Haaga-Helia
University of Applied Sciences Ltd.

Developing a technology-based learning environment to improve the teaching of high school mathematics in South Africa

Andile Mji

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Author(s)
Andile Mji

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Abstract

In this developmental study, the main objective was to develop a technology-based learning environment to improve the teaching of high school mathematics in South Africa. The basis for this was the few students who perform well in Grade 12 mathematics and as a result qualify for university entrance for professional qualifications. Before thinking about solutions, the study asked the following, (a) What are the attitudes of teachers about technology in general (affinity to technology)? (b) How likely were teachers to search for mathematical apps and incorporate these in their teaching? and (c) What are teachers' views about the utility of mathematical apps in their classrooms?

Participants were 22 Grade 12 mathematics teachers. Their ages ranged between 23 years and 53 years (M = 41.6 years; SD = 10.1). In addition, their teaching experience ranged between 4 years and 18 years (M = 11.9 years; SD = 4.6). The teachers initially completed an Affinity for Technology Questionnaire (ATQ). The ATQ is an instrument that is use to determine people who like or dislike technology. Following the completion of the ATQ, the teachers attended three workshops meant to expose them to teaching with technology, specifically, teaching mathematics using apps. At the end of the workshops, the teachers responded to one-on-one interviews where questions related to their experiences in the workshops.

The results revealed that on the main, the teachers had negative attitudes toward technology. While most rated themselves as technophobic. On the one-on-one interviews, the teachers' responses fell into three groups, namely, the *fear of failure*, the *early adopters*, as well as the *wait and see* group. In fact, the responses of most of the teachers complemented the quantitative findings in that they confirmed negative attitudes toward technology. The analysed data and the results were extremely useful in advocating for teaching with technology in South African schools. As a result, the researcher proposed a new module and a study guide for teaching with technology in the School of Education at TUT. In fact the study recommended that both pre- and in-service teachers should be trained to utilise technology in their classrooms. The study provides a business canvas that outlines the gains, risk and mitigation plans. The limitations of the study are also indicated including a personal reflection in undertaking the study.

Keywords
Affinity to technology, Learning environment, Teaching, Mathematics, Applications

Contents

Abbreviations

ATQ	Affinity for Technology Questionnaire
Apps	Applications
BSc	Bachelor of Science
CHE	Council for Higher Education
CPD	Continuing Professional Development
DBE	Department of Basic Education
HEQF	Higher Education Qualifications Framework
HEQSF	Higher Education Qualifications Sub-Framework
Hons	Honours
ICASA	Independent Communications Authority of South Africa
ICT	Information and Communication Technology
ITE	Initial teacher education
MSBE	Department of Mathematics, Science and Business Education
NQF	National Qualification Framework
SET	Science, Engineering and Technology
SoE	School of Education
TP	Teaching Practice
TUT	Tshwane University of Technology
UNISA	University of South Africa
UWC	University of Western Cape

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1 Introduction

> It can be said that there are four basic and primary things that the mass of people in society wish for: to live in a safe environment, to be able to work and provide for themselves, to have access to good public health and to have sound educational opportunities for their children. Currently, we as a society may be struggling in each of those four areas, but we must remain confident that with the personal commitment of each and every one of us we can and will overcome the obstacles towards development (Mandela 2007).

South Africa, as a developing country finds itself in need of specialist professionals in areas such as Accountancy, Chemistry, Engineering, Information and Communication Technology (ICT), Medicine, Physics, and many others. These professions are critical because South Africa has had an exclusionary system in its past which has resulted in a shortage of suitably qualified professionals in many fields of specialization. The exclusionary past has meant that generations of Africans did not attain professional qualifications. This invariably suggests that very few Africans could contribute meaningfully to the country's economy. Provided, are two examples that illustrate the need for critical professional skills. The first example is about medical doctors who are important in ensuring that the nation is healthy. In South Africa, there is one government-employed doctor expected to examine and treat 2 457 patients (Mwiti 2018). The second example is about engineers who are critical in a number of areas. Engineers are responsible for road and rail infrastructure, electricity generation, as well as developing lifesaving medical equipment. In South Africa though, there is one engineer servicing 2 600 people which is way above the international norm of one engineer to 40 people (Patel 2017).

What the foregoing shows is that the country certainly needs a number of school-going children to take subjects such as mathematics and science at school. Here, the hope is that they will proceed to complete degrees in the professional skills the country desperately needs.

1.1 Context

A major problem among Grade 12 students in South Africa is that very few of those taking mathematics and science perform well in order to receive university admission (see Table 1). The table shows that in five years (2014 – 2018), between 31.9% and 37.1% Grade 12 students achieved a mathematics mark that allowed them to register at a university. This suggests that between 63% and 68% are unable to proceed to degrees that the country needs. The resultant effect is that even fewer will take specialist degrees in Science, Engineering and Technology (SET).

Table 1.1 Grade 12 candidates' performance at 40% and above in mathematics for the years 2014 - 2018*

Year	**South Africa**		
	Wrote (n)	Achieved	%
2014	225458	79050	35.1
2015	263903	84297	31.9
2016	265810	89084	33.5
2017	245103	86089	35.1
2018	233858	86874	37.1

* Department of Basic Education (2019)

Literature has proffered a number of reasons for the poor performance in mathematics in South Africa. From the government perspective, the minister of Education has identified the teaching of the subject as of poor quality where the teachers were unable to answer questions on what they were supposed to teach (The Citizen 2016). Another area identified to present a problem in learning mathematics, is the language of, and the language used in mathematics. In this regard, the argument is that mathematical "… ability is coupled with the requirement to develop the language skills of the competent rational problem-solver (Chronaki & Planas 2018, 1103). This suggests that sometimes learners from different backgrounds may use their home language as long as they understand that they are "… socialised in a particular curriculum and schooling context mediated by the language of mathematics and the teacher" (Chronaki & Planas 2018, 1108). There is a possibility that the non-recognition of learners' home languages leads to them not performing well in mathematics in South Africa.

The poor student performance in mathematics may be a result of teaching approaches. The teacher is one of the key players in the learning and teaching context. It is important therefore that the approaches teachers follow in the classroom are more learner-centered than teacher-centered. About this, there has been criticism of traditional instructional methods for their failure to prepare contemporary societal challenges because lately the concentration is on constructivist approaches which are learner-centered (Hannafin & Land 1997). In learner-centered approaches, the teacher is the facilitator of learning. This suggests that learners assume the responsibility of learning. The learner-centered approach affords students the opportunity to be independent problem solvers. In addition, it gives them a chance to become lifelong learners. In the teacher-centered approach meantime, the teacher is the expert who decides proceedings in the classroom. The teacher is the only one who is active, which renders students passive.

Learning is a process that may result in a change of behaviour, thoughts and feelings based on what is experienced. It may take place within an individual or at a social level among a number of learners. In terms of a number of learners, learning may be collaborative in nature. Collaborative learning involves, for instance, students working together in groups to achieve a common goal. In most instances, students do not start with facts but rather with problems where they navigate through information to make sense of and find solutions. An advantage of collaborative learning is that students with different competencies on a topic may share what they know and may assist those who did not know about it. In this regard, the argument is that collaborative learning "… produces intellectual synergy of many minds coming to bear on a problem, and the social stimulation of mutual engagement in a common endeavour" (Smith & MacGregor 1992, 2). Of importance here, is the fact that students learn from each other. This sometimes may be from the guidance provided by their teacher.

A requirement for knowledge in any subject such as mathematics is trial and error including repetition of the learning of concepts and ideas. Students acquire knowledge when they take responsibility for their learning and share their experiences with others. In the 21st century that is, in the age of technology, connectivism has become an essential teaching approach. It is a learning theory of the digital age that is learner-centered while focussing on competencies and skills. Siemens (2005, 7) indicates the principles of connectivism as:

- Learning and knowledge rests in diversity of opinions
- Learning is a process of connecting specialized nodes of information sources
- Learning may reside in non-human appliances
- Capacity to know more is more critical than what is currently known
- Nurturing and maintaining connections is needed to facilitate continual learning
- Ability to see connections between fields, ideas, and concepts is a core skill
- Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities
- Decision-making is itself a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now it may be wrong tomorrow due to alteration in the information climate affecting the decision.

The premise of connectivism is sharing information, interrogating and creating new knowledge. Connectivism allows for active learning where students may pace their learning or work collaboratively. It affords students the opportunity to be in control and to determine their learning experiences. In fact, Thota (2015, 86) argues that the connectivist learner "… is seen as nurturing and maintaining connections to facilitate continual learning and as developing the ability to synthesize and recognize connections among fields, ideas, and concepts."

Technology forms the basis of connectivism through using gadgets such as smartphones and tablets; tools such as Moodle and electronic Mindmaps software; as well as facilities such as social media like Twitter and blogs. An important aspect here is that students should engage in meaning-making when using technology. This means that when using technology, a student has an opportunity to find new information. Using the information, the student has a chance to modify their beliefs because of what they have learned. With technology, the students also have a chance to learn and build on what they know by finding new information. An advantage of technology is that students do not need to memorise what they are learning because it is readily available.

The preceding has provided a context of the performance of Grade 12 mathematics students in examinations over a five-year period in South Africa. Specifically, the context revealed that more than 60% of the students failed to obtain marks that would allow them to register for SET degrees at university. A discussion on learner-centered teaching was introduced where the aim was to highlight how this approach could help improve learning. Furthermore, a discussion on collaborative learning and connectivism followed. Here the aim was to illustrate how technology may form part of the teaching approach in order to improve students' performance in mathematics. This is especially when one looks at the boom of apps in the last while. Literature points out that from 2008 to 2015, these increased from 5000 to 1.75 million in Apple's App Store while by 2020 the expectation is for these to rise to 5 million (Nelson 2016).

The Independent Communications Authority of South Africa (ICASA) reports that smartphone penetration was at 81.7% in September 2018 (Gilbert 2019). This suggests that most students and teachers in South Africa tend to possess a smartphone. Earlier a discussion on connectivism, which is technology-based, showed that it provides a good platform for active learning. That is, technology may provide a platform wherein students may learn mathematics for understanding. In utilising technology, students may work collaboratively for instance, and in doing that improve performance in tests and examinations. Improvement of performance in mathematics has the added benefit of increasing the number of students taking science, engineering and technology degrees in South Africa. On a long-term basis, the benefit will accrue to South Africa's economy because the numbers of accountants, doctors, engineers, and ICT specialists will improve. The aim of this study, therefore, was to explore the use of smartphones in teaching high school mathematics in South Africa.

The context presented here, was meant to reveal how very few Grade 12 students in South Africa get admitted for university education. In addition, how those who perform poorly lead to the country running short of professionals with qualifications desperately needed. Importantly, this context further provides a substantive justification for the undertaking of this developmental study.

1.2 Overview of chapters

This section provides a brief chapter-by-chapter outline of what each addresses.

Chapter 1: This chapter provides the introduction of the study. Included in the introduction is the context that provides a clearer picture of the state of the teaching and learning of mathematics from a South African perspective.

Chapter 2: The chapter deals with the study objectives. Included here, is a concise explanation of the expected outcomes. The chapter also presents the research questions, which form the foundational basis for undertaking this developmental study. Finally, the scope of the study is addressed.

Chapter 3: This chapter addresses the theoretical framework of this developmental study. Specifically, the chapter focuses on learning theories, teaching strategies as well as teaching with technology.

