation that the knowledge base of each of the two groups was the same before the intervention.

After the computer tablet intervention, the Group A learners improved their results with 7 marks on average whereas the Group B learners who received traditional mathematics training showed a decline of 3,6 marks on average. The fact that the average mark for learners in group B declined might be an indication that the post-test was a bit more difficult than the pre-test.

However, the learners in group A, who were taught using computer tablets, improved significantly.

The Cohen's d for Group A shows a value of:

$$\text{Cohen's } d = (49.8 - 42.8) / 6.281719 = 1.114345$$

This value exceeds 0.8 which means that the tablet intervention had a big effect on the learning.

Another control that needed to be considered was whether the outcome of the post-test favoured the learners who wrote a pre-test because they were familiar with the type of questions. This can be determined by comparing group B with group D as they both wrote the post-test but only group B wrote the pre-test. This function is what makes the Solomon four-group design more reliable than the simple pre-and post-test design.

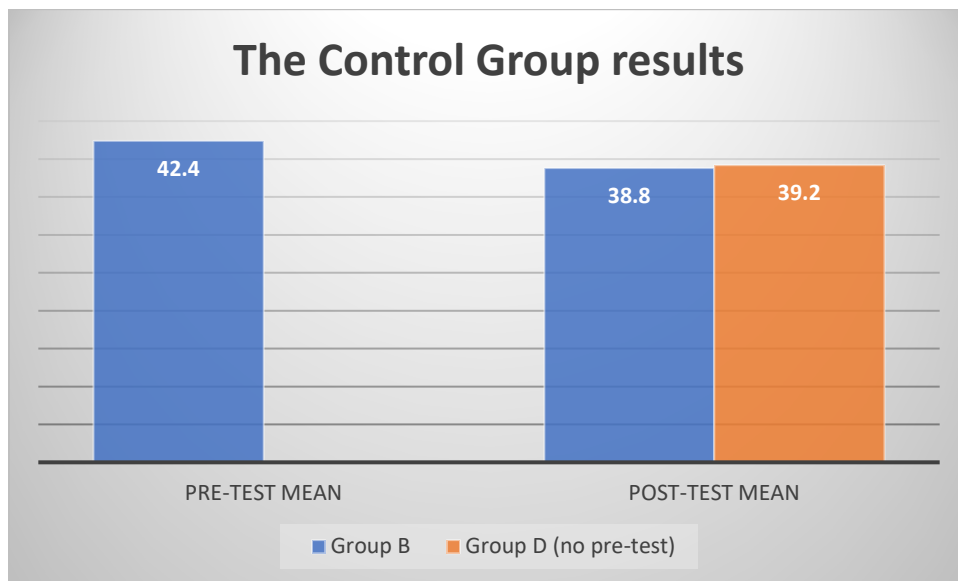
Table 5.8 below compares the results of the two groups that did not received computer tablet integrated lessons where group D did not write the pre-test.

**Table 5.8 Comparing the post-tests of the control group**

Control Groups	Pre-test Mean	Post-test Mean
Group B	42.4	38.8
Group D (no pre-test)		39.2

Figure 5.18 below shows the graph of the results for Grade 9C, where half of the class wrote a pre-test and both groups wrote the post-test.

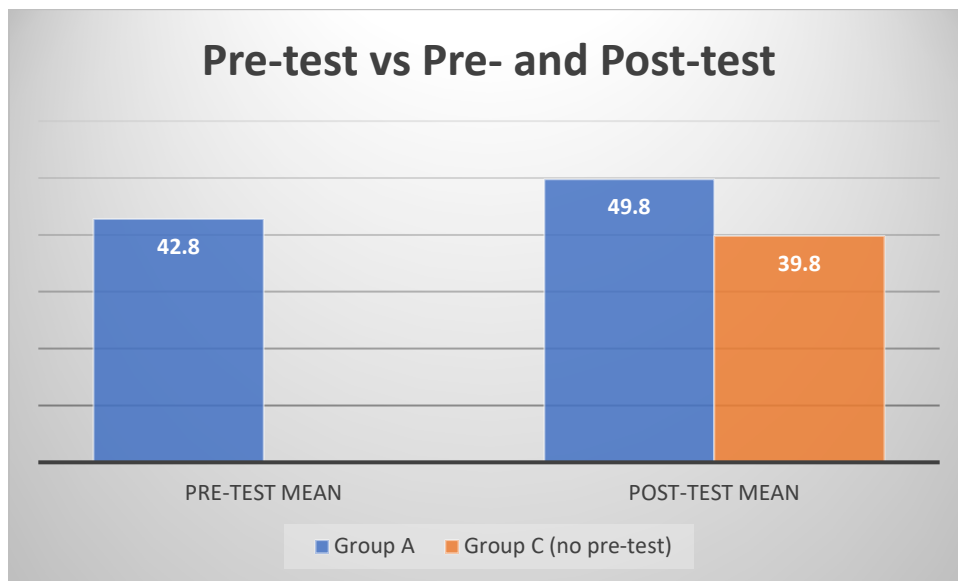




**Figure 5.18 A comparison between the two groups that had no computer tablet intervention**

From the graph one can deduce that both groups scored very similar marks on average in the post-tests. Group D achieved a slightly higher mark than Group B, even though Group B had written the pre-test. This is an indication that the writing of the pre-test was not to the advantage of Group B because Group B did worse in the post-test than Group D. This can also be contributed to the fact that the post-test was more difficult.

When one compares the results of learners in Group A and Group C, a few questions are raised. These learners were all part of the computer tablet integrated teaching. The only difference was that Group A wrote both pre-test and post-test while Group C wrote only the post-test.



**Figure 8 Comparing computer tablet integrated learners where one group wrote the pre-test.**

Looking at the graph, one might prematurely judge that the writing of the pre-test gave Group A an advantage. Fortunately, Figure 5.17 disproved this notion by showing that the group in the control class, Group B, which wrote the pre-test, scored the worst of the groups. It is interesting in Figure 5.19 that Group C scored less than the pre-test score of Group A. One reason might be that the post-test was more difficult than the pre-test. Another reason might be that with the selection it might have happened that lower achievers were selected to this group, Group C. However, what is enlightening is that even though Group C scored less than Group A, the learners still outscored in the post-tests both the two groups that received traditional mathematics teaching.

## 5.6. Summary

This chapter presented the findings of the research and comprised of two parts. The first part gave the results of the teacher survey that was sent to schools questioning the use of computer tablets, and the second part presented the analysis of the pre- and post-tests.

To answer the question of what Apps mathematics teachers used in the classroom, and why, and how they were using them, the researcher sent a survey to all the schools in the private school group for teachers to complete. The five most popular Apps that were used in the mathematics classroom were miEbooks, GeoGebra, YouTube, TeamViewer and Modlin. The researcher then discussed the features of these Apps, and this addressed the question of why

they used these specific Apps. To address the question of how teachers were using the Apps, the researcher looked at the methodology and the pedagogy of using these Apps in the mathematics classroom.

The quantitative part of the research followed, and the researcher discussed the outcome using the Solomon four-group design. This also allowed the issue of internal validity to be addressed with reference to pre-test interference. These results will be highlighted in the conclusion in the next chapter.

# Chapter 6

## Discussion of findings, Conclusion, Implications and Recommendations

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### 6.1. Introduction

The literature review on computer tablets in the classroom provides information on who uses computer tablets and where they are used globally. However, little is said about how they are used and the pedagogy regarding the use of computer tablets in the mathematics classroom (Luckin, et al., 2012; Parmar, 2017). This study set out to investigate the effectiveness of computer tablets in the classroom and posed four critical questions on the use of computer tablets.

This chapter provides an overview of the main findings and how the researcher answered the four research questions. The researcher then discusses the implications of this study with respect to policymakers, teachers, and the practice itself, and lastly the researcher makes some recommendations. These recommendations will cover the setup of a computer tablet project for new schools as well as recommendations for further research. The researcher concludes with the limitations to this study and proposes areas of this study that need to be further investigated.

### 6.2. Main research findings

The researcher investigated the use of computer tablets in the teaching of mathematics in a grade 9 classroom. The first three research questions were compiled using a survey and informed the last research question. The answers to the survey were used to select the Apps that were used to answer the last question.

### **6.2.1. The five most suitable Apps used in the mathematics classroom in South Africa**

The researcher questioned which Apps were used in mathematics classrooms in numerous schools in a specific school group in South Africa. Responses were received from 25 teachers and all indicated that they were using the miEbooks App. The GeoGebra App was used by 16 teachers, the YouTube App was used by 11 teachers, and TeamViewer and Modlin were used by 4 teachers, respectively.

None of these Apps were amongst the ten best Apps as rated by the Educational App Store. In fact, none of the ten best global Apps were mentioned in the survey responses. This might be an indication that teachers were not searching for the best mathematics Apps to use in the classroom. The Apps that these 25 teachers were using were those taught to them internally by their school. The miEbooks App was bought by their company to save on the buying of hardcopy textbooks that take up space and collect bacteria when used by different learners over five years. The GeoGebra App was integrated into the mathematics curriculum to use in addition to the curriculum and not every teacher was exercising that option. The YouTube Apps are quite familiar to teachers as they use the YouTube videos in some of their teaching. The TeamViewer App differentiated the digital teachers from the traditional teachers as this was used by teachers who wanted to project from their computer tablets by sharing their screen to their laptop display and then projecting it via their laptop. This method was also taught to all interested teachers in their training interventions. The Modlin App was purchased by the private school group to help with mediation in their poorer and lower achieving schools. The school featuring in this research was in that category.

There were further Apps taught to the schools in this group, but the five most popular ones were the ones addressed in this research.

The Department of Basic Education also made public a list of recommended mathematics Apps. This was published on its domain for access by all teachers in South Africa. This selection was poorly done as it included language and measuring units that were not used in South Africa. This list was also not properly maintained as three of the top ten Apps were no longer available on any App store platform.

Compared to the global standard, these five Apps were not the best mathematics Apps available, but they were the most used by the participating teachers. The GeoGebra App and the YouTube App with the Khan Academy videos, were amongst the ten Apps that were recommended by the South Africa Department of Basic Education.

### **6.2.2. The reasons why teachers are using these five specific Apps in their teaching of mathematics**

On the question of why teachers were using these specific Apps, the responses were diverse. From the data in Chapter 5, the following conclusions can be drawn.

The miEbooks App clearly had the most features that were valued by all teachers. It contained their textbooks and therefore it was imperative that all the learners used it. Teachers valued the feature that they could add enhancement materials that included pdfs, images, URLs, movies, MS Office documents and assessments. These assessments were marked by the software and feedback was instantaneous. The marks were then logged and made available in CSV format, which could be opened in any spreadsheet programme. The miEbooks App also allowed learners to highlight certain passages and summarised the highlighted parts for study purposes.

The GeoGebra App was valued for its ability to show images in three dimensions. This was ideal for a topic such as 3D images where learners could rotate and manipulate the images at will. Another useful feature was the double representation of the same function, where the learner could open two windows and immediately see the effect of any changes in the second window. For instance, if the function  $y = x$  was changed to  $y = x + 1$  in the first window, the graph in the second window would change accordingly. This is one of the outstanding features described by Nguyen (2014) and makes this App very powerful. The App allows for individual learning as learners can explore and test their answers.

Another remarkable feature in the functional design of the GeoGebra App's tools is that it can calculate different functions at the same time with the click of a button, for instance, circumference, area and volume (Nguyen, 2014) This feature makes it ideal for discovery learning as propounded by Bruner (Bruner, 1961). For GeoGebra to be used effectively, the teacher needs to have a well-prepared lesson plan. Tran *et al.* warned against lazy learners

who could just jump to the answer and miss out on the learning in the process (Tran, Nguyen, Bui, & Phan, 2014).

The YouTube App's power lies in the fact that it does streaming and has many videos on mathematics concepts. This was the medium that was being used in 2004 by Kahn when he sent his explanatory mathematics videos to his cousin Nadine who lived kilometres away from him (Khan, 2014). These videos can be downloaded by the teachers and transferred into the learners' textbooks via the miEbooks App and learners can watch these videos repetitively until they understand a concept. The learners can even watch these movies before they come to class, which make 'anytime and anywhere' learning possible and assists with the flipped classroom model (Raths, 2015).