Chapter 4: The chapter outlines an overview of the research methodology of this developmental study. This begins with a description of the research design of the study. Specifically, it provides a description of the methods used to obtain a sample, the procedure for qualitative and quantitative data collection as well as its analysis. Finally, ethical issues addressed in the study are outlined.

Chapter 5: The chapter on implementation and outcomes presents the results from both the qualitative and quantitative perspectives. Included here, is biographical data giving different aspects about the participants.

Chapter 6: This chapter discusses the results and in many ways connects these to literature. The chapter also deals with recommendations based on the outcomes. Importantly, the chapter addresses the process of developing a study guide at the university. In addition, the chapter provides information relating to the business canvass in respect of developing a module. The chapter concludes with a contribution on the limitations of the study and a personal reflection.

2 Objectives

In terms of megatrends in Africa, the Generation 2030 Africa report (UNICEF 2014) points to a number of issues that need to be considered in focusing on the objective of this study. The megatrends among others focus on Africa's demographics; the rise of individuals related to advances in education, health and technology; the influence of information and communication technology (ICT); climate change issues; and urbanization. For instance, it is projected that by 2030 more than 50% of Africa's population will be urbanized (UNICEF 2014). These megatrends suggest that future classrooms will be overcrowded. This means that there shall be more diverse groups of students which will need an emphasis on teaching with technology and equipping students with practical skills. In addition, the megatrends suggest that health requirements, food security and the need for suitable and safe housing will quadruple. These trends point to the fact that Africa is already in dire need of professionals in medicine, in agriculture, engineering and many other related professions. This is more so considering that 2030 is already less than a decade away.

What the foregoing shows is that there is need for a concerted effort to change the way teaching and learning takes place. Literature for example shows that the use of technology in the classroom remains somewhat limited in a number of schools (Teo 2009). This, despite the fact that technology has the potential to support constructivist approaches to learning and promote interaction and collaboration with others (Schindler, Burkholder, Morad & Marsh 2017). Literature points out that an effective method in the acquisition of procedural skills and knowledge in mathematics is working examples correctly (Große & Renkl 2007; Adams, et al. 2014). This is critical because it allows students to see how each step is covered in reaching a solution. The acquisition of procedural skills and knowledge becomes useful when, from a constructivist perspective, students have to draw from previous facts in solving problems that are more complex.

In this study, the researcher felt that incorporating technology in terms of mathematical applications (apps) would be ideal in helping high school mathematics teachers guide students in working examples correctly. This, especially since smartphone usage and ownership is high in South Africa. In addition, mathematical applications apps are readily available on Google Play (android) and App Store (Apple). Therefore, uploading apps would not necessarily be a burden for teachers. In addition, an advantage of using smartphones is that learning may take place anytime and everywhere, that is, even outside of the classroom (Drigas & Pappas 2015). Literature also points out that when good "… pedagogy drives the incorporation of technology into mathematics teaching and learning, ICTs have immense potential to enhance students' experiences with mathematics (Attard, & Northcote 2011, 30).

Importantly, technology has the advantage of presenting complex and sometimes abstract information in an easy to comprehend manner. In addition, through seeing an abstract concept, students may find a way of explaining it and as a result never forget it. About this issue, researchers (e.g., Kiyici, Erdogmus & Sevinc 2007; Kutluca & Tum 2017) report that both pre- and in- service teachers believed that visualisation (from using technology) was important in mathematics because it improved students' persistence, allowed them to use their time efficiently while assisting them to learn effectively. The primary objective of this developmental study therefore, was to improve Grade 12 mathematics students' performance in South Africa. Specifically, the endeavour was to develop a technology based learning environment to improve the teaching of high school mathematics. The view here was, by focussing on teachers in terms of finding ways and means to assist them to enhance their teaching; this would invariably improve students' performance.

In undertaking this developmental study therefore, the secondary objectives were three-fold. Firstly, to explore the teachers' attitudes toward technology. Especially teaching through using mathematical apps. Secondly, to establish the likelihood of the teachers looking for mathematical apps and incorporating such in their classrooms. Thirdly, to find out the teachers' views on whether using the apps had the potential to improve teaching as well as help improve students' performance in the subject. Accomplishing these secondary objectives involved (i) delving on reviewing relevant literature, (ii) engaging the stakeholders (teachers), (iii) designing, and developing a study guide.

(i) Literature review

The objective was to read literature dealing with teaching with technology and incorporate it here. This was done to justify the importance of two pedagogical issues. Firstly, to justify importance of the knowledge and skills in teaching with technology. Secondly, to justify how the teachers might use the knowledge and skills to help improve student understanding of and performance in mathematics.

(ii) Engaging the stakeholders

Here the objective was to engage teachers directly by introducing them to different mathematical apps. The aim here was to expose them to the different apps and thereby enhance their teaching competencies. This in effect would add a powerful teaching strategy that they could use to improve students' understanding of Grade 12 mathematics.

(iii) Design and develop a study guide for using apps in mathematics module

As the Head of the School of Education (SoE) at TUT, the researcher's objective was to propose the development of a study guide dealing with this subject area in the MSBE Department. The aim here was to ensure that all students taking education and specialising in mathematics and science were exposed to teaching with technology. In addition, offering such a module would mean that lecturers too had to familiarise themselves with the principles of teaching with technology. In doing that, this will empower the lecturers in the SoE to be experts in the area of teaching mathematics with technology. A fortuitous spin-off of the objective of a study guide on teaching with technology is that in the times of Covid-19, TUT may benefit immensely. TUT may benefit because teaching would take place through online connectivity, which should assist in respect of strict government imposed lockdowns. Lockdowns meant that traditional face-to-face teaching stopped. As a result, alternate methods had to be found if teaching and learning was to continue.

Literature points out that at the outset a hands on learning project should have well defined goals. This allows the project to contribute positively to students' education (Jazwa 2017). Researchers argue, "… goals specify the desired outcomes or performance that should be realized, whereas performance refers to what is actually accomplished" (van der Hoek, Groeneveld, & Kuipers 2016, 474). In this developmental study, the goals were four-fold. These were:

1. To introduce teaching with technology to teachers of mathematics
2. Demonstrate the utility of augmenting teaching through the use of mathematical apps
3. Encourage group work opportunities in which tasks are accomplished collaboratively
4. Encourage teachers to adopt using apps in their classrooms

These goals were consistent with this study's objective of developing a technology based learning environment to improve the teaching of high school mathematics. In addition, in successfully accomplishing the goals, this ostensibly would lead to better performance in mathematics by students. This view resonates with findings that mathematical apps help enhance students' learning and achievement (Etcuban & Pantinople 2018). What is certain is the fact that students come to the classroom possessing different understandings about and attitudes toward mathematics. It is important therefore that teachers should implement a variety of approaches to influence better outcomes (Ball 1988).

2.1 Expected outcomes

The strategies and methods teachers follow in their classrooms are generally rooted in previous teaching and learning experiences. In fact, Westbrook, et al. (2013, 7) argue that teachers' "… thinking and ideas are manifested in their overall pedagogic approaches, garnered from the kinds of teaching and learning experienced as school students themselves, the approaches promoted in initial teacher education (ITE) and continuing professional development (CPD)." This suggests for example that teachers whose previous experience was to memorise mathematics are likely to reproduce teaching activities leading students to memorization. Conversely, experiences from continuing professional development, such as the introduction of new learning environments, new teaching methods and assessment may facilitate change in their pedagogy. In this study, there are three anticipated development outcomes. Firstly, the anticipation is that both teachers and students will embrace a new teaching approach. That is, both will find the new teaching approach empowering and useful. Secondly, that the introduction of technology in teaching mathematics will help improve students' performance. Thirdly, that the results of the study will be used to convince the School of Education (SoE) at Tshwane University of Technology (TUT) to incorporate teaching with technology in its teacher education modules. In the long term, the hope here is that the introduction of teaching with technology will be beneficial to the country. Furthermore, the hope is that with students passing mathematics at Grade 12, more will register for degrees in mathematics, science and technology.

For TUT in particular, this study will open avenues for research for lecturers in the School of Education This will enable their work life development in that lecturers will become experts in the area of teaching with technology as well as conduct research in this area. Also, the lecturers will develop the ability to advise others on the importance of careers involving qualifications with specialisation in mathematics. TUT will also benefit from government subsidy which is paid for every student that registers in a study program. In terms of research outputs, the university will also receive more money in the form of a research grant that the South African government pays to universities for all journal articles published by lecturers. So, in essence this developmental study has the potential to immensely benefit the university while also positively impacting on the work life development of lecturers and support staff in the SoE.

2.2 Research questions

The problem this developmental study sought to address was poor performance in mathematics by Grade 12 students. To tackle this, the argument was, by helping teachers embrace and use technology in teaching mathematics, such an effort should assist in addressing the problem. In introducing technology to teachers of mathematics this would bring confidence in what they teach, provide them with wider knowledge as well as improve their teaching skills. The intention of introducing them to teaching with technology was to add another powerful teaching method in their repertoire. Therefore, this study explored whether mathematics teachers could learn about and incorporate mathematics apps in teaching rather than the traditional instructional approach of solving exercises using the prescribed textbooks. As a context, in most instances mathematics teachers simply transcribe examples as they appear in the textbook into the blackboard and the expectation is for students to basically, memorise these. The issue with this method is that a slight variation to the previously seen example means that students may find it difficult to solve a perceived standard problem. In contrast, mathematics apps provide an interactive platform. In the platform the user may encounter different problems and be guided in working out each without the need to memorise the steps to a solution.

As a result of the problem outlined here, the purpose was to explore whether mathematics teachers could embrace teaching using technology and incorporate mathematics apps in teaching rather than the traditional instructional approach of solving exercises using the prescribed textbooks. An undeniable fact in South Africa is that there are major problems with students not performing well in the subject. There is a variety of reasons leading to the poor performance by students. These range from home-related problems such as poverty, school-related problems such as teaching strategies, to government-related problems such as unrealistic education system demands and expectations. Nevertheless, the issue is not to dwell on the problems but to find solutions. In this regard, Jojo (2019) argues "… echoing the irregularities in the system will not help, but the existing challenges must be addressed." In a quest to find solutions to some of the school-related problems, a few questions were raised here. The research questions this developmental study sought to address therefore were:

(a) What are the attitudes of teachers about technology in general (affinity to technology)?

(b) How likely were teachers to search for mathematical apps and incorporate these in their teaching?

(c) What are teachers' views about the utility of mathematical apps in their classrooms?

Specifically here, the beneficial effect of the mathematical apps referred to teachers' views (i) on whether using the apps had the potential to improve their teaching, and (ii) on whether using the apps had the potential to help improve students' performance in the subject. With the teachers providing answers to these questions, this would address the primary objective of improving students' performance in Grade 12 mathematics in South Africa.

2.3 Scope of the study

Teaching with technology is an activity that forms part of learner centred teaching approaches. Of importance here, is that teaching with technology assists in defining the roles of student and teachers. This teaching approach involves a number of issues depending on hardware and software utilised. In terms of hardware, it depends on whether desktop computers, laptops, tablets are used and whether there is need for internet connectivity or not. On the other hand, the software is about materials and learning activities enabling the learning. For example, these include drill and practice software, tutorial software, educational games, as well as simulations. The software may be in the form of computer applications developed for aiding teaching and learning.

Recognising that there is a wide array of media and technologies to use in teaching mathematics, apps were the selected choice for the purpose of this study. This is because apps offer repetitive as well as cumulative learning experiences in mathematical concepts, they provide instantaneous feedback, offer an opportunity for individualized and self-paced learning (Fuchs, et al. 2008; Gersten, et al. 2009). What mediated this choice was the argument that one has to identify effective types of technology and ways of encouraging how it is used (Taylor & Duran 2006). In addition, as (Persson 2011, 3) points out "… implementation of new technology must always be preceded by a careful analysis of how it is meant to be used in education in practice." In this study, the focus was on encouraging mathematics teachers to create a technology enhanced learning environment in their classrooms. Essentially, the scope of this study was limited to the use of apps as the technology utilised to teach mathematics. The apps used were chosen because they included the mathematics content teachers had to teach in the Grade 12 syllabus. In addition, teachers would hopefully be happy to be introduced to new learning activities meant to help improve teaching and learning in their classrooms.

2.4 Summary

This chapter provided the objectives of this developmental study. The objectives of the study are outlined here including the goals meant to attain the objective of developing a technology based learning environment to improve the teaching of high school mathematics in South Africa. The scope of this study was outlined, including the expected developmental outcomes. In essence, this explained the secondary objectives of firstly, to establish the teachers' attitudes toward technology in general. Secondly, to determine their views on how likely they would search for mathematical apps and incorporate these in their teaching? Thirdly, find out whether using the apps had the potential to improve teaching as well as help improve students' performance in the subject.

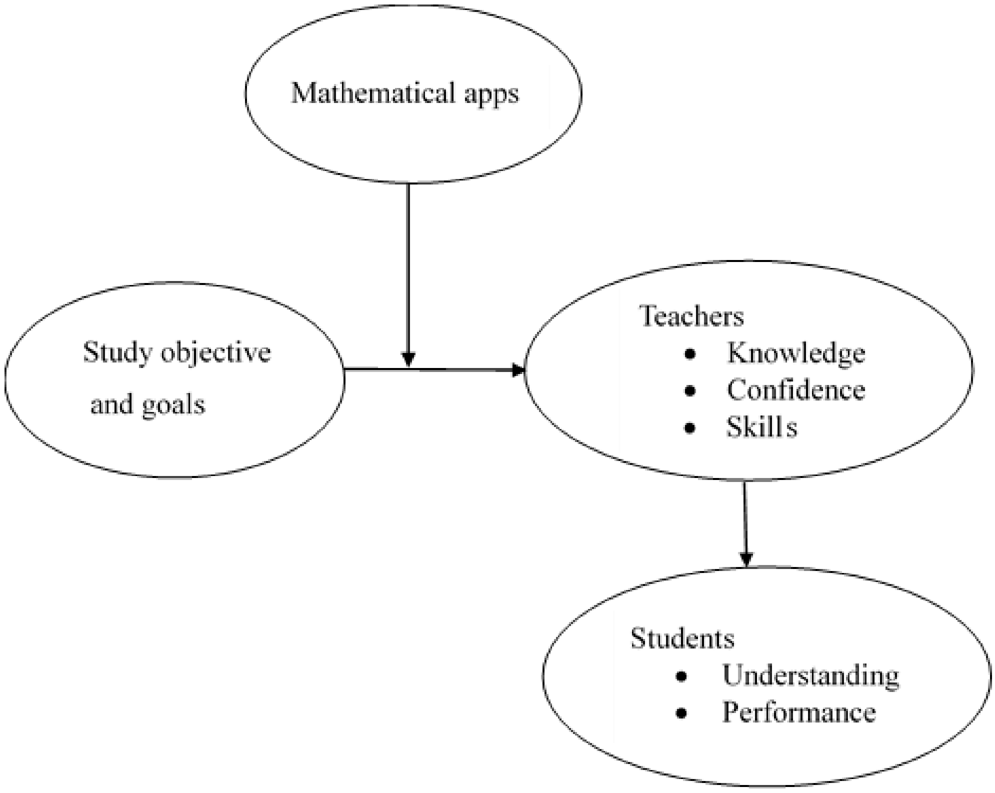

Figure 2.1. Conceptual model of the developmental study

Figure 2.1 shows a conceptual model that summarises the thought process on which this developmental study is based. The figure shows that the study objective and goals would be achieved through the introduction of mathematical apps to teachers. Following this, the teachers should gain knowledge, confidence in teaching with technology, and thereby acquire better skills. The acquisition of better skills better skills should result in positive attitudes toward technology. Finally, the teachers' improved skills should enable students to understand mathematics better and as a result perform well in the subject. This is important because studies report that students' attitudes do tend to be affected by those of their teachers (Christensen 2002). The following chapter reviews literature found to be relevant for the purposes of this developmental study. Specifically, a theoretical framework overview follows where teaching with technology is identified as an ideal process in order to improve students' performance in mathematics.

3 Theoretical framework

In developing, a technology based learning environment to improve teaching, one has to consider a number of pedagogical imperatives. Alexander (2008, 4) describes pedagogy as "… the act of teaching together with the ideas, values and beliefs by which that act is informed, sustained and justified …" This suggests that pedagogy is not only about teaching but it includes a value system that informs the education process. In this regard, Alexander (2001, 540) reiterates that it "… comprises teachers' ideas, beliefs, attitudes, knowledge and understanding about the curriculum, the teaching and learning process and their students, and which impact on their 'teaching practices', that is, what teachers actually think, do and say in the classroom."

From this developmental study's theoretical framework perspective, teaching with technology was most appropriate. Specifically, the researcher felt that if teachers were to create a learning environment in which content and methods were familiar to the students, then competencies students had to achieve would lead to positive learning outcomes. In this regard, teachers were exposed to mathematics apps in order to dissociate them with textbook-based traditional teaching methods. In addition, this would be beneficial to students and they would willingly embrace it. The view was that students would willingly embrace using mobile phones in learning mathematics for a number of reasons. For instance, this would be exploiting an area most feel comfortable in (using smartphones). In addition, explorations using smartphones would enable them to access even more apps not introduced or mentioned by teachers. Such explorations might also lead them to independently finding solutions to mathematics problems they encounter.

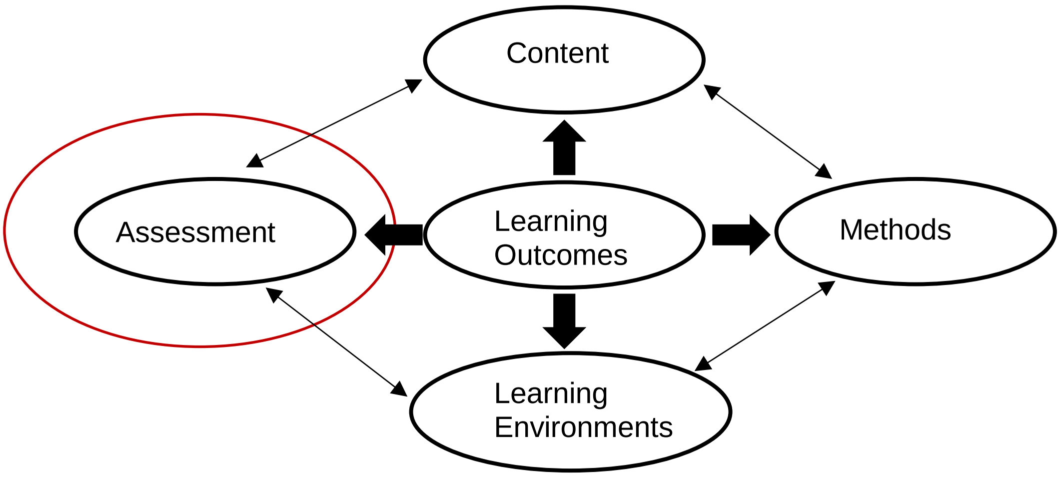

Figure 3.1 Framework for designing study modules and teaching sessions

In essence, this study sought to achieve the model shown in Figure 3.1. This framework was consistent with the view that a successful course design should form logical links that are educationally sound with planned intentions, course content, teaching and learning methods, and assessment, while recognising student characteristics (Newble & Canon 1989).

Importantly, the aim was to change the teaching focus from traditional methods to methods that concentrate on the mastery of competency. Figure 3.2 shows the Dubois and Rothwell's (2004) competence based approach. These authors point out that instruction should be student centred as opposed to the teacher being at the center. That is, students should be allowed to learn while drawing from their previous experiences (constructivism). Here, a teacher may also look at different approaches such as facilitating and guiding or arranging students for collaborative learning. The authors also point out that students should receive credits on the basis of mastering competencies as against passing a grade. In terms of study progress, they argue that this should be based on mastery and not on the scheduling of the programme. If all these are followed, then assessment should purely be based on the readiness of the students (Dubois & Rothwell's, 2004). What the foregoing shows is that assessment facilitates classroom instruction because it provides information about students' learning progress while enabling teachers to appropriately plan for future instruction (Suurtamm, et al. 2016).

Traditional	**Competency-based**
Instruction	Instruction
Teacher in the middle	Student-centered
Receiving credits	Receiving credits
Passing grade	Mastery of content
Study progress	Study progress
Scheduled programme	Upon mastery
Assessment	Assessment
End of the year period / year	When ready

Figure 3.2 Assessment in the traditional approach as against in the competence based approach (adapted from Dubois & Rothwell 2004)

In this developmental study the focus was on creating a technology driven teaching and learning environment. The technology driven teaching and learning environment used mathematical applications that are readily available online. Teachers were exposed to these to encourage them to move away from traditional to competency based approaches. An advantage of familiarising the teachers with mathematical apps was that they would use these with their students. The students would then possibly take over learning using the apps to master different mathematics concepts and solve problems at different levels of difficulty. This would mean that the assessment students' progress was indeed competency based.

In line with the objective of developing, a technology-based learning environment to improve the teaching of high school mathematics, this chapter focusses on relevant theory addressing this issue. In doing this, learning theories are compared, through explaining different aspects. Among these aspects, were questions such as *what is learning*? *how does teaching proceed*? *how and on what basis are the learning outcomes assessed*? and *advantages* of each of these theories. Following this is a focus on teaching strategies, wherein it is argued that competency based assessment leads to lifelong learning whose foundations are critical thinking and problem solving. The next issue addressed here is teaching with technology. While it is acknowledged here that not all teachers embrace technology, it is also shown that (a) it allows teachers to experiment more in pedagogy and get instant feedback as well as (b) helps ensure full participation in the classroom. In the end, the chapter focusses on mobile learning and apps for mathematics. Here, it is shown that apps in the mathematics classroom enhance learning. Finally, the chapter ends with a summary.

3.1 Learning theories

From a pedagogy perspective learning theories cover a range that comprises behaviorist, humanist, cognitive, constructivist, socio-cultural and connectivism. All these theories define aspects of the learning process differently. Of importance, here is the fact that learning is perceived from a different standpoint from one theory to another. For instance from a behaviorist perspective, the focus in learning is directed at changing the behavior of the students. On the other hand, from a constructivist perspective, the focus is on the knowledge students bring and construct for themselves as they learn. Meanwhile, from a connectivism perspective, learning is seen as a continuous process, which is activated immediately a student connects to technology and feeds information into a learning community. A more comprehensive presentation of the learning theories is shown in Appendix 4 (adapted from Wordpress.com 2021; Griffl.org 2020).