It is important though to note that in a study by Kelly and Rutherford (2017) where one grade 7 class was taught using these YouTube videos and the majority of the learners did mainstream mathematics, no significant difference was seen, and the probability factor was 0.596. However when Zengin (2017) combined the Kahn Academy videos with the flipped classroom model, he had significant success, which included visualisation of concepts and retention of knowledge. The flipped classroom approach ensured that learners came to class prepared.

The TeamViewer App allowed participants in the lesson to share each other's screens. The teacher could see anyone's screen at any given moment and any screen could be projected onto the whiteboard. This feature was not found in the literature reviews as it was a new technology not used by many.

The Modlin App was used for remedial work. This App can assess a learner and take remedial action. It will either allow learners to go to more difficult questions or give them more of the same if they did not pass the assessment. The teachers used this App for extramural exercises. They could see which learners were using the App at home, what exercises they attempted and how long they spent in the programme. Of the 20 learners who had access to this App, only four used it extensively.

### **6.2.3. The pedagogical approaches in using the Apps in the mathematics classroom**

The answer to how these Apps were used gave two different responses. Some teachers answered from a methodological approach and others from a pedagogical stance. The

methodological approach entails the way that teachers set up their equipment. The method ss by which they are connecting their devices and how they are projecting it as well as how they get the learners devices to sync with one another. The pedagogical approach refers to how the teachers are using the devices to teach effectively. This aspect of the integration of Apps and computer tablets is less emphasised in the research (Parmar, 2017; Luckin, et al., 2012).

Before one starts with the implementation of computer tablets, one needs to install infrastructure to support the venture. The data received in the survey revealed that all the learners' computer tablets were connected to the same Wi-Fi. Each class had a Wi-Fi access point that was Internet enabled. The learners downloaded their Apps at the start of the new year with the right textbooks for their new grade. The teachers worked on the back end of the miEbooks App and could add anything to the learners' computer tablets from their laptops. When the learners arrived at school, they just pushed the refresh button on the miEbooks App and all enhanced resources that the teacher has planned for them would open in the miEbooks App. The TeamViewer App was used to display the screens of the learners and the teacher on the whiteboard.

Some teachers used a blended approach like the flipped classroom, where the teacher transferred YouTube videos onto the learners' computer tablets a day before the actual lesson. The learners watched these videos at home and could engage in a discussion about the concept the next day in class. This approach is part of the 21st Century learning skills where the learners practice collaboration, critical thinking, and communication. Luckin *et al.* (2012) also indicated that computer tablet interventions could have an impact as a tool for only a few learning styles, including the 21st Century learning skills.

Literature shows that once teachers hit the "sweet spot" of the TPACK model, they have a good balance between the content, the technology, and the pedagogy and the three knowledge areas work together to optimize tablet integrated learning (Koehler & Mishra, 2009). The SAMR model is a good measurement to determine the level of computer tablet interaction (Puentedura, 2016). Some teachers only used the computer tablet as a textbook, which constitutes the Substitution level (see 5.4 p 90). Some teachers entered the Augmentation level where the learners added some functionality to the e-book by highlighting and summarising some of the content. The Modification level was entered when a teacher gave learners an assessment on the computer tablets and the marks were presented immediately as an Excel file. The



Redefinition level of the SAMR was entered by teachers during the South Korean project where learners managed to build a 3d builder and a drone within a period of a week (see 5.4.3 p 93).

Parmar (2017) suggested another model similar to the SAMR that showed four different pedagogical styles where the elementary stage was drill and practice. This stage only stimulated low levels of learning in learners. The next stage was known as the stage of independent exploration which already included higher levels of learning and allowed for a constructivistic approach. The next level was that of guided interaction and was still allocated in constructivism. The highest level was that of communication and collaboration and took teachers to the theory of Lev Vygotsky and his zone of proximal development (ZPD) where learners worked in groups and from their personal experiences collaborated and learnt from each other to develop (McEachern, 2016).

The role of the teacher changes gradually as the level of teaching rises (Williams, 2009; Clarke & Svanaes, 2014). The teacher becomes an orchestrator or a facilitator, and the classroom becomes more learner centred. This environment is conducive to collaboration.

#### **6.2.4. The effectiveness of computer tablet use in the mathematics classroom**

The data in Chapter 5 showed that there was a significant improvement in the scores of learners who had computer tablet intervention compared to the learners who received traditional teaching. The difference in marks between the two groups was quite remarkable. The group of learners who were taught using the traditional style saw a decrease in marks from the pre-test to the post-test. It is possible that the post-test could have been more difficult. Nevertheless, the computer tablet intervention group improved from 71.3% to 83%, with a Pearson Correlation of more than 0.7. This strong positive correlation meant that even though they scored high marks in the pre-test, in the post-test they scored even higher. It is not difficult to improve when marks are low, but to raise marks that are already high by 12.7% is excellent.

This significant improvement was achieved even though the learners did not use the best rated Apps. It is possible that with world-rated Apps they could do even better. One must not forget that when Kelly and Rutherford researched the Salman Kahn YouTube videos in isolation there was no significant improvement, but when combined with the flipped classroom pedagogy there was great success (Kelly & Rutherford, 2017; Zengin, 2017).

It was not one App alone that made the difference in this study. It was the combination of different Apps as the need and opportunity presented itself. The teacher would download YouTube videos on the next day's topic and push them to the learners' computer tablets using the miEbooks App (see teacher 15 p 85). The learners downloaded them at school to watch at home. This flipped classroom model ensured that the learners came to school prepared for their lesson as they had already watched the videos. The teacher would then use the GeoGebra App to teach the lesson from anywhere in the classroom as the computer tablet screen was cast to the laptop, which was connected to the data projector. The TeamViewer App allowed for the mirroring of screens so that the teacher can share the screen of the tablet with the computer screen in order to project what is on the tablet. Group discussions were also possible, as the learners all watched the videos and could engage in peer teaching via their computer tablets on the big screen using TeamViewer. The teacher used the TPACK and SAMR models where applicable. The Modlin App was given to learners for extramural exercisers as it allowed for mediation and self-development.

In conclusion, this intervention was successful, but it was preceded by substantial preparation and training. A teacher venturing into this computer tablet implementation process needs to do a fair amount of groundwork first.

### **6.3. Implications for integrating the computer tablet in the mathematics classroom**

The outcome of this study has implications for policy writers, for teachers and for the learning practice itself.

#### **6.3.1. Implications in the selection of computer tablets and Apps**

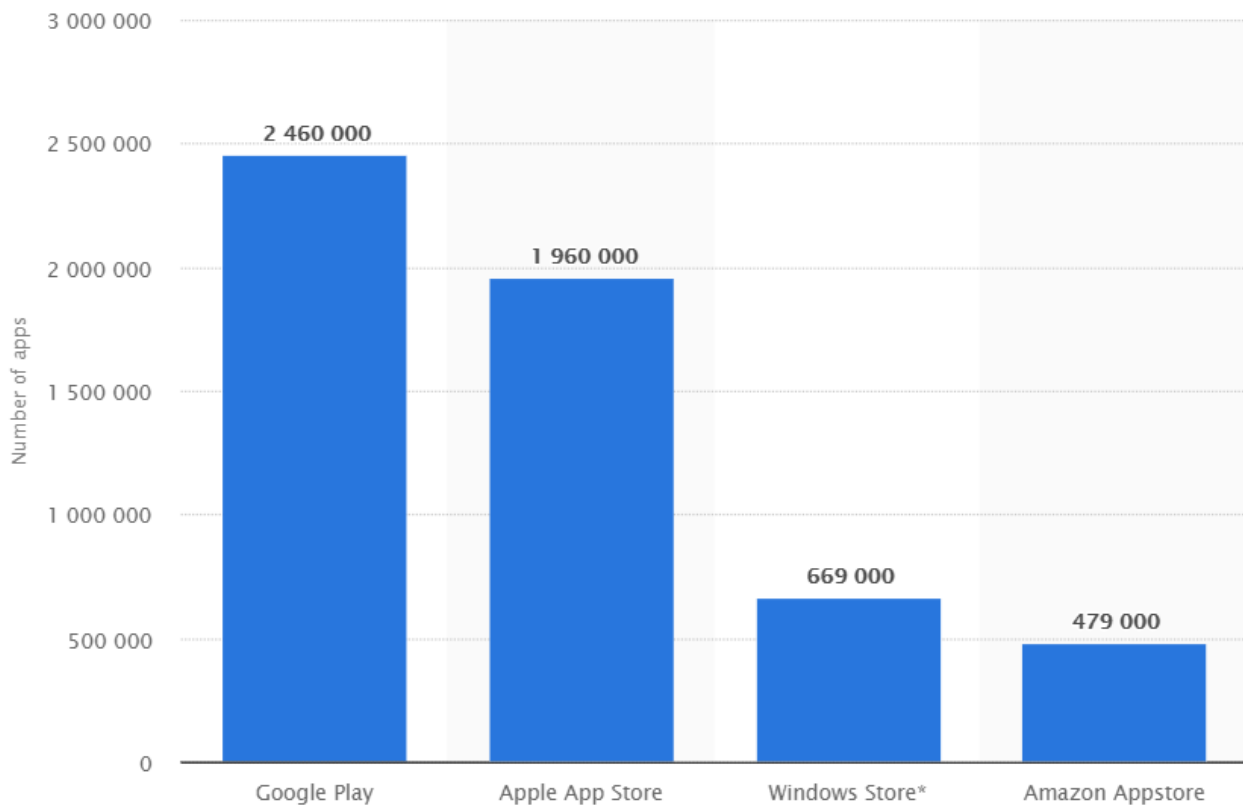
The researcher used the Apps that were familiar in the schools of this private school group. This saved a lot of training. When starting from scratch, it is advisable to consult the Educational App Store and identify the best Apps on the market. Many of these educational Apps are free, and some of the paid ones are worth paying for.

Cherner, Dix and Lee (2014) found the number of Apps overwhelming for teachers, so they introduced a framework to classify these Apps into three categories. The first category was

called, skill-based and it used recall, memorisation, and skill-and-drill strategies. This kind of testing corresponded with the lower levels of Bloom’s taxonomy, namely remembering and understanding (Forehand, 2011). The second category was content-based and included the application and analysis of levels of Bloom’s taxonomy (Cherner, Dix, & Lee, 2014; Forehand, 2011). The third category was called function-based and it corresponded to the evaluation and creation levels of Bloom’s taxonomy (Cherner, Dix, & Lee, 2014; Forehand, 2011).

In this study, miEbooks and YouTube represented the skill-based Apps, GeoGebra and Modlin were content-based and the TeamViewer App was function-based.

The private school group decided to buy Windows 2-in-1 devices to use as computer tablets in the schools. This decision limited their choice as the Apple Appstore and the Google Play Store had many more educational Apps than the Windows Store (Clement, 2019). A comparison is shown in Figure 6.1 below.



**Figure 9 Comparison of App stores in Feb 2019 (Clement, 2019)**

If they had decided on Android with Google Play, they would have had about four times more Apps at their disposal.

Globally, many institutions have decided on the “bring your own device” model. This can be more affordable than having to buy a specific computer tablet. This is a good strategy, yet there need to be parameters regarding the operating system, the processor speed and the size of its internal storage. When the learners installed the Modlin App, many had no more memory space left as the offline App was more than 1 Gb in size, and their computer tablets stopped responding. Apps can be easily shared on the Windows and Android platforms, but on the iOS platform, the parent needs to give consent, which makes it a challenge when the sharing of Apps happens at school. It is also easier to support only one operating system.

Every school must draw up a policy of good conduct and rules regarding the use of computer tablets. They need to be fully charged overnight and the classrooms need to be fitted with multi-plugs in case the batteries do not last for the day. Charging periods need to be scheduled. When learners do practical work for instance, their computer tablets could be charging. The school needs to have spare computer tablets which learners can use in case something happens to a computer tablet. All content needs to be updated on a server daily. When someone’s computer tablet breaks, they simply log onto the network and restore their content on the loaned device.

The school’s network administrator needs to have good security in place to prevent learners from hacking into the server or from surfing undesirable sites. The learners should not be able to get onto the teachers’ sites as they contain questionnaires and marks. The Internet should be limited to only allow educational sites. The school should have a “whitelist” of sites where learners can surf.