3.2 Teaching strategies

Literature points out that students need teaching strategies whose intent is to stimulate the innate curiosity and interest to learn (Akpan & Beard 2016). This suggests that strategies in which teachers take over are not ideal for learning. In fact, in classrooms where teachers are dominant some students invariably lose interest and never concentrate on proceedings. What is needed here are teaching strategies that focus on competency based instruction as opposed to traditional instruction. That is, the emphasis of the teaching strategies should be on students mastering the content rather than on passing a grade. What is important is that teachers should strive to help students acquire ways of thinking and problem solving that underpin competency (Entwistle, Hoursell Macaulay Situnayake & Tait 1989). An inherent goal of competency based teaching is to afford students an opportunity to master certain skills that would enable them to be successful adults (Juraschka 2021). In South Africa, there is this perennial emphasis on students' performance at the end of Grade 12 with perhaps less focus on ensuring students' mastery and competence. Compounding this problem is the fact that provisioning in the entire schooling system remains inadequate. In this country, researchers report "… poor student performance at school level continues due to a lack of provision of quality teachers, textbooks, and time-on-task …" (Chetty & Pather 2015). In addition, from a South African perspective, researchers report that teachers rely "… on teacher-led instructional methods and formal assessments" and for this reason, recommend "… that professional development courses ought to focus on helping teachers to increase their repertoire of teaching and assessment strategies" (Umugiraneza, Bansilal & North 2017, 1).

There are a number of teaching strategies that teachers could use to guide their students to master content and be competent in subjects like mathematics. Such strategies include among others, using collaborative learning as well as using technology. Collaborative learning takes place when a teacher allows students to work together with the intention of finding a solution to a defined task. About this, literature points out it occurs "…between two or a few human or artificial agents for a well-defined learning or problem solving task" (Dillenbourg 1999, 4). In agreement, Roschelle and Teasley point out that collaborative learning involves the "... mutual engagement of participants in a coordinated effort to solve the problem together" (1995, 70). About collaborative learning, researchers (e.g., Laal & Ghodsi 2012) argue that collaborative learning "… compared with competitive and individualistic efforts, has numerous benefits and typically results in higher achievement and greater productivity, more caring, supportive, and committed relationships; and greater psychological health, social competence, and self-esteem."

With regards to using technology in the classroom literature points out that it influences student engagement (Schindler, et al. 2017); enhances students' mathematical learning (Clark-Wilson, Robutti & Sinclair 2014); is good for student collaboration (Arya 2017); and that it leads to higher levels of student learning resulting in improved student achievement (Protheroe 2005). What is important in the teaching process is the quality of teaching. The quality of teaching is characterised by a number of factors and activities, such as the passion of a teacher, the teacher sharing learning outcomes before a lesson, using technology to reach out to students, planning for group activities, making sure that assessment is competency based as well as ensuring that regular and honest feedback is provided to students. These characteristics benefit students in many ways. For instance, when students understand clearly defined learning outcomes and the competency based assessment, this invariably leads to lifelong learning whose foundations are critical thinking and problem solving. Eventually, this leads to accessing learning that culminates in success.

3.3 Teaching with technology

Edison and Geissler (2003, 137) argue "[T]echnology affects everyone as it changes the fabric of society." This view suggests that from a schooling perspective, technology has the potential to also affect teaching strategies and how students learn. The reality, as these authors point out, is that not everyone embraces technology. Some people become reticent and will, as much as possible, avoid technology while others welcome and look forward to utilising it in their daily lives (Edison & Geissler 2003). In fact, some teachers try as much as they can to avoid using technology in their classroom. About this, literature points out that "… another element that prevents more teachers from using computers frequently with their students is their own limited skill and expertise in using computers themselves (Becker 2000, 7). It is crucial therefore, that teachers should be trained in the use of technology in their classrooms because of the benefits that students might derive from that.

An advantage of using technology is that it allows for hands on learning and instruction. Hands on learning is instruction that allows students to handle things for themselves thereby doing whatever is required. About hands on learning, literature points out that it "… enables students to acquire personal experiences … that help them retain concepts and skills long after a lesson or practical exercise is completed" (Clarkson & Shipton 2015, 158). The Top Hat Blog (2021) in pointing to the advantages of teaching with technology, suggests that

1. Using technology in the classroom allows teachers to experiment more in pedagogy and get instant feedback
2. Technology in the classroom helps ensure full participation
3. There are countless resources for enhancing education and making learning more fun and effective
4. Technology can automate a lot of a teacher’s tedious tasks
5. With technology in the classroom, a teacher’s students have instant access to fresh information that can supplement their learning experience

The next section briefly deals with mobile learning including apps in the mathematics classroom.

3.4 Mobile learning and apps for mathematics

The advent of smartphones, tablets and other mobile gadgets has meant that the internet is readily available on the go and to everyone. As a result of this technology teaching and learning is now possible outside the classroom. Smartphones allow for “… visual and dynamic affordances, touchscreens open up more direct interaction with mathematical phenomena, while the mobile affordance allows for easy transference between different learning situations, including home and outdoor, and more flexible ways for students to work collaboratively” (Larkin & Calder 2016, 1). The ability to learn both inside and outside the classroom has meant that mobile learning is now a reality. Mobile learning relates to the ability to deliver learning material to students through wireless internet into their smartphones and tablets (Wang, Wu & Wang 2009). It may be that not everyone embraces mobile learning yet however, one recalls that computers were larger, room based and not readily available to everyone. Over a few years they have become smaller to a point where they are portable and anyone can purchase one. Size and portability has allowed for teaching and learning to take place in different settings. As a result, mobile learning is not only an area that is rapidly developing, it is recognised as the future of learning (Trifonova 2003).

One of the early mathematical learning tools to be freely available online was GeoGebra. This tool was developed at the University of Salzburg, Austria by Markus Hohenwarter in 2001/2002 as part of a master's and PhD qualifications in mathematics education and computer science (Hohenwarter & Preiner 2007). About GeoGebra, these authors point out that it

> … extends concepts of dynamic geometry to the fields of algebra and calculus. You can use GeoGebra both as a teaching tool and to create interactive web pages for students from middle school up to college level. Specifically designed for educational purposes, GeoGebra can help you to

> foster experimental, problem-oriented and discovery learning of mathematics (Hohenwarter & Preiner 2007).

To date there are hundreds of mathematical apps available on platforms such as Android and Apple's App Store. This abundance means that teachers may select apps that are suitable for their purposes. Examples include Math4Mobile, AGILMAT and the Nokia Mobile Learning for Mathematics project. In its website, wwwmath4mobile.com it is explained that "… the project examines opportunities of ubiquitous and personal technologies for educational purposes, specifically of using the mobile phone for teaching and learning mathematics." According to Drigas and Papas (2015, 21) AGILMAT is a web application, "… designed by Tomas, Leal and Domingues in 2007 to help students learn mathematics and especially high-school algebra." From a South African perspective, there has been an attempt at a mathematical app. This was in the form of a Nokia Mobile Learning for Mathematics project (Roberts & Vänskä 2011). In the project, "… students and teachers had access to interactive mathematics learning materials through a mobile platform with a social media application support (Drigas & Papas 2015, 19). What is important with apps in the mathematics classroom is that they enhance learning. About this, literature indicates that the "… use of the math apps improved student learning in mathematics and reduced the achievement gap between struggling students and typical students (Zhang, Trussell Gallegos & Asam 2015, 32). Of importance though is the training of teachers before they use mathematical apps in their classrooms because digital tools are beneficial than replacing other instruction methods completely (Hillmayr, Ziernwald Reinhold Hofer & Reiss 2020).

3.5 Summary

The purpose of this chapter was to review relevant literature that focusses on the issues this developmental study sought to address. Specifically, the focus addressed learning theories, which were shown to be important in the learning and teaching context. Following this, was theory dealing with different teaching strategies. Here, it was shown that how teachers teach affect how students learn. This suggests that the quality and mastery of competency as well as skills attained are a function of the teachers' presentations and how they assess the subject they teach. The importance and advantages of teaching with technology were outlined. It is observable from the theory that in this developmental study teaching with technology in reality is about teaching mathematics using applications. The chapter then focused on literature specifically elaborating on teaching mathematics using apps. It should be mentioned here that the use of mathematical apps has its limitations too. For example, the in-app costs as well as the cost of being connected online have to be a consideration in teaching using mathematical apps. The next chapter deals with the methods followed to conduct the study.

4 Methodology

The previous chapter dealt with the theoretical framework deemed to be relevant in this study. In this chapter, the methods followed to address the objective of developing a technology based learning environment to improve the teaching of high school mathematics are described. To do this, the design of the study is described. The description starts with addressing the sample and how it was gathered. Following the sample, methods of collection of data are described. In that regard, a description of the collection of quantitative and qualitative data is advanced including the procedures followed to carry this out. For clarity purposes, a description of the different workshops involving the teachers in the sample is advanced. Next is an explanation of the processes followed in analysing both the quantitative and qualitative data. Finally, is a section that deals with ethical considerations that were observed in dealings with the participants of this study.

The purpose of this developmental study was to explore whether mathematics teachers could learn about and incorporate mathematics apps in their teaching. As an overview, the study followed a mixed methods procedure, which involved collecting data through both quantitative and qualitative means. In essence, three activities were carried out. The first was the collection of quantitative data. To collect quantitative data, the Affinity for, and Global Attitudes Toward Technology Questionnaire was administered (see Appendix 1). In this developmental study, the central issue was to illustrate to teachers how technology might form part of their teaching approach in order to improve students' performance in mathematics. Therefore, it was important to identify teachers with high affinity and those with lower affinity because such knowledge would be useful for training purposes (Edison & Geissler 2003). Training as alluded to was the natural progression, so it constituted the second activity. The second activity involved three, four-hour long workshops (see Section 3.3). These workshops introduced the teachers to mathematical apps. Specifically, the workshops introduced the teachers to hands-on learning. In the hands-on learning, the teachers explored three selected mathematical apps. The last activity involved the collection of qualitative data. Data gathering in this instance was through one-on-one interviews (see Appendix 2). This type of interview was important because it allowed each teacher the opportunity to talk about the phenomenon of teaching with technology from their own perspective. In a sense this provided the teachers the chance to voice their views and feelings about mathematical apps. Here, teachers responded to a number of questions related to their experiences in the workshops. Due to government-sanctioned lockdowns because of the Covid-19 pandemic, the one-on-one interviews were conducted remotely. Specifically, each teacher was allocated a time slot at which the interview was to be held. In observance of Covid-19 pandemic protocols, all the interview sessions were conducted using Microsoft Teams.

4.1 Research design

A research design essentially provides the blueprint of a study (Bryman & Bell 2015). That is, it provides a plan that deals with different activities such as, identifying the problem, who the participants are, how data will be collected as well as its analysis and interpretation. About research design, Parahoo (1997, 142) points out, that this is a "… plan that describes how, when and where data are to be collected and analysed." A mixed methods design was used to explore the use of smartphones in teaching high school mathematics. A mixed method design in simple terms relates to the use of "… both quantitative and qualitative designs in the same research study" (Caruth 2013, 113). Researchers argue that used together, quantitative and qualitative methods are useful in enhancing insights into research questions than when used independently (Creswell 2012; Frels & Onwuegbuzie 2013). In this study it was important to collect data using both quantitative and qualitative data. This was because quantitative data provided immediate information that could be used to plan for the workshops. On the other hand, qualitative data from the one-on-one interviews allowed for the teachers to talk to the phenomenon of teaching with technology, from their view point. Quantitative and qualitative data were collected from 22 teachers. In the quantitative aspect, the aim was to establish teachers' attitudes toward technology usage in the classroom. Specifically, the collection of this data was in order to establish participants' affinity to technology. On the other hand, qualitative methods were used to understand the participants' use of technology in their classrooms. In this instance, one-on-one interviews were conducted through the Microsoft Teams platform. The one-on-one interviews essentially allowed the teachers the opportunity to voice their feelings and views about teaching mathematics using applications.

4.1.1 Sample

The sample comprised 22 high school mathematics teachers. Originally, the aim was to contact schools and thereby request for participants. The lockdown meant that this was impossible because schooling immediately stopped. Through word of mouth I managed to obtain approximately 30 phone numbers of Grade 12 mathematics teachers from schools nearby the university (TUT). I contacted all and explained the research study and my intention. All 30 agreed to participate and indeed completed the questionnaire, which comprised the quantitative aspect of the study. However, for lack of data, eight teachers did not complete the 12 hours dedicated to the mathematical app workshops. This meant that they could also not participate in the one-on-one interview sessions on Microsoft

Teams either. As a result, 22 teachers comprising 15 men and seven women formed the sample of this study.

4.1.2 Quantitative data and procedure

In qualitative research, data collection

The collection of quantitative data in this study was through a questionnaire. The questionnaire followed a Likert type response format. That is, the teachers had to select responses on a five point scale anchored by strongly disagree and strongly agree. The questionnaire was the most appropriate here for three reasons. Firstly, this type of data collection instrument made it easy to reach the teachers. Secondly, it allowed them to respond anonymously. Thirdly, because of the response format, this allowed for accurate data capture into the statistical software, which allowed for ease of analysis.

From a quantitative perspective, the participants' attitudes toward technology were initially explored. According to Ajzen and Fishbein (2000, 3) attitudes " … refer to the evaluation of an object, concept, or behavior along a dimension of favor or disfavor, good or bad, like or dislike." So, for this study's purposes attitudes toward technology referred to the participants' views about their liking or disliking (desirable or undesirable) technology. The purpose of determining the participants' attitudes toward technology was two-fold. Firstly, was to gain insight on their views about the use of technology in their classrooms. Secondly, on the basis of the former, plan relevant and suitable training in using applications to teach mathematics. This study used an adapted version of the Edison and Geissler (2003) Affinity for Technology Questionnaire. Included here, was a Global Attitude towards Technology measure, reportedly suggested in literature (Edison & Geissler, 2003) (see Appendix 1). In terms of the internal consistency (reliability) of the Affinity for Technology Questionnaire, the authors report two Cronbach (1951) alpha values of 0.89 and 0.88 for different instances in which they used the instrument. An important aspect of determining and reporting internal consistency or reliability is that if it is good, then it makes it acceptable to make decisions or report believable results about participants. The converse is also true, that is, if the reliability is poor then it becomes difficult to make decisions or report acceptable results about participants.

To collect Quantitative data, the researcher used a questionnaire made up of three parts (see Appendix 1). The first part requested the teachers to furnish biographical information, such a gender, age and teaching experience. The second part was the Affinity for Technology Questionnaire (ATQ) developed by Edison and Geissler (2003). The basis for using the ATQ was Modahl's (1999), characterisation of people who like technology as ‘technology optimists’ and those who do not as technology pessimists’. Therefore, this questionnaire was used in this developmental study to be able to categorise teachers in terms of their affinity to technology (optimists or pessimists). In categorising the teachers, the aim was to use this new information and knowledge in the workshops. That is, the gained information from the results would assist in the workshop hands-on activities when introducing the teachers to working with mathematical apps. Further, literature points out that teachers’ beliefs about technology are a significant element that explain why the adoption of computers in the classroom succeeds or not (Hermans, Tondeur van Braak & Valcke 2008). It was for this reason that I sought to understand teachers’ attitudes (affinity for technology).

Here, face validity of the questionnaire was accepted a priori. The acceptance suggests that in this developmental study the questions as developed by Edison and Geissler (2003) were accepted as they were. That is so because, the questions related to what this study intended to establish from the teachers. In terms of the reliability of the ATQ, in instances where the authors used this instrument, they reported internal consistency values of $\alpha = 0.892$ and $\alpha = 0.88$ (Edison & Geissler 2003). Therefore, reliability in this study would be acceptable if the internal consistency alpha value was in the reported range as reported by these authors. The third part was the Global attitude Towards Technology Measure. Edison and Geissler (2003) opine that this particular measure was suggested by literature. Here, the teachers had to rate their phobia to technology on a scale of four points anchored by Highly Technophobic to Not Technophobic (see Appendix 1).

The questionnaire was sent through to the teachers using WhatsApp. This suggests that the questionnaires were received in picture format. The teachers were encouraged to answer the relevant and applicable questions on a piece of paper and send their responses using WhatsApp or SMS. As an example, in answering the question on the highest academic qualification, teachers had to only indicate what was applicable to them rather than write all the qualifications and select one.

In this study, the teachers also had to indicate their highest qualification. It is perhaps important to explain the qualifications structure for teachers from a South African perspective. This is because qualifications are one of the contributing factors in the poor performance in mathematics by student. In the South African Higher education system, the lowest qualification is a Higher Certificate (see Table A6.1 – Appendix 6). A person with such a qualification would not qualify to be a teacher. There are however teachers from the old dispensation (pre-1994) who would have attended Teacher Education

Colleges. Such teachers would qualify with a Diploma in Education. All the colleges were subsequently closed (post-1994). This means that there are older teachers possessing such a qualification still in the system. A number of teachers in the education system currently possess a degree or a degree plus a teaching qualification. Teachers possessing a degree may be holders of qualifications such as a Bachelor of Science (BSc). The education system allows such persons to be teachers even though they are not trained to be. This is because in their qualifications they will have studies essential subjects such as mathematics, biology, computing, physics and chemistry at university. The education system accommodates people with these qualifications because of the shortage of suitably qualified teachers. About this, Beckmann (2018, 1) argues that a high "… percentage of educators may be regarded as poor performers and approximately 20 per cent of them do not have the required minimum qualifications for the tasks they have to perform." Suitably qualified teachers on the other hand, are those who possess say a BSc and a teaching qualification or a Bachelor of Education (BEd). The difference here is that such teachers have also undergone pedagogical training. In some instances, there are suitably qualified teachers who also possess higher qualifications such as a BSc honours plus an education diploma or a BEd honours degree.

4.1.3 Qualitative data and procedure

In qualitative research, data collection is through three methods, namely, ethnography, grounded theory, and phenomenology. In ethnography, the researcher usually becomes part of the people they are researching and collect data by observing them. About ethnography, it is pointed out that researchers "… typically gather participant observations, necessitating direct engagement and involvement with the world they are studying" (Reeves, Kuper & Hodges 2008, 512). In grounded theory, the main aim of research is to conduct research whose results lead into theory. About this it is pointed out that grounded theory involves "… logically consistent set of data collection and analytic procedures aimed to develop theory" (Charmaz 1996, 27 – 28). In a similar manner, it is argued that a key feature of grounded theory is that "… a researcher has to set aside theoretical ideas in order to let the substantive theory emerge" (Urquhart 2017, 7). About phenomenology, Donale (2004, 516) argues that at the end of the research "… the goal is the exhaustive, essential description of the phenomenon under study". In addition, Gill (2020, 83), suggests "… phenomenological approaches attempt to describe experiences from the point of view of the 'experiencer'." This developmental study was conceptualised from a phenomenological perspective. Here, the teachers through one-on-one interviews were given an opportunity to describe the phenomenon of teaching with technology from their point of view. It is because of this, that one-on-one interviews formed the basis for the collection of qualitative data in this study. Essentially the one-on-one interviews were semi structured in nature. The selection of this data collection method was also because it would allow for a dialogue between the researcher and the teachers. Importantly, it is "… guided by a flexible interview protocol and supplemented by follow-up questions, probes and comments" (DeJonckheere & Vaughn 2019, 1). Furthermore, the interview sessions being online meant that there was observance of Covid 19 protocols as stipulated by government. Appendix 2 shows the interview protocol without the follow up questions.

Outlined in this section, are the procedures followed to collect qualitative data. Here, one-on-one interviews were held with the teachers. It should be pointed out that teaching with technology is not something that teachers have embraced in South Africa. There are a number of reasons for this. For example, (a) a number of teachers will have qualified at a time when traditional teaching methods were the norm; (b) a majority of the teachers will never have had training on teaching with technology; (c) In South Africa, connectivity in schools is unheard of. That is, very few or no schools have internet or Wi-Fi facilities; (d) most teachers will only have used their mobile phones for the basic functions of messaging and voice calls. This suggests that teaching using mobile phones, for instance, is not something teachers were likely to incorporate in their classrooms.

The qualitative process started with three workshops wherein teachers were introduced to three mathematical apps. The objective here was to show them how they could use smartphones to teach the subject. As there were three selected apps for the purposes of this developmental study, introduction and different activities took approximately four hours each, spanning three days. The total time dedicated to the workshops was therefore 12 hours. Following the workshops, qualitative data were collected through one-on-one interviews. In this developmental study, essentially the intention of the one-on-one interviews was to establish the teachers' attitudes in terms of what they felt (affective). The basis was the view that in measuring attitudes, the concern should solely be with the affective domain (Fishbein & Ajzen 1975). Therefore, teachers were asked questions relating to their experiences (how they felt) about the activities with mathematical apps used in the study (see Appendix 2). Importantly, the questions sought to establish the teachers' views about and what teaching the subject using mathematical apps meant to them. This is in line with the view that interviews help in finding out about phenomena "… in terms of the meanings people bring to them" (Denzin & Lincoln 2003, 5).

As all activities took place in the backdrop of a lockdown, the interviews took place on Microsoft Teams. This platform was most convenient especially with everyone observing Covid-19 pandemic protocols. Also, with the interviews being one-on-one, it created this sense of being face-to-face with the interviewees. An advantage of this type of technology is that it allows for "… an interview that closely resembles the natural back-and-forth of face-to-face communication, including verbal and nonverbal signals" (Salmons 2012, 2). Also, as literature points out, online interviewers can create "… rapport more easily during individual online interviews than during online group discussions" (Gruber, Szmigin Reppel & Voss 2008, 257). In organising the process, teachers were allocated a time slot at which the interview was to be held. On average, each interview took approximately 30 minutes.

Here, teachers responded to the same set of questions as shown in Appendix 2. A slight variation to the question protocol or additional questions were only introduced in cases where answers were different or interesting. For example, in the first question if one teacher indicated that they had previously used apps to teach, then a follow up question would ensue. For instance, the teacher was asked, Which apps have you used? Can you show give an example of how you have used them? It should be mentioned that some of the questions, although they referred to students were important because it is teachers who determine what happens in the classroom. About this issue, literature points out that it is teachers who decide what and how technology (mathematical apps) may be integrated within classrooms (Rehmat & Bailey, 2014). The next section provides a narrative of the three workshops wherein the teachers participated.