A computer tablet fee should be negotiated to cover the expenses of broken tablets. Many computer tablet projects around the world have been cancelled due to the cost associated with breakages (Clarke & Svanaes, 2014). This fee should also make provision for buying extra computer tablets to use as loan devices. Legislation should be carefully drawn up to guard against theft and vandalism. The R17 billion project at Boitumelong is a reminder of how a computer tablet project can fail if security measures are not in place (Mbola, 2015).

Policy can also be written to control the number of photocopies made at school since computer tablets allow teachers to share content with learners and even do assessments online. In turn, a large amount of paper can be saved, which is good for the environment. Patterson (2015) also added that attendance improved after computer tablets were introduced.

The school policy writers should build in training time for teachers to keep them informed and empowered. Arrange practice times where learners stay a day at home to practice online teaching in case of emergencies when learners cannot come to school. They also need to know how the physical connections work as Clarke and Svanaes (2014) blamed connectivity problems as the major stumbling blocks for teachers and learners. Policy should prevent learners from cyberbullying and teachers need to learn how to sense and address this. Guidelines should be drawn up to teach learners how to care for and maintain their computer tablets properly. Policy makers should consider smaller class sizes as this is more effective for computer tablet integration (Clarke & Svanaes, 2014). Personal ownership is crucial to the success of a computer tablet intervention according to Clarke and Svanaes (2015). Schools should consider going into partnership with communications companies like MTN and Vodacom to offer two-year contracts to learners, who will in any case be buying their data.

Another factor contributing to the success of computer tablet intervention is leadership. Vu (2015) reported that schools where the principal set clear expectations showed more progress than other schools where teachers were left to their own devices.

### **6.3.2. Implications for teaching**

The computer tablet intervention programme has many implications for teachers. Most of these are positive influences, even though some teachers will have to adjust from their comfort zones. Teachers need to embrace this change and learn to work with their computer tablets and explore the Apps. Teachers who are not comfortable using their computer tablet will always fear the unexpected (Vu, 2015).

Karsenti and Fievez (2013) reported that the greatest challenge to both teachers and learners was device training. Teachers not only need to use their computer tablets effectively, but also need to know the Apps that they are using. The TPACK model refers to as a lack of technology training. They need to become technically competent in order to teach effectively. They need

to know how to design and project content and activities to the learners' computer tablets using miEbooks, for instance. They need to know the specific strengths of an App and when to use that strength. They also need to distinguish between suitable and unsuitable Apps. Some Apps use the imperial system and South African learners know the metric system, and units like feet and inches might confuse them. Some Apps are grade specific but might not correspond with the South African curriculum. Other Apps might just give the learners the answer right away and have very little pedagogical value. In fact, learners might use them for cheating on the homework exercises. Henderson and Yeow (2012) referred to how learners can be tempted to chat and be dishonest which leads to poor performances. Kievlan (2013) warned against Apps that show learners step-by-step solutions to a problem. Some Apps like Trigonometry Mathematics are good for introducing learners to new content. The Khan Academy App helps learners to understand mathematics using videos. Research in chapter 2 found that by using these videos, learners experienced a reduction in mathematics anxiety and an improvement in mathematics self-belief (Murphy, Gallagher, Krumm, Mislevy, & Hafter, 2014). However, although this helped learners with procedural skills it did not necessarily help with deeper learning.

Computer tablets can vastly reduce a teacher's workload by filing e-content to be used again the next year (Fullan & Donnelly, 2013). Teacher 3 (p 85) refers to the amount of time that is freed and teacher 17 (p 85) is not making photostat copies anymore. This advantaged was echoed by many teachers in their responses to the survey on why they were using the miEbooks App . They can create an ideal environment for flipped classroom learning, especially with the YouTube App and the Khan Academy videos. This model sets up a case for practicing the 21st Century learning skills that include collaboration, critical thinking, creativity, and communication. Using this model changes the teacher's role from instructor to facilitator. The lesson becomes learner-centred and the teacher just orchestrates (Williams, 2009). Some of these Apps even assess the learners' learning in a fun way like the Rocket Maths and Math Facts Mahjong Game, and give immediate feedback (Clarke & Svanaes, 2015; Fullan & Donnelly, 2013). Although there are many guidelines on how to use the computer tablet and how to use specific Apps, there are not many guidelines as to the pedagogy of computer tablets in the classroom. Computer tablets, if not integrated well, can be a distracting factor and can be a barrier to effective learning as forewarned by Henderson and Yeow (2012).

What is imperative is that teachers must make the use of computer tablets compulsory for their teaching (Norris & Hossain, 2012). Learners must know that they will use the computer tablet every day somewhere in their learning experience. As soon as teachers do not use the computer tablet, learners start to doubt whether to keep it charged or even bring it to school. Learners must adapt to a culture of computer tablet use in their learning.

### **6.3.3. Implications for learners**

One of the main implications is that learners do not have to carry heavy school bags anymore as all their textbooks are in e-format on their computer tablets. This also puts a responsibility on them in that if it is not present or charged, they do not have a textbook to work from and will not get the enhancement material like videos and assessments provided by miEbooks. Basically, learners will waste the day if they do not have their computer tablet ready for class. Learners like the 7-inch screen as it is big enough to see a real sized face as they communicate with each other and it is also small enough to hold it with one hand and navigate with the other hand. The fact that it is portable and without barriers like a lid between them and their peers contributes to this success (Steward, 2013). The microphone, speakers and the camera on the computer tablet make it ideal for presentations.

Learners need to know how to download and share Apps, how to connect to the Wi-Fi and the server and even how to connect with other computer tablets via screen casting. These features make the use of the computer tablet more exciting and create high levels of satisfaction. Once the learners are connected to the Internet, they are in an environment of seamless learning, i.e. anywhere, anytime learning (Van't Hooft, 2013). Computer tablets have an impact on certain kinds of learning styles, like collaborative learning, learning from experts and inquiry learning (Luckin, et al., 2012).

Learners need to be acquainted with the affordances of the Apps as the inability to use these Apps will limit their learning experience. The subject-tool-object triangle of the activity theory addresses the importance of knowing your tool also referred to as the mediating artefact in chapter 3. For instance, they need to know how to highlight text in miEbooks and how to summarise it for study purposes. They need to know how to print it out in hardcopy if that is how they prefer to study. They need to watch the YouTube videos before the lesson to make flipped classroom learning possible. They can re-watch them as many times as they want until

they understand the concept. They need to explore the double representation function in GeoGebra to enhance their understanding of the mathematical concepts and how to manipulate real-time data in GeoGebra. They must understand that although GeoGebra is multifunctional, it will help them if they work out certain functions by themselves, for instance, area and volume will both be given, but it will benefit the learners to work this out for themselves. Only when the learners actively engage with the Apps will they excel in their learning. Learning remains the responsibility of the learner.

#### **6.4. Suggested policy framework for the implementation of computer tablet use in South African schools**

What is lacking in this research is information on how to set up a computer tablet intervention laboratory. This thesis ventures to make some recommendations to help with the successful implementation of computer tablets in South African classrooms.

The South African government, under the leadership of president, Cyril Ramaphosa has big plans for South Africa concerning digital learning. This time, the president plans to do a roll-out of computer tablets to all pupils in 23 700 schools (Masondo, 2019). He is determined not to make the same mistakes as in 2015 when the computer tablet project failed dismally. A government team made an assessment and addressed several challenges, including “theft and the use of computer tablets for downloading non-education material such as pornography and games” (Masondo, 2019). One of the measures that was taken to make this implementation a success, was to insulate the computer tablets “against the downloading of any material that was not educational” (Masondo, 2019). These computer tablets will also be inexpensive, so they do not offer much value to thieves (Masondo, 2019).

The researcher will highlight a few issues that need to be addressed before a school invests in computer tablets.

##### **6.4.1. Recommendation on infrastructure**

The school should firstly invest in a functional Wi-Fi infrastructure with Internet access and with access points that will allow for a whole class to work on the system at the same time without



buffering or bottle-necking. There should be one access point for every classroom and the teacher should have control over when to allow learners onto the Internet or not.

#### **6.4.2. Recommendation on computer tablet devices**

The school should also decide on the type of computer tablet and operating system that will be used. The bring-your-own-device (BOYD) policy creates quite a lot of unnecessary challenges, but it can be managed if there are guidelines regarding the operating system and the minimum specification requirements. The iOS platform limits the learners' access as they cannot share or download Apps as easily as on the Android platform. They need access passwords that are linked to their family account at home. Android has an App called Shareit which allows learners and teachers to share Android package kit (Apk) files for installation. The Windows platform is also very accessible to users but does not have as many Apps as the iOS and the Android platforms.

It is also necessary to identify a suitable computer tablet that is low cost yet has an adequate Central Processing Unit (CPU) with enough hard drive space as well as external space. When considering the size of a computer tablet, take into consideration how the learners will carry it. A 7-inch computer tablet fits inside a blazer pocket. The screen is the size of an A5 page which makes reading easy as most learners are familiar with reading that size of book. The battery life of such a computer tablet needs to be able to provide power for the full duration of the school day. Alternatively, the school should provide charging docks where learners can charge their computer tablets' batteries. These charging docks should ideally be inside a classroom in case a learner's battery dies while in use.

Schools need to consider a few questions when buying these computer tablets. Will learners be responsible for their own computer tablet? Will the school have telecommunications companies such as Vodacom and MTN to give contracts that are included in the school fees? This is a recommended method as the telecommunications company will then have to repair the computer tablet when it breaks under guarantee and there are many outlets where learners can take their computer tablets for repairs. This also exempts the school from dealing with such logistics as breakages were one of the reasons why the tablet project failed in 2015 in South Africa (Davis, 2012). The school should, however, have extra devices that can be offered on loan in case a learner's computer tablet breaks and needs to be sent in for repairs. An App like

miEbooks also synchronises the learners' work onto a server, so if the computer tablet breaks, learners just connect to the server via the Wi-Fi and download all their content as well as highlighted summaries.

#### **6.4.3. Recommendation on computer tablet training**

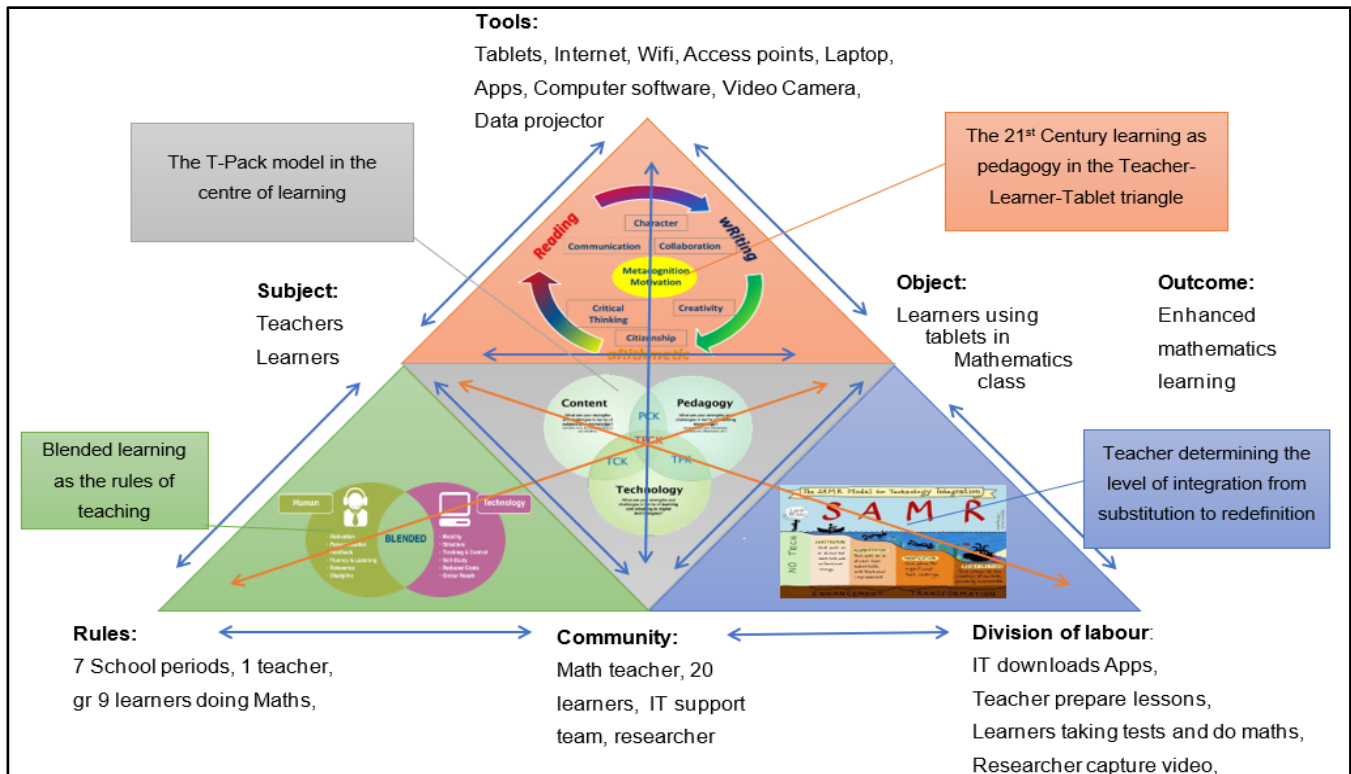
It is recommended for a school implementing computer tablets for the first time that the teachers get their devices first. Giving them a head-start can boost their confidence and assist in the quest to stay ahead. Teachers need to know how to maintain their computer tablets, how to download Apps, how to reset their Apps and how to update them. They need to be confident in connecting it to the Wi-Fi and should be able to cast their computer tablet screen onto their laptops. This is important because their laptops can be connected to the data projector via VGA or HTML ports. In cases where classrooms have Wi-Fi projectors, the computer tablet can be projected directly onto the whiteboard, but most South African schools do not have this technology yet. Every school should have a technical support person to assist the teachers, especially at the beginning of the project. Teachers need to collaborate with one another in the use of these Apps. Teacher training should be done months prior to the intervention to give them a chance to practice their skills repeatedly.

When the learners connect their devices, there should be a pilot period where all the different connections and functions are tested. The computer tablet intervention should only start when teachers and learners can operate their own computer tablets. The class environment for this period should be that of helping each other to successfully operate their computer tablets. An each-one-teach-one policy is recommended. Teachers need to explore different pedagogical approaches to teach with these computer tablets.

#### **6.4.4. Recommendation on Pedagogical Practice within the Activity Theory**

After the teacher and the pupils have their computer tablets, the teachers can start practicing their pedagogical teaching models. This is probably the most important requirement. Teachers must know how to use these computer tablets effectively in the classroom. They should familiarise themselves with teaching models such as the TPACK, the SAMR, blended learning, flipped learning and learning theories to know how best to facilitate the learning process. The researcher compiled a conceptual framework for the models as in the figure below. Initially, the

researcher had these models as sequential interactions but now sees them as an integrated part of the Activity Theory. The following picture in Figure 6.2 embeds the teaching models within the interactive triangles of the Activity Theory as propounded by Engeström.

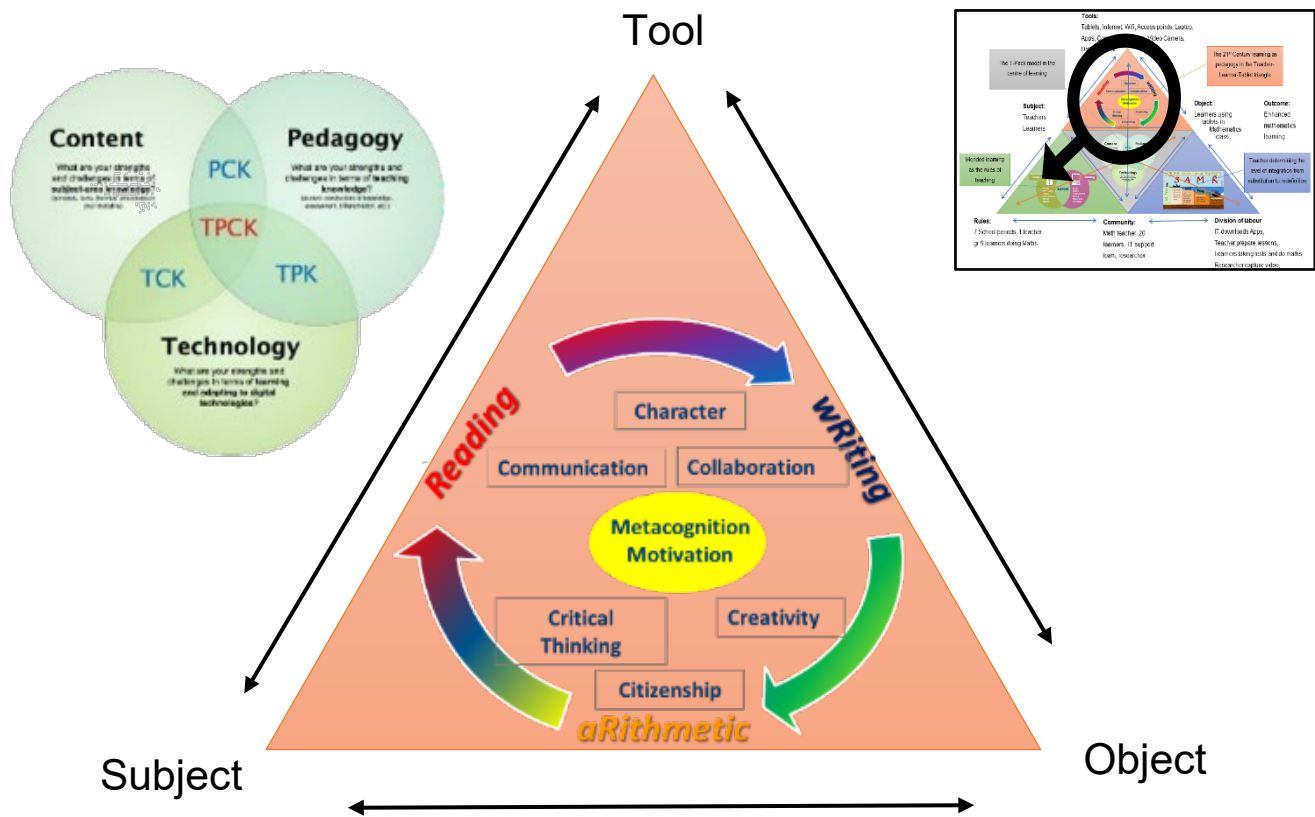


**Figure 6.2 Conceptual framework of teaching models within a learning theory**

This whole pedagogical vision needs to be embraced by teachers and the school management should implement ways and strategies in order to guide it. The Activity Theory consists of many smaller triangles between the role-players: ‘Subject’, ‘Tools’, ‘Object’, ‘Rules’, ‘Community’, and ‘Division of Labour’. The arrows show the different triangles.

#### 6.4.4.1. Subject-Tool-Object Triangle

This triangle is the top triangle of the Activity Theory as in Figure 36 above. This triangle consists of the ‘Subject’, the ‘Tool’, and the ‘Object’ as described in the Activity Theory. This is the most common scenario of all the triangles within the Activity Theory as it includes the Learners (Subject), the Tablet (Tool) and Learning taking place (Object). When one focuses on these three elements, the ideal pedagogic models are TPACK and 21st Century Skills.



**Figure 6.3 The top triangle of the Activity theorem with the 21<sup>st</sup> Century skills and the TPACK model embedded in it**

The ‘Subjects’ in this triangle are the teacher and the learners. The ‘Tool’ refers to the computer tablet device, the Wi-Fi, the infrastructure, the access points, the laptop, and the data projector. The ‘Object’ refers to the learners using these devices successfully in the mathematics class. The ‘Subject’ needs to be trained in using the computer tablet confidently. The results can easily be skewed if the teacher cannot teach or the learners do not know how to use their devices. Teachers need to be trained on how to connect their devices to the computer in order to project it on the whiteboard. They also need to be trained on the Apps that will be used in their lesson. Teachers need to know how to push content from their laptop to the learners’ devices. This should be done a day before the actual lesson so that learners can watch the videos at home. This constitutes the flipped classroom model. Learners will come to class having pre-knowledge regarding a topic so that effective collaboration can take place. As for the pedagogy in this interaction, the teacher can teach the class using the 21st Century Skills. This comprises communication, critical thinking, creativity, collaboration, citizenship and character building.

The teacher can be guided by the TPACK model to find the right balance where the content, the pedagogy and the technology can be combined effectively.

#### 6.4.4.2. Subject-Object-Division\_of\_Labour Triangle

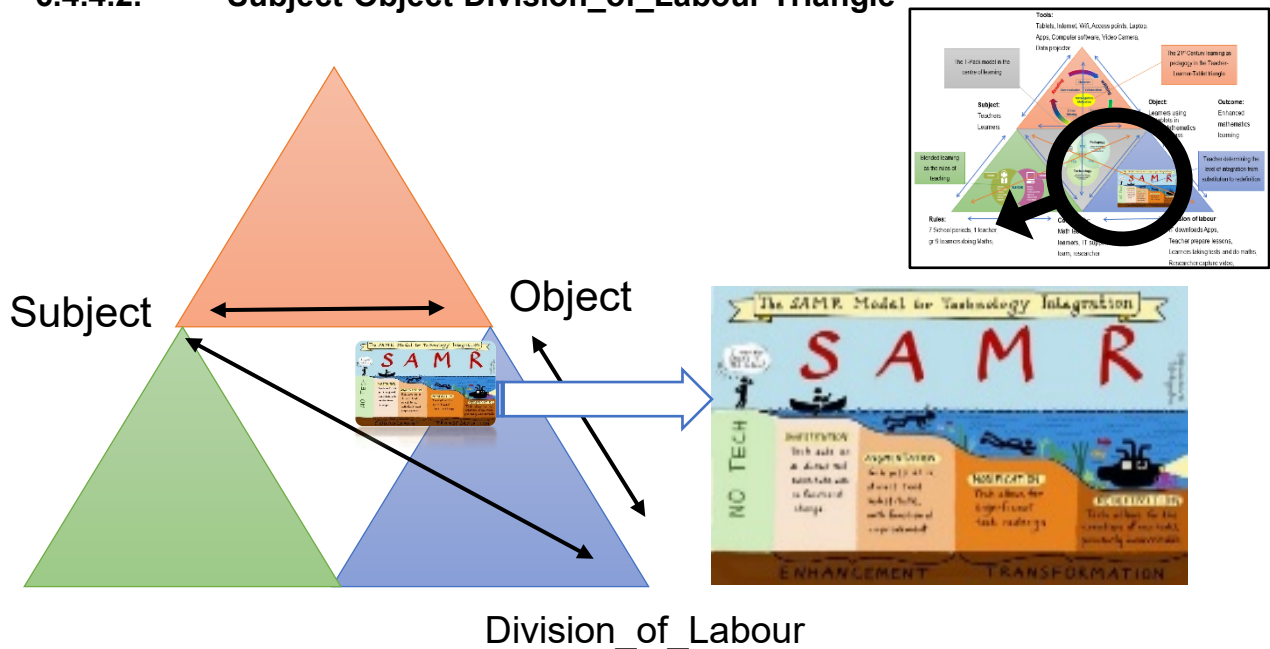
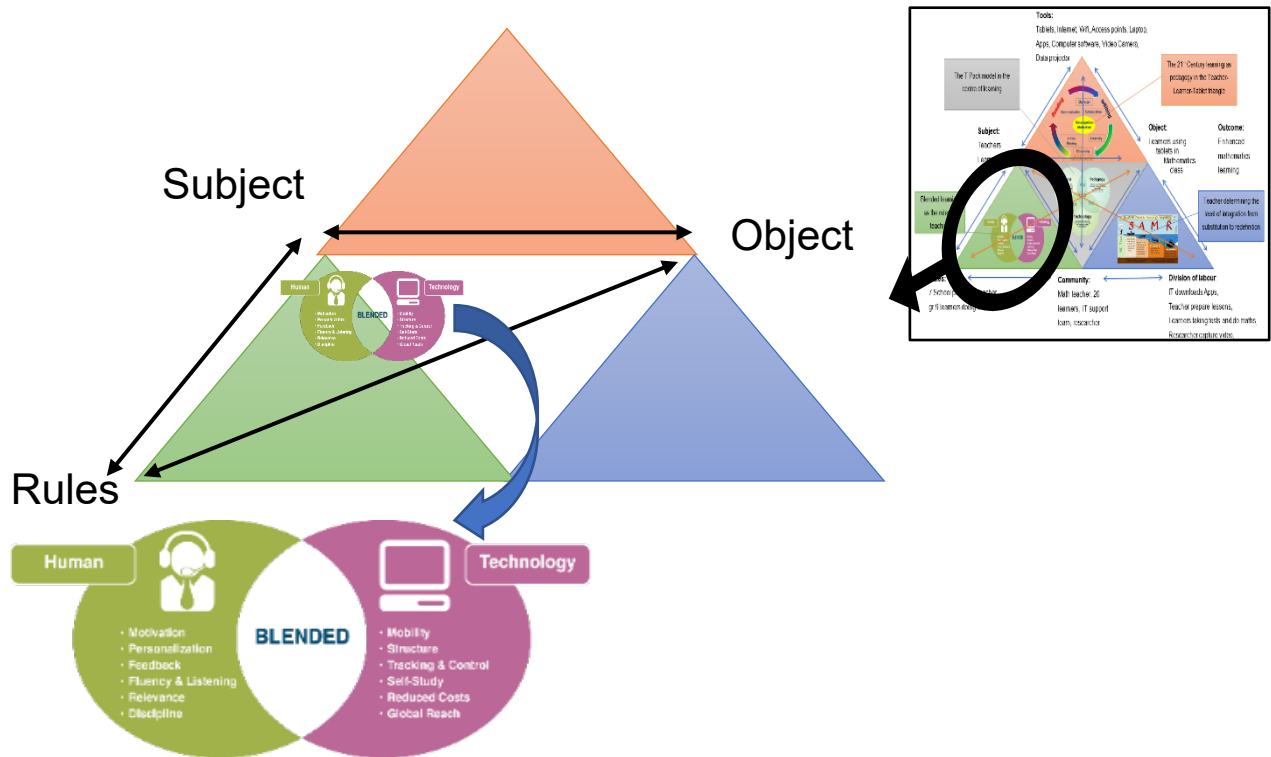