4.2 Selected mathematical apps

For the purposes of this developmental study, three mathematical apps were chosen (see Figure 3.1). The choice was for three reasons. Firstly, the apps covered relevant mathematical content prescribed in the South African Grade 12 mathematics syllabus. Secondly, these specific apps allowed for a higher degree of interest in participation as opposed to generic apps covering mathematics that had no bearing to what teachers had to teach. Thirdly, the three were chosen specifically to familiarise the teachers with potential apps they could use. App stores are replete with many of these, freely available. In this developmental study, the three were adequate to avoid information overload. In addition, in terms of what they offered, this meant that exploring the three apps could be more in-depth and in much, more detail.

Figure 4.1 The three mathematical apps teachers worked with

In the following subsections, a description of workshops dedicated to the use of the three apps is described. The first and the third workshops are briefly described for brevity's sake and to avoid repeating some of the interactions common to all. The second workshop is described and explained in much more detail. The detail is also meant to illustrate how the teachers found themselves immersed in working with mathematical apps. This is an activity they admitted they did not know and had never done previously (see Section 4.3).

4.2.1 First workshop - Geometry app

The first workshop started with me asking the teachers to go to the Google Play icon on their Android smartphones while those on Apple's iPhone were directed to the App Store. It should be mentioned that all the teachers had a smartphone. To arouse interest, the researcher opened the PressReader app and explained that this was used to read any newspaper or magazine. It was explained to the teachers that this was irrespective of whether a newspaper or magazine was printed in South Africa or anywhere in the world. To illustrate this, the United States icon was clicked, and a full display of American newspapers and magazines appeared. The researcher proceeded to open and downloaded a current copy of the Washington Post. It was pointed out to the teachers that following the download, the newspaper could be read at any time. Further, the teachers were told that access to the PressReader app was because TUT has universal admittance for all staff. Following this introduction, it was then explained that not all apps were available through cash purchase. It was pointed out that some allowed functionality for a number of activities while offering in-app cash purchases, while others were freely available to use.

The next step was for the teachers to explore different apps of their choice (these were not related to the mathematical apps). Each teacher was given a minute to explain an app they had opened and what it was about. The aim was to assist them to gain confidence in searching for apps and exploring what they offered [time allocated to this activity was approximately 10 minutes]. Following this activity, the teachers were encouraged to download the three apps shown in Figure 4.1. Together, it was time to explore the first geometry app as seen in Figure 4.1.

The first app focuses only on geometry. On opening the app, the welcoming page shows the different geometric activities one can work with (see Figure 4.2). Each activity is clickable, and another window appears after clicking. For instance, on clicking the AREA activity, different shapes such as a triangle, parallelogram, cube and cone appear, and the user may determine the area of each of these shapes.

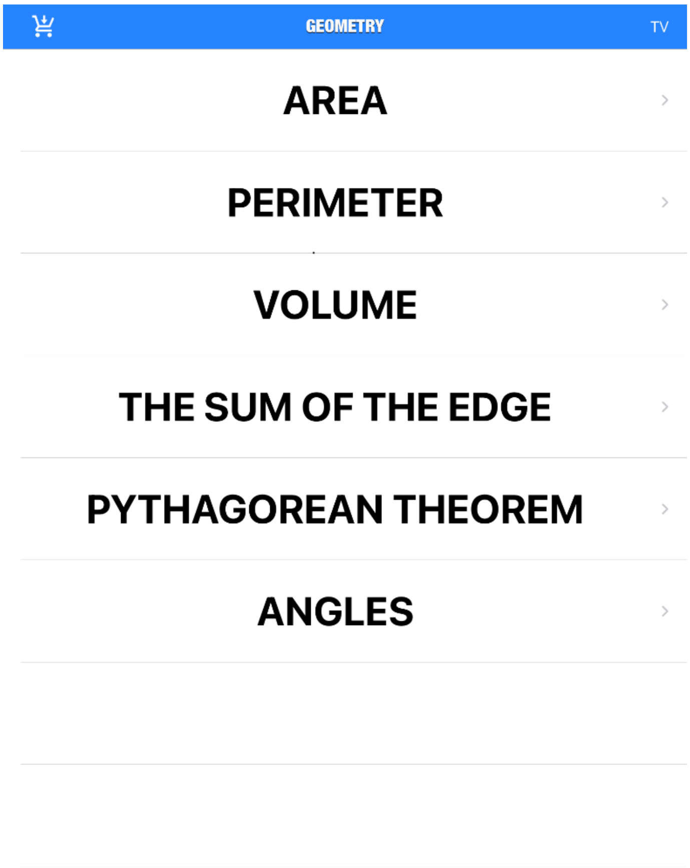

Figure 4.2 Welcome page of the first Geometry app

For each shape in the activity *AREA* the formula for calculating the area of a particular shape is provided. Users may then add different numbers to calculate areas of differently sized shapes (See Figure 4.3). The figure depicts an example of calculating the area of an equilateral triangle. The app provides the formulae for different calculations. In the workshop we started with the question: *Calculate the height of an equilateral triangle with* sides of 4cm. All the teachers inserted 4 in the provided space and clicked for the app to provide the answer.

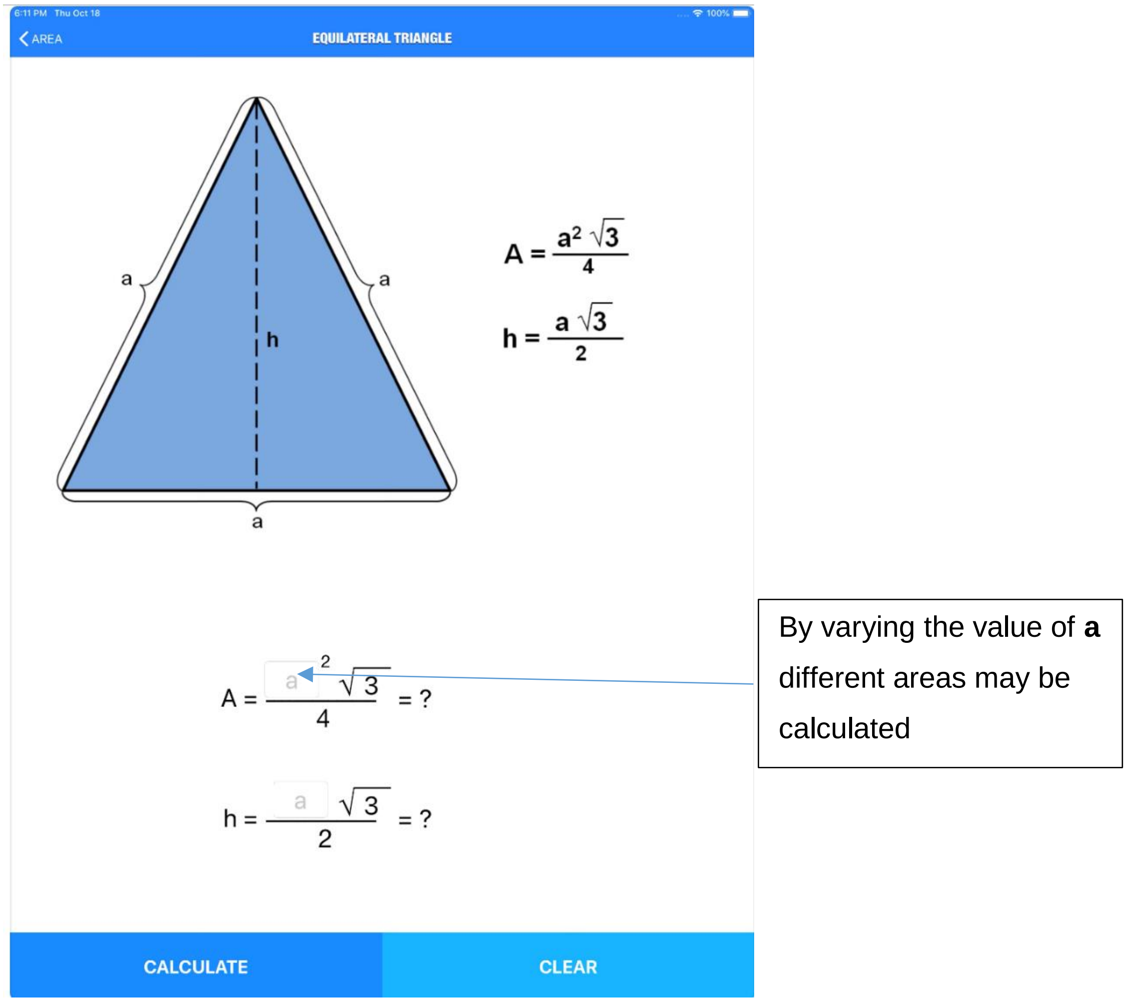

Figure 4.3 An example depicting the calculation of the area of an equilateral triangle

This process continued for several minutes with areas and heights determined for not only an equilateral triangle but for different shaped triangles. After the teachers were familiar with the different examples involving triangles, they were introduced to other geometric shapes. So, for example, they had to determine the perimeter or volume of a cone. The app supplied the formula for the cone while the teachers had to determine say the area given varying sides. In other instances, the area could be supplied, and the teachers had to find the height of the cone given other variables. To determine the volume for instance the app follows a similar process as previously explained. The teachers had to input any values they so wished and determined the volume of a cone say.

It is worth pointing out that as the time went by and the teachers were confident and comfortable in handling the app, the excitement was easy to discern. Another activity in this app involved the Pythagorean Theorem. As an example, the teachers looked at the right-angled triangle shown in Figure 4.4. In this instance, the theorem was applied by focusing on the three sides of a right-angled triangle. They kept on changing the sizes of the sides of the triangle and not only finding the value of **a** but also **b** and **c**. The excitement these activities generated was not anticipated in this study.

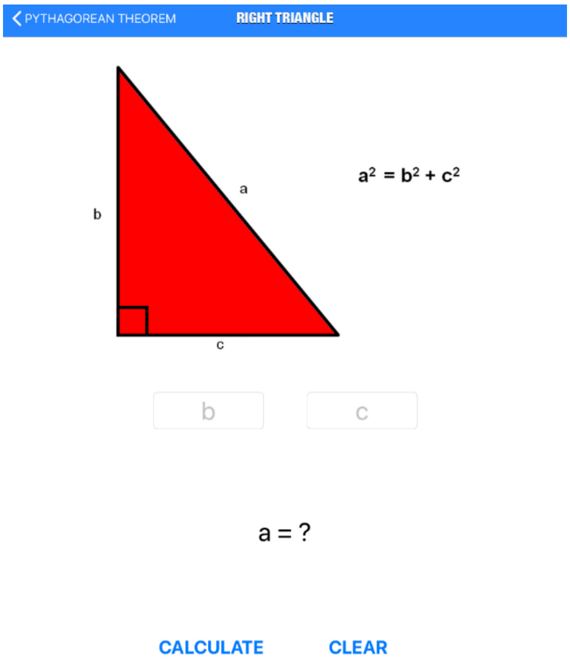

Figure 4.4 Geometry app showing the Pythagorean Theorem

After some time, it became intuitive to the teachers that actually no matter what the values of **b** and **c**, the value of **a** squared was always the sum of each of the other two numbers squared. After a while, Pulane a 27 year old woman who possesses a BSc degree and no teaching qualification, who had a teaching experience of 5 years said, **I have always followed the book on this one … I am so happy I can conclude on my own that**:

In a right angled triangle, the sum of the squares of the two sides is equal to the square of the hypotenuse.