Figure 6.4 The SAMR model embedded into the Activity Theory

The teacher needs to be familiar with the SAMR model and where and when to incorporate it into the actual lesson. The SAMR model will determine the extent of the computer tablet use and distribute different tasks to different groups in a class. The 'Division\_of\_Labour' refers to who is doing what. This includes the technical support, the teachers planning the lessons and the learners engaging in learning. The technical support should make sure that the classrooms have Internet connections with Wi-Fi and that access points can connect to the learners' devices. They should also be responsible for getting these Apps onto the learners' computer tablets. The learner's role should be to engage actively in the learning experience and to watch the movies at home a day before the lesson. Teachers should plan to what level on the computer tablet they will engage the learners, guided by the SAMR model. If the learners only use their computer tablets to read their textbooks, this constitutes the Substitution phase. The computer tablet merely substitutes the textbook. The Augmentation phase is when substitution is done with some functional improvement. Learners are still using the computer tablet as a textbook, but now sentences can be highlighted and shared between devices. Summaries can be compiled using these highlighted texts to study for the exams. The Modification stage allows

for significant task modification. Now the computer tablets are used as a textbook having more functionality and the ability to do assessments on a trial basis. The learners can interact with the Apps and will receive immediate feedback on their assessments. The Apps can even determine the level where the learners are and even suggest remedial work. The last level constitutes using the devices for tasks that were previously inconceivable. This is the Redefinition stage.

### 6.4.4.3. Subject-Object-Rules Triangle



**Figure 6.5 The Blended learning model embedded in the Subject-Object-Rule triangle of the Activity Theory**

Teachers should think and question themselves about the frequency of use of computer tablets in the classroom. Will it be effective if it is used every day? Will it be used for every lesson or are there lessons that will be more or less effectively taught with other methods? These questions involve the learners (Subject), the learning taking place (Object) and guidelines (Rules). The Blended learning model addresses these questions as part of the Activity Theorem as in Figure 6.5. The ‘Rules’ in the Activity Theory triangle comprise specific parameters that need to be negotiated, for instance, how many learners, how many teachers, how many periods

and how much time, etc. Teachers should plan precisely how many periods the learners will engage in and for how long. Will they use the computer tablet as an introduction to a lesson, at the end of the lesson, or as an assessment? How frequently will the class do these assessments? How much time will be spent working on the computer tablet compared to doing other hands-on activities. This gives rise to the Blended model of learning. If the teacher uses the computer tablet for every action, then it will become as dull as the talk-and-chalk method. The teacher must select the best times for interaction. This becomes part of the planning on when to integrate the computer tablet into a lesson.

#### **6.4.5. Recommendation on the culture of the use of computer tablets**

Learners need to establish a culture of use. They need to prioritise their content focusing on educational resources. It was found that the majority of learners at the school in the study downloaded music and videos and were on chat groups. This behaviour filled the internal drive of the computer tablet. The Modlin App needed about 1 Gb of disc space as it downloaded a lot of content to the computer tablet, and some learners could not load this App due to insufficient space.

Learners must also learn to get into the habit of charging their computer tablets the night before. Dimming the screen also helps to save battery life. Learners need to adapt their lives around the safeguarding of these computer tablets. Crime in South Africa is rife, and a computer tablet is a valuable commodity. Learners need to take care with computer tablets as they are much more fragile than the textbooks that they were used to. The most common accidents with computer tablets are the breakage of screens.

Learners need to discipline themselves as to the use of their computer tablet for educational purposes. The temptation to download games and visit indecent sites is always a concern. Learners will need to develop a culture of responsibility and self-directed learning. The upside is that as learners change into responsible students, this gradually becomes the norm and many of the challenges faced during the computer tablet honeymoon period will gradually diminish.

A pictorial summarising the above recommendations is shown in Figure 6.6 below. These recommendations are mainly focused on schools integrating computer tablets for the first time.

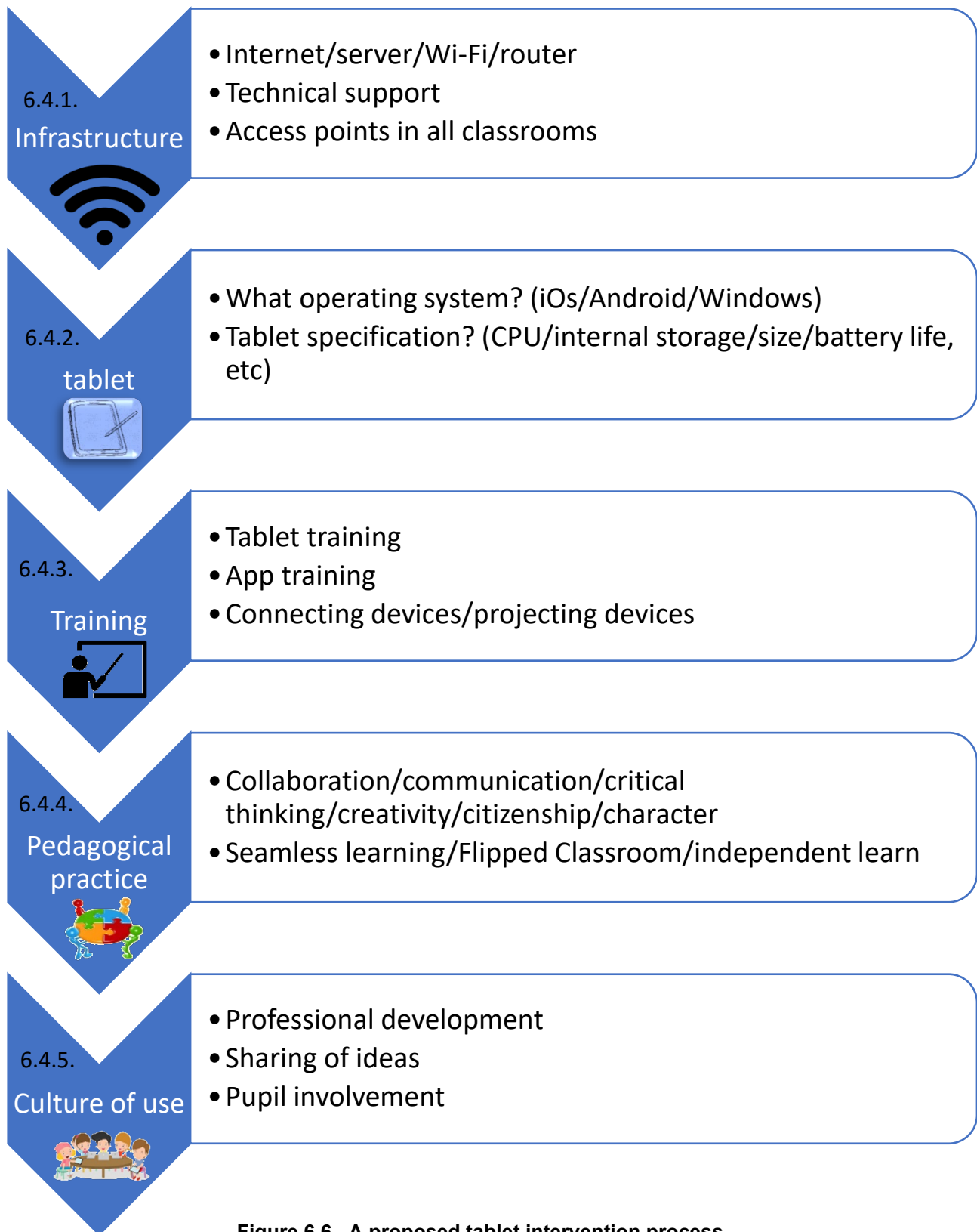


Figure 6.6 A proposed tablet intervention process



## **6.5. Limitations of the study**

The researcher selected to carry out the research in an affluent private school in the Western Cape and hence the results cannot be generalised outside of this school. It cannot be compared to any of the Department of Basic Education (DBE) schools with a different socio-economic background. The biggest challenge that the government faced when rolling out its computer tablet project in poor schools was theft and entitlement, where learners did not give back the computer tablets to the school after the intervention period (BusinessTech, 2015).

The researcher focused on Grade 9 learners' performance in geometry. The topic of the study was 3D images which were visual and graphical and could be viewed effectively on a screen or monitor. The results might not have been so significant if a 2D topic was used.

These learners were from the middle class, and all of them had their own computer tablets, which they could take home. The class size was between 20 to 25 learners compared to government schools with a class size of about 40 learners. The class size made it possible to adhere to different computer tablet challenges such as connection errors and download bottlenecking. In bigger classes, one might need a technical assistant to help with troubleshooting challenges.

The mathematics teachers received training on the use of computer tablets before the study commenced, so this study cannot be reciprocated in other schools where teachers might have challenges in operating a computer tablet. The teacher was very comfortable in the use of the technology.

The language of instruction was English, which made it convenient as this was the same language that the Apps were written in. For Afrikaans speaking learners, the outcome might be different as they would encounter other barriers to learning.

## **6.6. Issues for further research**

Computer tablet adoption will become easier as more learners and teachers are exposed to it. The researcher in this study used one App for a specific focus for instance, Team Viewer was used for communication whereas GeoGebra was used to aid the instruction. Further research

could be done to assess and compare different Apps with the same focus, for instance two different instructional Apps, and to test which one has the better results.

Another challenge was the criteria used to measure the effectiveness of the Apps. A potential topic for further study might be to draw up criteria or a checklist to accurately assess the learning value of these Apps.

A crucial investigation would be to find out how effective computer tablet integrated teaching would be when learners are at home with no physical contact with teachers.

## **6.7. Overall Conclusion**

This research investigated the use of computer tablets in the mathematics classroom in order to contribute to the making of informed decisions relating to the future of mathematics teaching.

The first three questions were used to establish what the mathematics Apps were that teachers used in the classroom. Teachers also reported on why they were using these Apps and how they were integrating Apps and computer tablets into their lessons. The researcher then used this information and selected the five best Apps to study in the fourth research question. The teacher at a specific school was trained in using computer tablets with these Apps.

The teacher taught two classes – one with the traditional textbooks and whiteboard and the other with computer tablets. On the question of how effective the computer tablet integration was, the class using the computer tablets showed a significant improvement compared to the class that was taught in the traditional way.

The private school group that piloted the use of computer tablets in the mathematics classroom made a good decision. The implementation of this computer tablet project proved to have made a significant difference in the school in this study.

Computer tablet intervention might be the answer to lift the ANAs score of Grade 9s from the average of 10.8% to the 30% where other grade averages reside (Nkonkobe, 2014). Computer tablet intervention might just be the answer that South Africa is looking for.

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# Appendix A

## Signed Letter from Language Editor

---

TO WHOM IT MAY CONCERN

This is to confirm that I have proofread/edited the PhD thesis of Anthony Williams entitled:

**Investigating the use of computer tablets in the teaching of mathematics in a grade 9 classroom**



**KM ROBERTS**

MSc Chemistry

14<sup>th</sup> February 2020

# Appendix B

## Ethical Clearance Certificate

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**OFFICE OF THE DIRECTOR: RESEARCH  
RESEARCH AND INNOVATION DIVISION**

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23 June 2016

Mr A Williams  
Language Education  
CHS Faculty

**Ethics Reference Number: HS/16/3/20**

**Project Title:** Investigating the use of computer tablets in the teaching of mathematics in a Grade 9 classroom.

**Approval Period: 10 MAY 2016 – 10 MAY 2017**

I hereby certify that the Humanities and Social Science Research Ethics Committee of the University of the Western Cape approved the methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval. Please remember to submit a progress report in good time for annual renewal.

The Committee must be informed of any serious adverse event and/or termination of the study.

A handwritten signature in black ink, appearing to read 'Patricia Josias'.

*Ms Patricia Josias  
Research Ethics Committee Officer  
University of the Western Cape*

**PROVISIONAL REC NUMBER - 130416-049**

# Appendix C

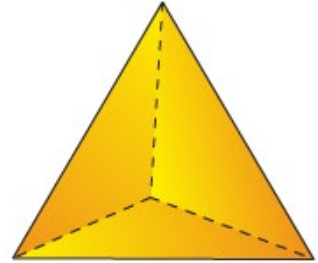
## Pre-test on 3D Geometry

---

### Platonic solids

1 What is the name of this shape?

- a. Cube
- b. Tetrahedron
- c. Octagonal Prism
- d. Square Pyramid



2 Cubes, octahedrons, and icosahedrons are all examples of:

- a. Cylinders
- b. Platonic solids
- c. Pyramids
- d. Prisms

3 Which of the following properties is true for all five Platonic solids?

- a. All faces have the same number of sides.
- b. The same number of faces meet at each vertex.
- c. Both (a) and (b) are true.
- d. Neither (a) nor (b) are true.

4 An octahedron has 8 faces and 12 edges. How many vertices does an octahedron have?

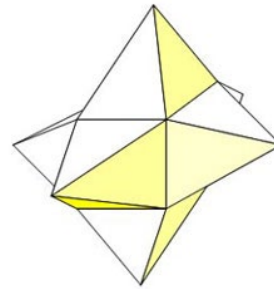
- a. 16 vertices
- b. 6 vertices
- c. 14 vertices
- d. 8 vertices

6 How many faces does an octahedron have?

- a. Six
- b. Seven
- c. Eight
- d. Nine

7 Elena created a model as follows. She began with a cube, but then she replaced each face of the cube with a square pyramid. The resulting figure had 24 faces and 36 edges. How many vertices did this figure have?

- a. 12 vertices
- b. 13 vertices
- c. 14 vertices
- d. 15 vertices



8 A dodecahedron is a Platonic solid with 12 faces. What is the shape of each face?

- a. Square
- b. Triangle
- c. Pentagon
- d. Octagon

9 How many edges does a cube have?

- a. 10 edges
- b. 12 edges
- c. 13 edges
- d. 16 edges

## Euler's Formula

10 According to Euler's Formula, the value of  $F + V - E = \underline{\hspace{1cm}}$ .

- a. 5
- b. 4
- c. 2
- d. 6

11 If  $F$ ,  $V$ , and  $E$  represent the number of faces, vertices, and edges of a polyhedron, insert addition and subtraction symbols to make the following equation true:  $F \underline{\hspace{0.5cm}} V \underline{\hspace{0.5cm}} E = 2$

- a.  $F - V \times E = 2$
- b.  $F \times V - E = 2$
- c.  $F + V - E = 2$
- d.  $F - V + E = 2$

12 A heptagonal prism (a prism whose bases have 7 sides) has 14 vertices and 9 faces. How many edges does a heptagonal prism have?

- a. 23 edges
- b. 14 edges
- c. 21 edges
- d. 31 edges

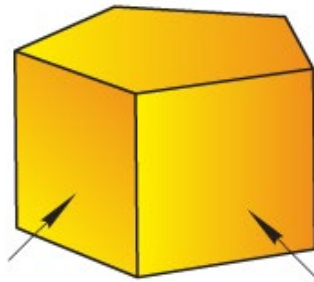
13 Buckyballs are chemical configurations discovered by Buckminster Fuller. A Buckyball is a polyhedron with 32 faces and 60 vertices. How many edges does a Buckyball have?

- a. 75 edges
- b. 90 edges
- c. 48 edges
- d. 95 edges

### Building 3D models / Prisms

14 What is the name given to the rectangles that connect the bases of a prism, as indicated by the arrows below?

- a. Lateral Faces
- b. Tetrahedron
- c. Octagonal Wall
- d. Sides



15 What polyhedron has two congruent bases that are pentagons and five lateral faces that are rectangles?

- a. Rectangle Prism
- b. Pentagonal Prism
- c. Pentagonal Cube
- d. Pentagon

16 How many faces does a pentagonal pyramid have?

- a. 4 faces
- b. 12 faces
- c. 8 faces
- d. 6 faces

17 How many edges does a pentagonal prism have?

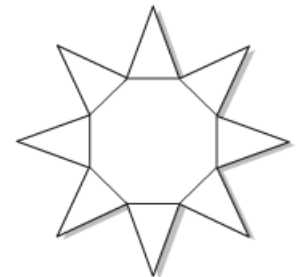
- a. 12 edges
- b. 13 edges
- c. 14 edges
- d. 15 edges

18 How many vertices does an octagonal pyramid have?

- a. 8 vertices
- b. 9 vertices
- c. 10 vertices
- d. 12 vertices

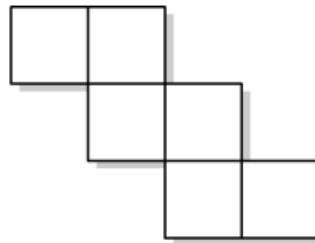
19 What is the name of the polyhedron that can be formed from the net below?

- a. (Right) Triangle
- b. (Right) Octagonal Pyramid
- c. (Right) Prism
- d. (Right) Platonic



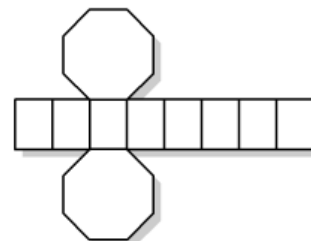
20 What polyhedron can be formed from this net?

- a. Cube
- b. Tetrahedron
- c. Octagonal Prism
- d. Square Pyramid



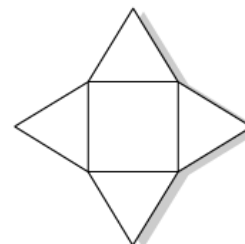
21 What polyhedron can be formed from this net?

- a. Cube
- b. Tetrahedron
- c. Octagonal Prism
- d. Square Pyramid



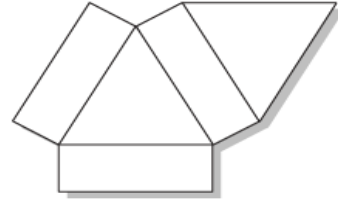
22 What polyhedron can be made from the net shown below?

- a. Pentagonal Prism
- b. Tetrahedron
- c. Platonic Solid
- d. Square Pyramid



23 What is the name of the polyhedron that can be formed from the net below?

- a. Triangular Pyramid
- b. Triangular Prism
- c. Rectangular Pyramid
- d. Rectangular Prism



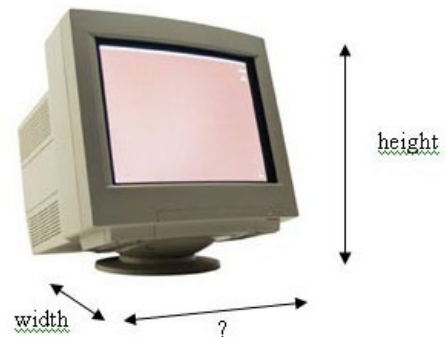
### Properties of Polyhedra including Spheres and cylinders

24 What are the three dimensions along which every object is measured?

- a. Volume, Surface, Area
- b. Diameter, Circumference, Length
- c. Length, Width, Height
- d. Area, Circumference, Height

25 Which dimensions is missing from the image below?

- a. Shape
- b. Screen Size
- c. Depth
- d. Length



26 What is the surface area of a rectangular prism that measures  $2\text{ cm} \times 5\text{ cm} \times 8\text{ cm}$ ?

- a. 132 cm
- b.  $132\text{ cm}^2$
- c.  $80\text{ cm}^2$
- d. 80 cm

27 One face of the tetrahedron shown below is  $12\text{ cm}^2$ . What is the surface area of the tetrahedron?

- a.  $48\text{ cm}^2$
- b.  $28\text{ cm}^2$
- c.  $38\text{ cm}^2$
- d.  $58\text{ cm}^2$

28 What is the volume of a cylinder with radius 5 cm and height 6 cm?

- a.  $128\pi$ , or approximately 402,  $\text{cm}^3$
- b.  $150\pi$ , or approximately 471,  $\text{cm}^3$
- c.  $108\pi$ , or approximately 380,  $\text{cm}^2$
- d.  $113\pi$ , or approximately 120,  $\text{cm}^3$

29 What is the surface area of a cube with edge length 7 cm?

- a.  $234 \text{ cm}^2$
- b.  $294 \text{ cm}^2$
- c.  $284 \text{ cm}^2$
- d.  $224 \text{ cm}^2$

30 \_\_\_\_\_ is all of the space inside a three-dimensional object.

- a. Surface Area
- b. Symmetry
- c. Volume
- d. Width

Thank you!



# Appendix D

## Post-test on 3D Geometry

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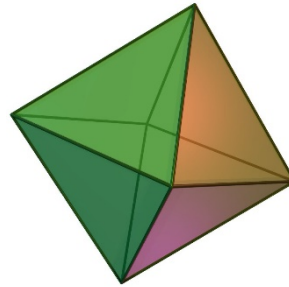
Name: \_\_\_\_\_

Grade: \_\_\_\_\_

### Platonic solids

1 What is the name of this shape?

- a. Cube
- b. Tetrahedron
- c. Octahedron
- d. Square Pyramid



2 Tetrahedrons, octahedrons, and icosahedrons are all examples of:

- a. Cylinders
- b. Platonic solids
- c. Pyramids
- d. Prisms

3 Which of the following properties is true for all five Platonic solids?

- a. All faces have different number of sides.
- b. Different number of faces meet at each vertex.
- c. Both (a) and (b) are true.
- d. Neither (a) nor (b) are true.

4 A cube has 6 faces and 12 edges. How many vertices does an octahedron have?

- a. 16 vertices
- b. 6 vertices
- c. 14 vertices
- d. 8 vertices

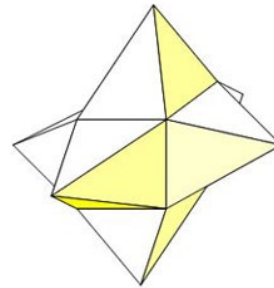
5 How many edges does a tetrahedron have?

6 How many vertices does an octahedron have?

- a. Six
- b. Seven
- c. Eight
- d. Nine

7 Elena created a model as follows. She began with a cube, but then she replaced each face of the cube with a square pyramid. The resulting figure had 24 faces and 36 edges. How many vertices did this figure have?