A pleasing aspect of this activity was that the teachers found this on their own and drew this conclusion for themselves. Critically, they are likely to understand and explain the principle of the theorem as opposed to reading it for students directly from a textbook (traditional method). It was exciting to see this, because the approach would allow the teachers to guide students to gain knowledge through delving on hands on activities. At the end of the four hours of the workshop, not one teacher wanted to logoff. The next section describes the activities of the second workshop.

4.2.2 Second workshop - Geometry app

The second workshop was about the other Geometry app (the middle app in Figure 4.1). Although it is a Geometry app, it covers a number of areas in high school mathematics with 85 slides in total (most are free while some need to be purchased). Each slide has a heading that indicates the topic handled at any point. Each slide presents a number of examples needing different solutions at varying ability levels. All topics are in video format and allow for moving the video forward and back. After following the instructions, users may attempt problems themselves (practice). Following this, users may attempt a test on different problems based on the instructions. Figure 4.5 shows a typical welcoming window of the Geometry app where the mathematics learning area is on tangents.

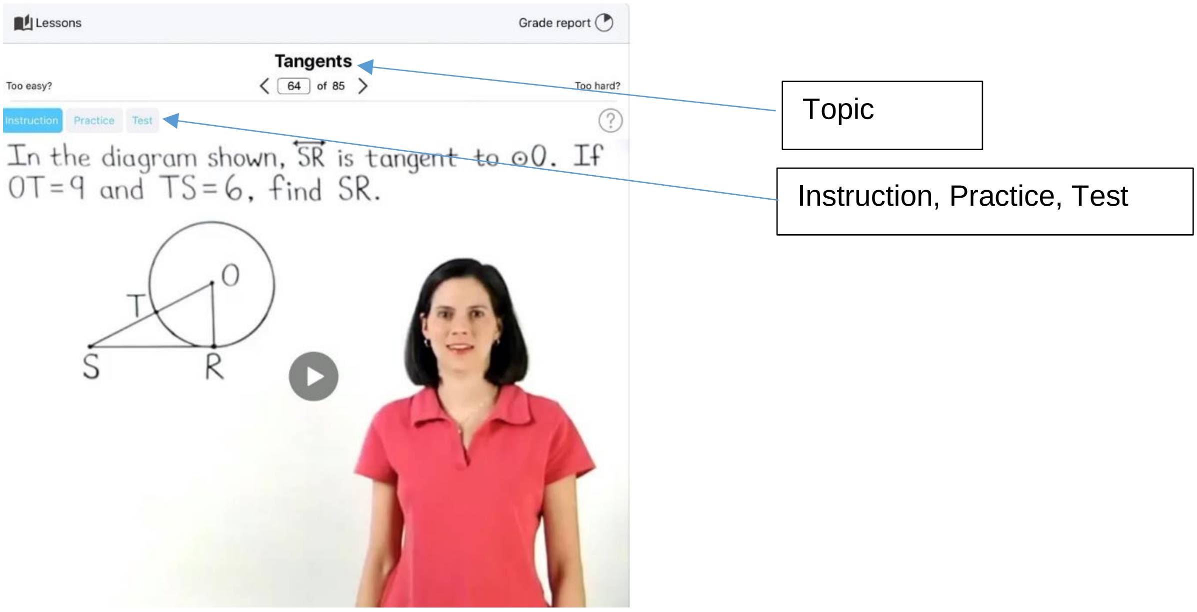

Figure 4.5 Welcoming window of the *Geometry* app

Once more, in a four-hour duration the teachers attempted a number of examples through Microsoft Teams. They started by attempting basic solutions of algebraic systems by addition. Following that, they proceeded to solve higher-level examples still focusing of solving a system by addition. Example 1 illustrates a typical exercise teachers attempted.

Example 1:

In this instance, the guiding instructor in the video explains that the first step is to identify the variables with the smallest coefficients. For example, looking at the two equations, the variable **c** has bigger coefficients compared to those of variable **d** (see Figure 4.6). It is worth mentioning that selecting the smallest coefficients is for the ease and convenience of solving the problem. That is, it does not mean that if the bigger coefficients are selected there would be a problem in arriving at a solution. The solution would still be the same.

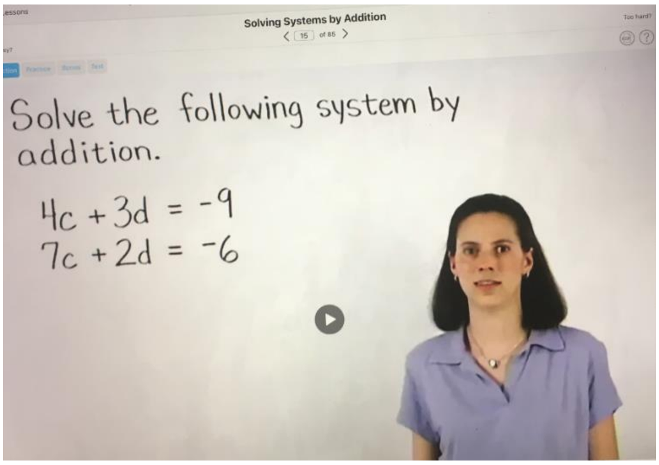

Figure 4.6 Addition of terms with different coefficients in the equations.

If the smallest coefficients are selected as is the case in Figure 4.7, the teachers were reminded that the objective of doing that was to make the expression in **d** (in this case) equal but with opposite signs. To accomplish that, the first equation was multiplied by 2, as shown in Figure 4.7.

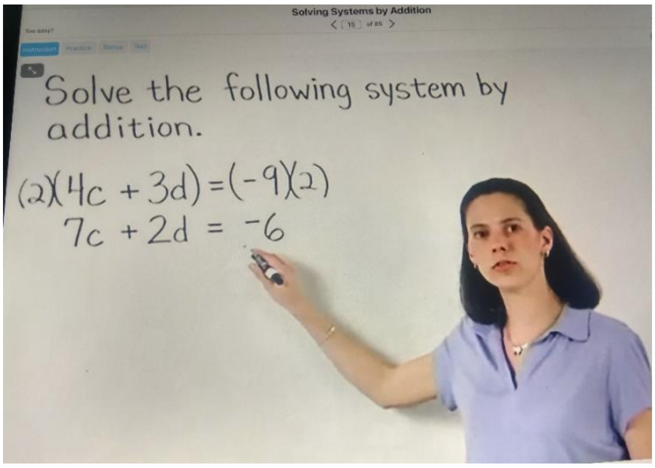

Figure 4.7 Selecting the best coefficients to work with

The 2 comes from the second equation. It is the coefficient of **d** in the equation. In order to make the **d** coefficients equal but with opposite signs then it means the second equation should be multiplied by - 3. As in the previous case, the 3 comes from the first equation while the negative sign is added in order to cancel out the subsequent equal expressions in **d** (see Figure 4.8).

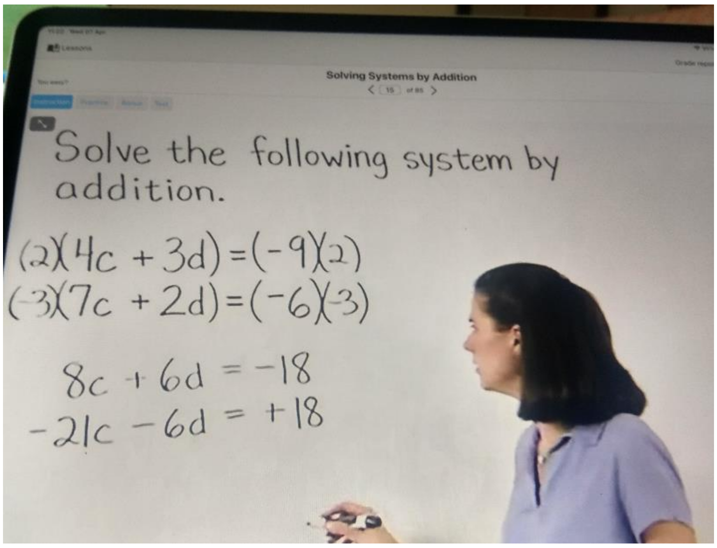

Figure 4.8 Working with equalised expressions in **d**

It may be observed from Figure 4.8 that the expressions in **d** as well as the numbers on the right hand side of each equation, cancel each other out (see Figure 4.9). Therefore, the result of the addition is as the figure shows.

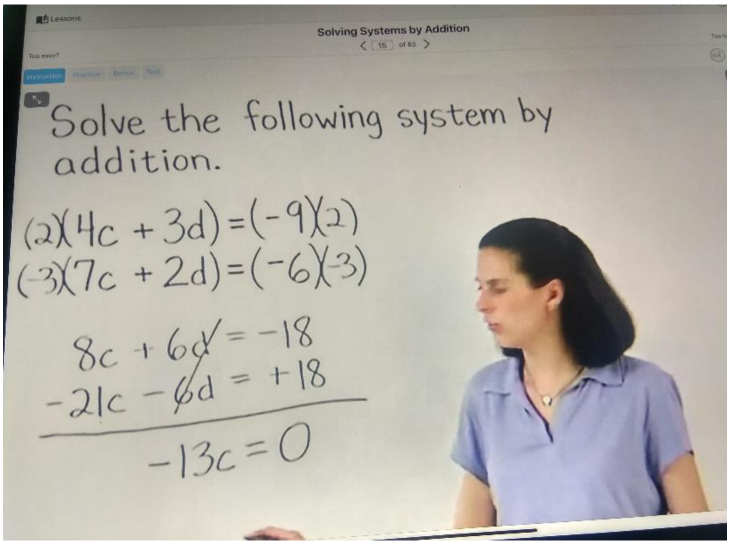

Figure 4.9 Effecting the addition on either side of the equation

The next step as shown in Figure 4.10 is to divide both sides of the equation by the coefficient of the expression in **c**, which is – 13. The result shows that c = 0. Now that the value of **c** is determined, next step is to substitute **c** in any of the two equations in order to establish the value of **d**. The substitution including the steps followed in doing this are shown in Figure 4.10.

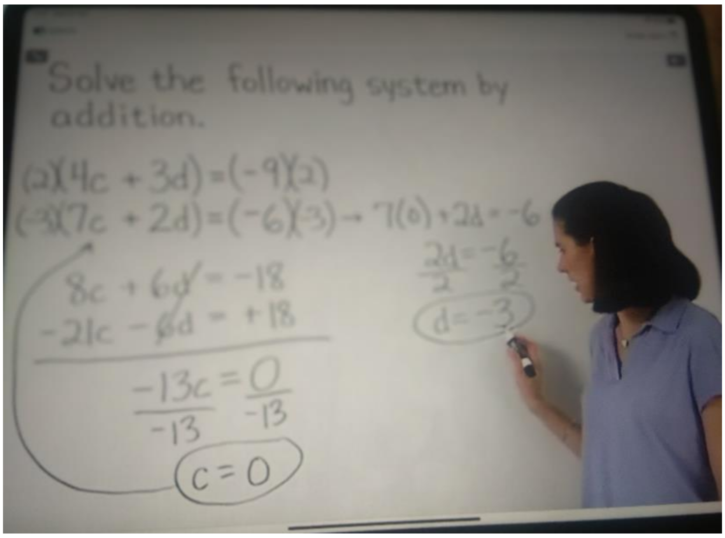

Figure 4.10 Effecting the addition on either side of the equation

Figure 4.11 shows the final step in the calculation and the solution is confirmed to be (0, -3).