- a. 12 vertices
- b. 13 vertices
- c. 14 vertices
- d. 15 vertices



8 A dodecahedron is a Platonic solid with 12 faces. What is the shape of each face?

- a. Square
- b. Triangle
- c. Pentagon
- d. Octagon

9 How many edges does a tetrahedron have?

- a. 10 edges
- b. 12 edges
- c. 13 edges
- d. 8 edges

## Euler's Formula

10 According to Euler's Formula, the value of  $F + V - E - 2 = \underline{\hspace{2cm}}$ .

- a. 0
- b. 4
- c. 2
- d. 6

11 If  $F$ ,  $V$ , and  $E$  represent the number of faces, vertices, and edges of a polyhedron, insert addition and subtraction symbols to make the following equation true:  $F \text{ ___ } V \text{ ___ } E = 2$

- a.  $F - V \times E = 2$
- b.  $F \times V - E = 2$
- c.  $F + V - E = 2$
- d.  $F - V + E = 2$

12 A heptagonal prism (a prism whose bases have 7 sides) has 14 vertices and 21 edges. How many faces does a heptagonal prism have?

- a. 11 Faces
- b. 9 Faces
- c. 13 Faces
- d. 12 Faces

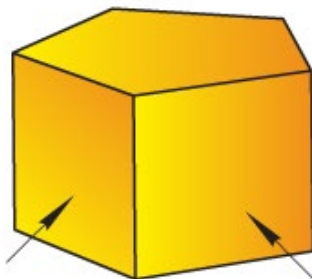
13 Buckyballs are chemical configurations discovered by Buckminster Fuller. A Buckyball is a polyhedron with 32 faces and 90 edges. How many Vertices does a Buckyball have?

- a. 120 Vertices
- b. 90 vertices
- c. 60 Vertices
- d. 58 Vertices

### Building 3D models / Prisms

14 What is the name given to the rectangles that connect the bases of a prism, as indicated by the arrows below?

- a. Lateral Faces
- b. Tetrahedron
- c. Octagonal Wall
- d. Sides



15 What polyhedron has two congruent bases that are pentagons and five lateral faces that are rectangles?

- a. Rectangle Prism
- b. Pentagonal Prism
- c. Pentagonal Cube

d. Pentagon

16 How many faces does a pentagonal pyramid have?

- a. 4 faces
- b. 12 faces
- c. 8 faces
- d. 6 faces

17 How many edges does a pentagonal prism have?

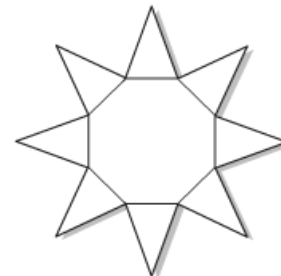
- a. 12 edges
- b. 13 edges
- c. 14 edges
- d. 15 edges

18 How many vertices does an octagonal pyramid have?

- a. 8 vertices
- b. 9 vertices
- c. 10 vertices
- d. 12 vertices

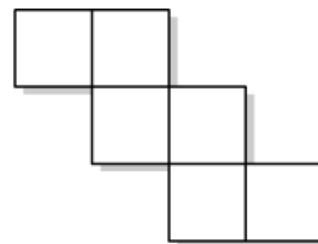
19 What is the name of the polyhedron that can be formed from the net below?

- a. (Right) Triangle
- b. (Right) Octagonal Pyramid
- c. (Right) Prism
- d. (Right) Platonic



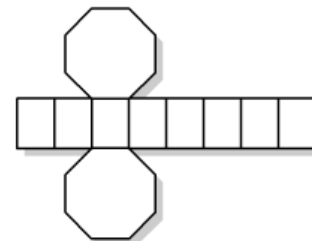
20 What polyhedron can be formed from this net?

- a. Cube
- b. Tetrahedron
- c. Octagonal Prism
- d. Square Pyramid



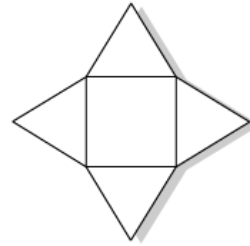
21 What polyhedron can be formed from this net?

- a. Cube
- b. Tetrahedron
- c. Octagonal Prism
- d. Square Pyramid



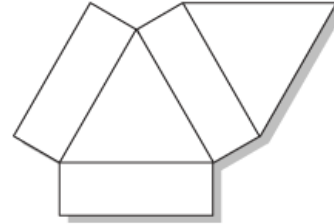
22 What polyhedron can be made from the net shown below?

- a. Pentagonal Prism
- b. Tetrahedron
- c. Platonic Solid
- d. Square Pyramid



23 What is the name of the polyhedron that can be formed from the net below?

- a. Triangular Pyramid
- b. Triangular Prism
- c. Rectangular Pyramid
- d. Rectangular Prism



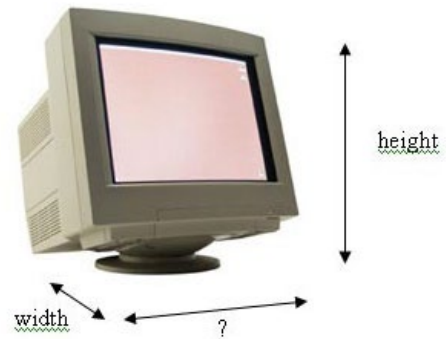
### Properties of Polyhedra including Spheres and cylinders

24 What are the three dimensions along which every object is measured?

- a. Volume, Surface, Area
- b. Diameter, Circumference, Length
- c. Length, Width, Height
- d. Area, Circumference, Height

25 Which dimensions is missing from the image below?

- a. Shape
- b. Screen Size
- c. Depth
- d. Length



26 What is the surface area of a rectangular prism that measures  $2\text{ cm} \times 5\text{ cm} \times 4\text{ cm}$ ?

- a. 76 cm
- b.  $76\text{ cm}^2$
- c.  $40\text{ cm}^2$
- d. 40 cm

27 One face of the tetrahedron shown below is  $10 \text{ cm}^2$ . What is the surface area of the tetrahedron?

- a.  $40 \text{ cm}^2$
- b.  $50 \text{ cm}^2$
- c.  $38 \text{ cm}^2$
- d.  $30 \text{ cm}^2$

28 What is the volume of a cylinder with radius 5 cm and height 6 cm?

- a.  $128\pi$ , or approximately 402,  $\text{cm}^3$
- b.  $150\pi$ , or approximately 471,  $\text{cm}^3$
- c.  $108\pi$ , or approximately 380,  $\text{cm}^2$
- d.  $113\pi$ , or approximately 120,  $\text{cm}^3$

29 What is the surface area of a cube with edge length 3 cm?

- a.  $18 \text{ cm}^2$
- b.  $9 \text{ cm}^2$
- c.  $54 \text{ cm}^2$
- d.  $36 \text{ cm}^2$

30 \_\_\_\_\_ is all of the space inside a three-dimensional object.

- a. Surface Area
- b. Symmetry
- c. Volume
- d. Width

Thank you!

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# Appendix E

## Topic Plan

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**Geometry of 3D objects**

**Time: 3,5 hours**

**Term 4: Week 3**

**Topic Planning:**

Lesson 1: Pre-test on 3D objects

Lesson 2: Platonic Solids and Euler's formula

Lesson 3: Properties on Spheres and Cylinders

Lesson 4: Surface area and volume of Prisms and Cylinder

Lesson 5: Nets on 3D objects

Lesson 6: Consolidation

Lesson 7: Post-test on 3D objects

# Appendix F

## Curriculum and Assessment Policy Statement

CONTENT AREA	TOPICS	CONCEPTS AND SKILLS	SOME CLARIFICATION NOTES OR TEACHING GUIDELINES	DURATION (in hours)
	3.2 <b>Geometry of 3D objects</b>	<b>Classifying 3D objects</b> <ul style="list-style-type: none"> <li>• Revise properties and definitions of the 5 Platonic solids in terms of the shape and number of faces, the number of vertices and the number of edges</li> <li>• Recognize and describe the properties of:               <ul style="list-style-type: none"> <li>- spheres</li> <li>- cylinders</li> </ul> </li> </ul> <b>Building 3D models</b> <ul style="list-style-type: none"> <li>• Use nets to create models of geometric solids, including:               <ul style="list-style-type: none"> <li>- cubes</li> <li>- prisms</li> <li>- pyramids</li> <li>- cylinders</li> </ul> </li> </ul>	<b>What is different to Grade 8?</b> <ul style="list-style-type: none"> <li>• Properties of spheres and cylinders</li> <li>• Nets of cylinders</li> </ul> <b>Platonic solids</b> <ul style="list-style-type: none"> <li>• Properties of Platonic solids should be revised</li> <li>• Platonic solids are a special group of polyhedra that have faces that are congruent regular polygons.</li> <li>• There are only 5 Platonic solids:               <ul style="list-style-type: none"> <li>- tetrahedron</li> <li>- hexahedron (cube)</li> <li>- octahedron</li> <li>- dodecahedron</li> <li>- icosahedrons</li> </ul> </li> <li>• The name of each Platonic solid is derived from its number of faces.</li> <li>• Platonic solids provide an interesting context in which to investigate the relationship between the number of faces, vertices and edges. By listing these properties for all the Platonic solids learners can investigate the pattern that emerges, to come up with the general rule:  <math>V - E + F = 2</math>, where <math>V = \text{number of vertices}</math>; <math>E = \text{number of edges}</math>; <math>F = \text{number of faces}</math></li> </ul> <b>Using and constructing nets</b> <ul style="list-style-type: none"> <li>• Using and constructing nets are useful contexts for exploring or consolidating properties of polyhedra.</li> <li>• Learners should recognize the nets of different solids.</li> <li>• Learners should make sketches of the nets using their knowledge of the the shape and number of faces of the solids, before drawing and cutting out the nets to build models.</li> <li>• Since learners have more knowledge about the size of the internal angles of polygons, and can measure angles, their constructions of nets should be more accurate.</li> <li>• Learners have to work out the relative position of faces of the nets in order to build the 3D model.</li> </ul>	Total time for geometry of 3D objects:  9 hours



# Appendix G

TEACHER TIMETABLE: M. Thiar												
		1	2	3	4	1st Break	5	6	7	2nd Break	8	9
<b>Monday</b>	07:45 - 07:55 REG	08:00 - 08:40 9.2	08:40 - 09:20 9.3	09:20 - 10:00 9.3	10:00 - 10:40 9.1	10:40 - 11:05	11:05 - 11:45 ADMIN	11:45 - 12:25 9.2	12:25 - 13:05 10	13:05 - 13:30	13:30 - 14:05 ADMIN	14:05 - - 14:40 11
<b>Tuesday</b>	07:45 - 07:55 REG	08:00 - 08:40 9.1	08:40 - 09:20 ADMIN	09:20 - 10:00 9.3	10:00 - 10:40 ADMIN	10:40 - 11:05	11:05 - 11:45 ADMIN	11:45 - 12:25 9.2	12:25 - 13:05 10	13:05 - 13:30	13:30 - 14:05 11	14:05 - - 14:40 11
<b>Wednesday</b>	07:45 - 08:35 REG / CHOIR	8:35 - 09:10 9.3	09:10 - 09:45 10	09:45 - 10:10 1st BREAK	10:10 - 10:45 9.2	10:45 - 11:20 9.1	11:20 - 11:55 11	11:55 - 12:20 2nd BREAK	12:20 - 12:55 9.2	12:55 - 13:30 10	13:30 - 14:05 ADMIN	14:05 - - 14:40 9.1
<b>Thursday</b>	07:45 - 07:55 REG	08:00 - 08:40 ASSEMBLY	08:40 - 09:20 11	09:20 - 10:00 11	10:00 - 10:40 10	10:40 - 11:05	11:05 - 11:45 9.3	11:45 - 12:25 9.1	12:25 - 13:05 10	13:05 - 13:30	13:30 - 14:05 9.1	14:05 - - 14:40 9.2
<b>Friday</b>	07:45 - 07:55 REG	08:00 - 08:35 MINI TEST		08:35 - 09:15 11	09:15 - 09:40 1st BREAK	09:40 - 10:20 ADMIN	10:20 - 10:55 9.1	10:55 - 11:30 10	11:30 - 11:55 2nd BREAK	11:55 - 12:30 9.2	12:30 - 13:05 9.3	13:05 - - 13:40 9.3

# Appendix H

## Application letter to school

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1 February Close  
Helderzicht  
Somerset West  
7130  
16 September 2006

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Principal  
Meridian Pinehurst

Dear Sir

### **Application for conducting research at Meridian Pinehurst**

I hereby wish to apply for permission to conduct research for my PhD Degree at your school. I also ask permission for the use of your Mathematics Room for 1 one-hour session per week with a selected group of grade 9 learners.

I do intend to intervene for a maximum of 3 months, but I will be considerate enough not to cause a distraction to your normal daily programme.

Furthermore, I request your permission to conduct interviews with your Mathematics teacher as well as the grade 9 learners.

I do thank you for your attention.

Yours faithfully  
Mr A. Williams  
083 235 2154

# Appendix I

## Software Assessment Rubrics

	5	4	3	2	1	Remarks
<b>Instructional Adequacy</b>						
Are the outcomes of this lesson clearly stated?						
Are the instructions easy to follow?						
Do you understand what you are doing?						
Is there a lot of interaction needed from you to reach the outcomes?						
Does the programme give you examples of how things must be done?						
Is the computer addressing you by name?						
Is the computer guiding you through the steps?						
Is there a Help button or any button of assistance?						
The pupil determines the pace at which the lesson conducted?						
Were you enthusiastic to finish the lesson?						
Could you score any marks?						
Could the computer store your marks to continue at another time?						
Could you stop at any stage of the lesson?						
Is the screen space used effectively?						
Is the screen attractive?						
Did the colour and/or sound disturb you in any way?						
Did you like the effects on the screen?						
Did you have to scroll up or down?						
Was the lesson appealing to you?						
<b>Curriculum Adequacy</b>						
Is the topic relevant to the present syllabus?						
Does the programme enhance knowledge, skill and attitudes?						
Does the lesson contain information that is likely to become outdated?						
Can the lesson be complete within a school's period?						
Has it taken less time than your normal experiment in class?						
<b>Cosmetic Adequacy</b>						
Do you need special hardware to run this programme?						
Could you acquire any skills from using this programme?						
Do you enjoy this way of teaching?						
Was this lesson more fun than your normal chemistry class?						
Can this lesson also be integrated with other subjects at school?						

<b>Programme Adequacy</b>						
Will this programme run on any standard computer?						
Did you have any problems in operating the programme?						
Can you save your work and continue at another stage?						
Can anybody else work on your experiment after you log out?						
Does the system terminate when you press a wrong key?						
Does the programme have an assessment build into it?						
Does it give guidance in case of a wrong answer submitted?						
Can you give more than one right answer to a question?						
Does the programme allow different case answers, spelling errors, etc?						
Does the lesson display information accurately?						

# Appendix J

## Responses to Survey Question 2

**Q2. What are the Apps that you are using in the Mathematics classroom?**

Teacher	Responses	
Teacher 1	GeoGebra, YouTube, MiEbooks,	
Teacher 2	GeoGebra, YouTube, MiEbooks, Modlin, TeamViewer	
Teacher 3	GeoGebra, MiEbooks, Intelligent Practice	
Teacher 4	GeoGebra, Everything Maths, MiEbooks	
Teacher 5	MiEbooks, Share It, YouTube	
Teacher 6	YouTube, MiEbooks, Modlin	
Teacher 7	GeoGebra, MiEbooks, Excel	
Teacher 8	YouTube, MiEbooks	
Teacher 9	GeoGebra, MiEbooks	
Teacher 10	GeoGebra, MiEbooks, Excel	
Teacher 11	GeoGebra, MiEbooks	
Teacher 12	GeoGebra, YouTube, MiEbooks, TeamViewer	
Teacher 13	GeoGebra, MiEbooks, Kahoot	
Teacher 14	GeoGebra, YouTube, MiEbooks,	
Teacher 15	GeoGebra, MiEbooks	
Teacher 16	MiEbooks, Modlin	
Teacher 17	GeoGebra, MiEbooks	
Teacher 18	Everything Maths, MiEbooks, YouTube	
Teacher 19	MiEbooks, Kahoot	
Teacher 20	GeoGebra, YouTube, MiEbooks,	
Teacher 21	GeoGebra, MiEbooks, TeamViewer	
Teacher 22	YouTube, MiEbooks	
Teacher 23	GeoGebra, MiEbooks	
Teacher 24	MiEbooks	
Teacher 25	MiEbooks, Modlin, YouTube, TeamViewer	

Q2 Export ▾

## What are the Apps that you are using in the Mathematics classroom?

Answered: 25 Skipped: 2

● Responses (25) ☁ Text Analysis 📁 My Categories

**PRO FEATURE** ✕

Use text analysis to search and categorize responses; see frequently-used words and phrases. To use Text Analysis, upgrade to a GOLD or PLATINUM plan.

[Upgrade](#) [Learn more »](#)

Categorize as... ▾ Filter by Category ▾ Search responses 🔍 ?

Showing 25 responses

Only the textbook	10/20/2016 10:30 AM	<a href="#">View respondent's answers</a>
Geogebra	10/18/2016 12:41 PM	<a href="#">View respondent's answers</a>
Geogebra, You tube, MieBooks, Modlin Grade 11	10/14/2016 12:43 PM	<a href="#">View respondent's answers</a>
GeoGebra Mi-EBooks Intelegant Practice (Maths) Unity	10/13/2016 2:49 PM	<a href="#">View respondent's answers</a>
App-Geogebra Website-Everything maths Website-Kahoot	10/12/2016 12:14 PM	<a href="#">View respondent's answers</a>
share it, you tube, miEbooks,calculator,my files,s planner,s note,google.	10/12/2016 10:06 AM	<a href="#">View respondent's answers</a>
none	10/12/2016 8:14 AM	<a href="#">View respondent's answers</a>

**Figure 6.7** A screenshot of the survey on “what Apps are teachers using in the classroom”

# Appendix K

## Responses to Survey Question 3

### Q3. Please elaborate on why you are using these specific Apps?

Teacher	Responses	
Teacher 1	Useful and Fast. Cool Visuals. Discovery learning. Electronic Assessments. Timesaving	
Teacher 2	User-friendly. Assist in understanding. Cool Visuals. Feedback	
Teacher 3	Pushing resources. Textbook. Assessments. Discovery learning. User-friendly. Extra Exercisers. Electronic Assessments. Timesaving	
Teacher 4	Understanding. Fun and Interesting. Flip Classroom. Discovery learning. Cool Visuals. User-friendly. Extra Exercisers. Features and Flexibility	
Teacher 5	Pushing resources. Assist in understanding. Textbook. Electronic Assessments. Timesaving. Feedback. fast	
Teacher 6	Assist in understanding. Textbook. Cool Visuals. Electronic Assessments. Flipped Classroom	
Teacher 7	Pushing resources. Textbook. User-friendly. Extra Exercisers. Flipped Classroom. Accessible. GeoGebra on two screens helps learners with understanding	
Teacher 8	Assist in understanding. Discovery learning. Part of learners' life. All the learners' textbooks on one tablet. Flipped classroom helps with collaboration in class.	
Teacher 9	Pushing resources. assist in understanding. Textbook. Extra Exercisers. Flipped Classroom. Features and Flexibility. Learners do not need to carry heavy textbooks.	
Teacher 10	Pushing resources. assist in understanding. Textbook. Extra Exercisers. Electronic Assessments. Flipped Classroom. Useful. Immediate feedback and tracking in Modlin helps the learners to assess themselves.	
Teacher 11	Assist in understanding. Discovery learning. Accessible. Learners can connect to one screen to make collaboration possible.	
Teacher 12	Pushing resources. Textbook. Cool Visuals. Feedback. Accessible	
Teacher 13	Pushing resources. Assists in understanding. Timesaving. Features and Flexibility. Useful especially in watching educational videos. Learners can watch it repetitively.	
Teacher 14	Pushing resources. Textbook. User-friendly. Extra Exercisers	
Teacher 15	Discovery learning. Cool Visuals. User-friendly. Electronic Assessments. Timesaving. Flipped Classroom. Videos can be sent to learners prior to the lesson for them to watch.	
Teacher 16	Pushing resources. Assist in understanding. Discovery learning	
Teacher 17	Sharing enhanced resources in the textbook. No need to make copies for learners anymore. Assist in understanding. Textbook	
Teacher 18	Discovery learning makes classes meaningful.	

Teacher 19	Pushing resources. Textbook. User-friendly. Extra Exercisers. E-books are cheaper than hardcopy books.	
Teacher 20	Assist in understanding. Discovery learning. Part of learners' life	
Teacher 21	Pushing resources. Assist in understanding. Only App available	
Teacher 22	Pushing resources. Textbook. Cool Visuals. Learners can even project on the screen from their tablets.	
Teacher 23	Pushing resources. Assist in understanding. Textbook. Only Apps available. TeamViewer makes it possible to project from my tablet.	
Teacher 24	Cool Visuals. User-friendly. Electronic Assessments. Only Apps available. YouTube teaches both learners and teachers.	
Teacher 25	Pushing resources. Textbook. Electronic Assessments. Part of learners' life. GeoGebra runs quickly even on the Raspberry Pi computers.	



# Appendix L

## Responses to Survey Question 4

**Q4. Please describe how and when you are using the Apps mentioned above.**

Teacher	Responses	
Teacher 1	Use GeoGebra for functions.	
Teacher 2	Use Apps on a daily basis.	
Teacher 3	For teaching specific topics in GeoGebra. MiEbooks for every lesson.	
Teacher 4	For explanation of concepts. Learners do discovery and independent learning. Self-evaluation in testing answers or graphs.	
Teacher 5	As Introduction. For recapping purposes. In conclusion to summarise.	
Teacher 6	For verification of answers. Learners would first do the functions manually in the workbooks and then go to GeoGebra and verify their results.	
Teacher 7	Substituting the textbook and adding resources.	
Teacher 8	Visual images help learners to understand better.	
Teacher 9	To introduce new concepts.	
Teacher 10	As a recapping tool. Learners can engage with the Modlin App at home as it is adjusting the exercisers to the learners' level of understanding. If a learner is not successful. the App will give more of the same exercisers until it is mastered.	
Teacher 11	To teach inductively and draw conclusions. Learners played around with variables and saw the changes in the graph on the second window. Learners could now detect patterns and conclude with a rule.	
Teacher 12	Discovery learning and communication. The MiEbooks App allows me to post work well before the time and the App releases it a day before the actual class.	
Teacher 13	For collaboration in class. For groupwork. The assessment in MiEbooks displays differently on the learners' tablets as it is randomised. Learners sitting next to each other will have different questions in different order.	
Teacher 14	To watch simulations and videos beforehand. I use the Educator Console as the back-end of MiEbooks to load videos onto the learners' tablets for them to watch at home the day before. For video conferencing.	
Teacher 15	To assist in doing investigations. After projecting images on the whiteboard. the teacher can manipulate the image by turning the image and inspect the back of it. Learners can now easily count the faces, the edges and vertices of a 3D image.	

Teacher 16	For assessment in MiEbooks. Learners do assessments in the MiEbooks App. The tablet marks their results and post it in a log file where the learners have access to the marks.	
Teacher 17	Use as revision and consolidation of concepts.	
Teacher 18	Connect tablet to Computer via TeamViewer and project on whiteboard.	
Teacher 19	For independent learning. Learning by discovery. Learners would watch the coursework at home and collaborate the next morning in groups. This flipped classroom technique is quite powerful.	
Teacher 20	For graphing and manipulating graphs.	
Teacher 21	Self-learning. As a homework tool and for remedial purposes through Modlin.	
Teacher 22	For teaching certain geometry topics.	
Teacher 23	To share screens of learners and project on whiteboard. Learners do not have to walk to the whiteboard to share their work with the rest of the class, they can simply connect to the teacher's laptop and everyone can watch their work on the big screen.	
Teacher 24	To push videos and other resources to learners. Videos are power learning tools and learners can watch it over and over until the grasp the concept.	


# Appendix M

## Survey

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### Tablets in the classroom

#### Survey on the use of tablets in the mathematics classroom


1. Are you currently using tablets in your classroom? 

Yes

No

2. What Apps are you currently using in the mathematics class? 

3. Why are you using these particular Apps in the maths classroom? 

4. How are you using these Apps in the mathematics classroom? 

Done