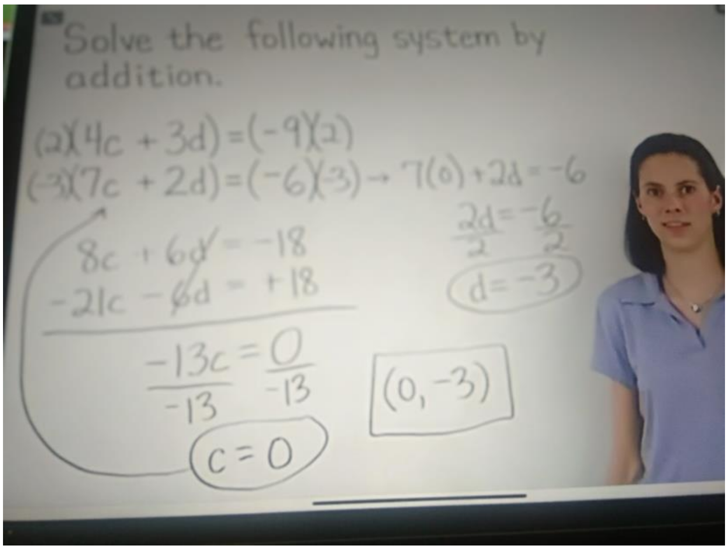

Figure 4.11 Solution, c = 0 and d = - 3

The teachers attempted a number of exercises involving this type of solving systems by addition. It was once more observable that the teachers found the workshops extremely beneficial. There was no need to ask them during the workshops how they felt about the entire process. From their body language and conversations with the researcher and among themselves, it was discernible that the objective of introducing teaching with technology through mathematical apps was an unmitigated success.

4.2.3 Third workshop - Mathway App

The third workshop was about the Mathway app. This app allows a user to interact in its interface (see Figure 4.12). The app provides a window where a user may enter a problem they seek to solve. After selecting the method in which to find the solution, it shows a window where on tapping, one may see the steps taken to reach the solution.

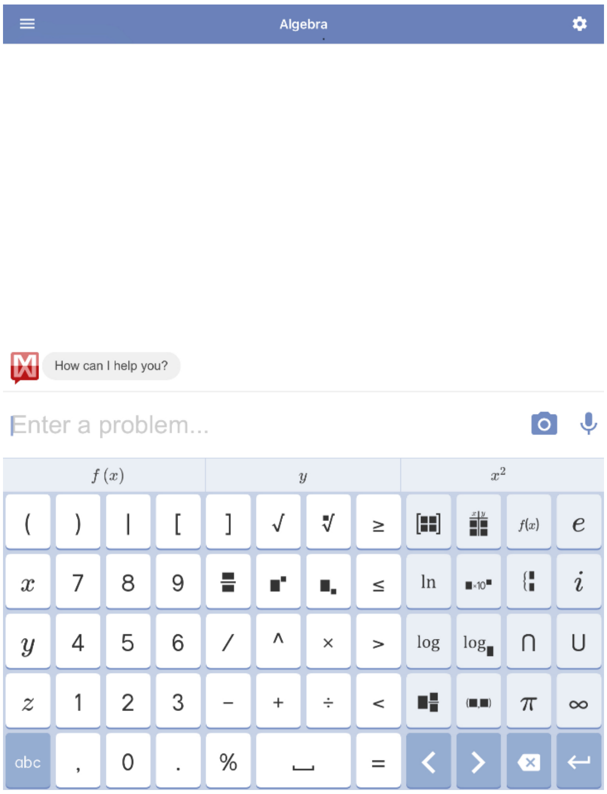

Figure 4.12 Welcoming window of the Geometry app

The teachers were given an opportunity to inset a number of different problems in algebra, geometry and trigonometry. At times, the teachers were allocated to separate rooms in groups of five and they were allowed to work on problems of their choice. At a pre-determined time, each group presented what they worked on, in the app.

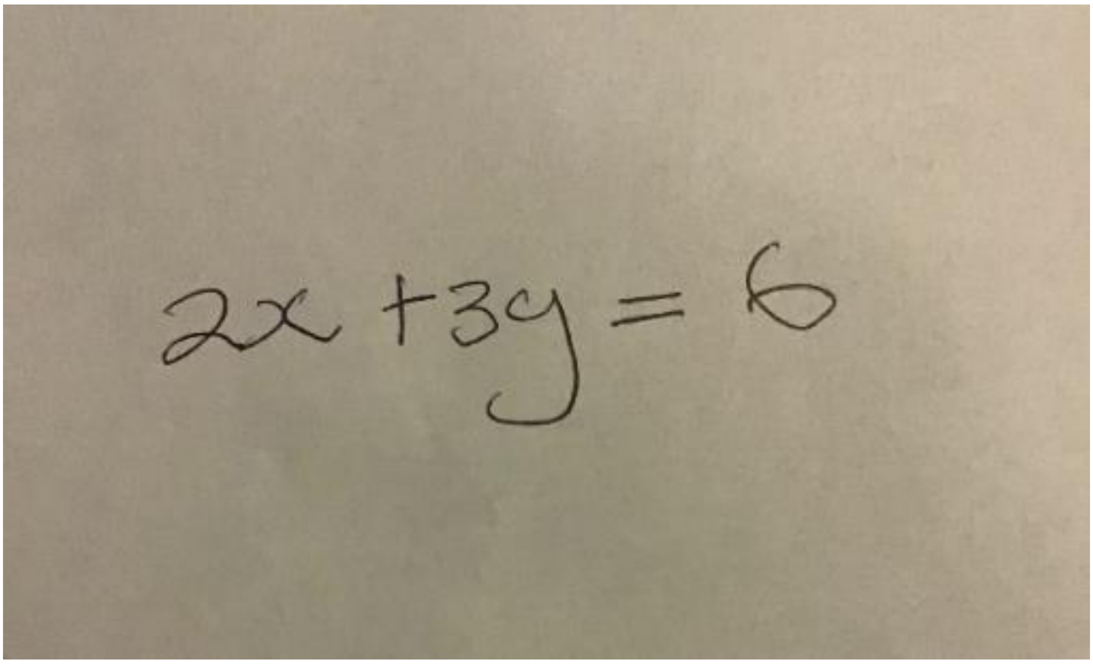

Figure 4.13 Formula written on a piece of paper

There was utter disbelief and amazement when teachers were told that the app allowed the user to write a problem on a piece of paper and take a picture. The equation representing the formula of a straight line was written on a piece of paper (see Figure 4.13). Using the app, a picture of the formula was captured. In processing the captured picture, the app progresses to a screen that sought to find out how the teachers wanted to solve the equation. Here a user may select any relevant mathematical solution method as displayed. For the workshop's purposes, the selection was the ***Graph Using a Table of Values*** option (see Figure 4.14).

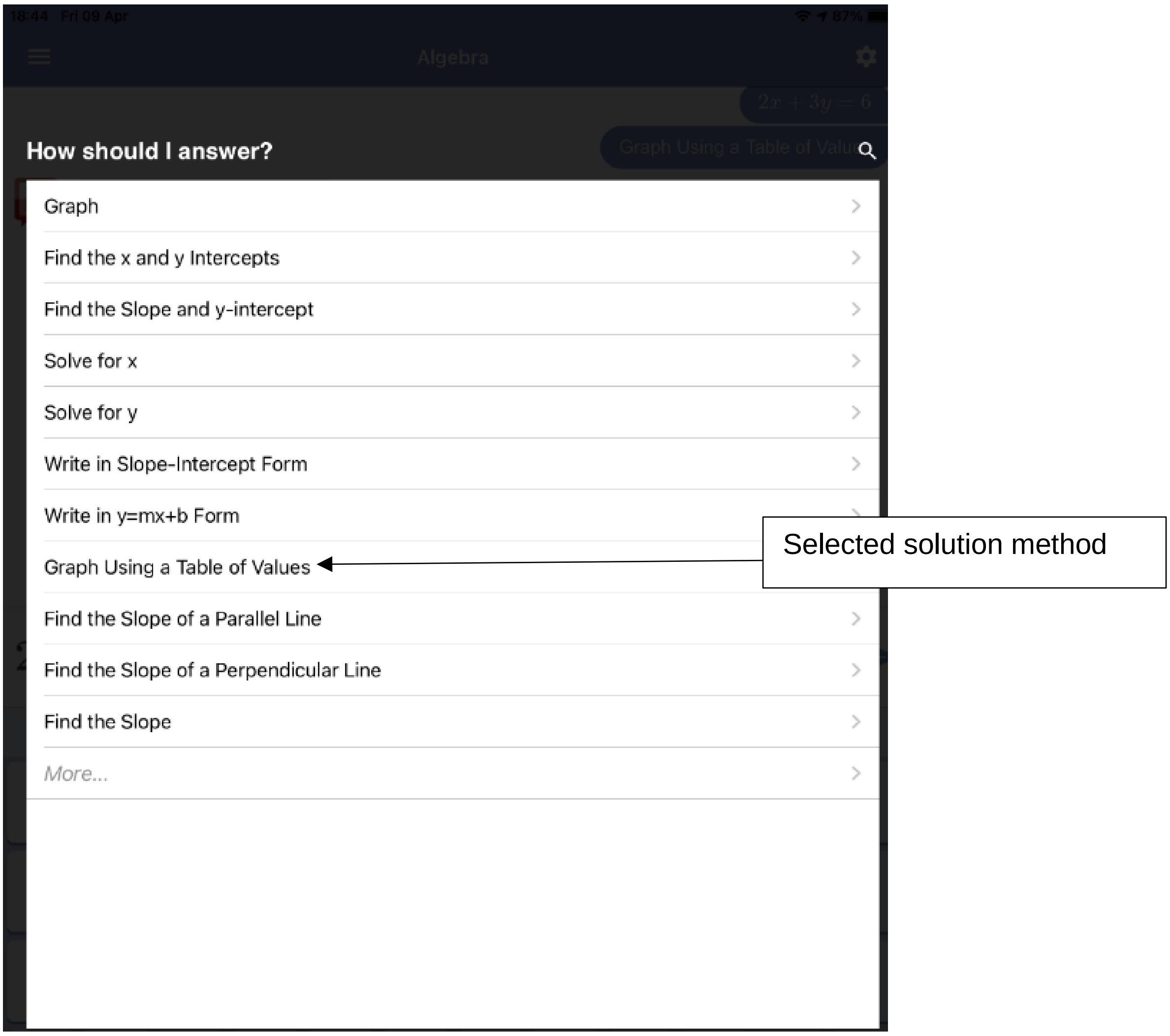

Figure 4.14 Choices the app provides to solve a captured problem

Figure 4.15 shows the solution based on the selected choice. The app produced a straight line graph as everyone had expected. It also produced a table of values wherein given a value of **x**, they could then determine the corresponding value of **y**. Once more the app had had a window wherein, they could tap to view the steps involved. From the graph the teachers were able to work out the intercepts, that is, where the straight line crossed the two axes. In no time they could work out that when **x** = 0 then **y** = 2 and when **y** = 0, **x** = 3.

The researcher was extremely proud for introducing the teachers to the apps through the workshops. The workshops were filled with energy, enthusiasm and eagerness. This is what was fulfilling because at the beginning there was a sense of apprehension and perhaps a fear of the unknown because the teachers had never used mathematical apps in their teaching. Asked if they would use apps going forward, a resounding ‘undoubtedly’ was the answer. In many ways this heralded an accomplishment on its own, when one considered the primary objectives of this developmental study.

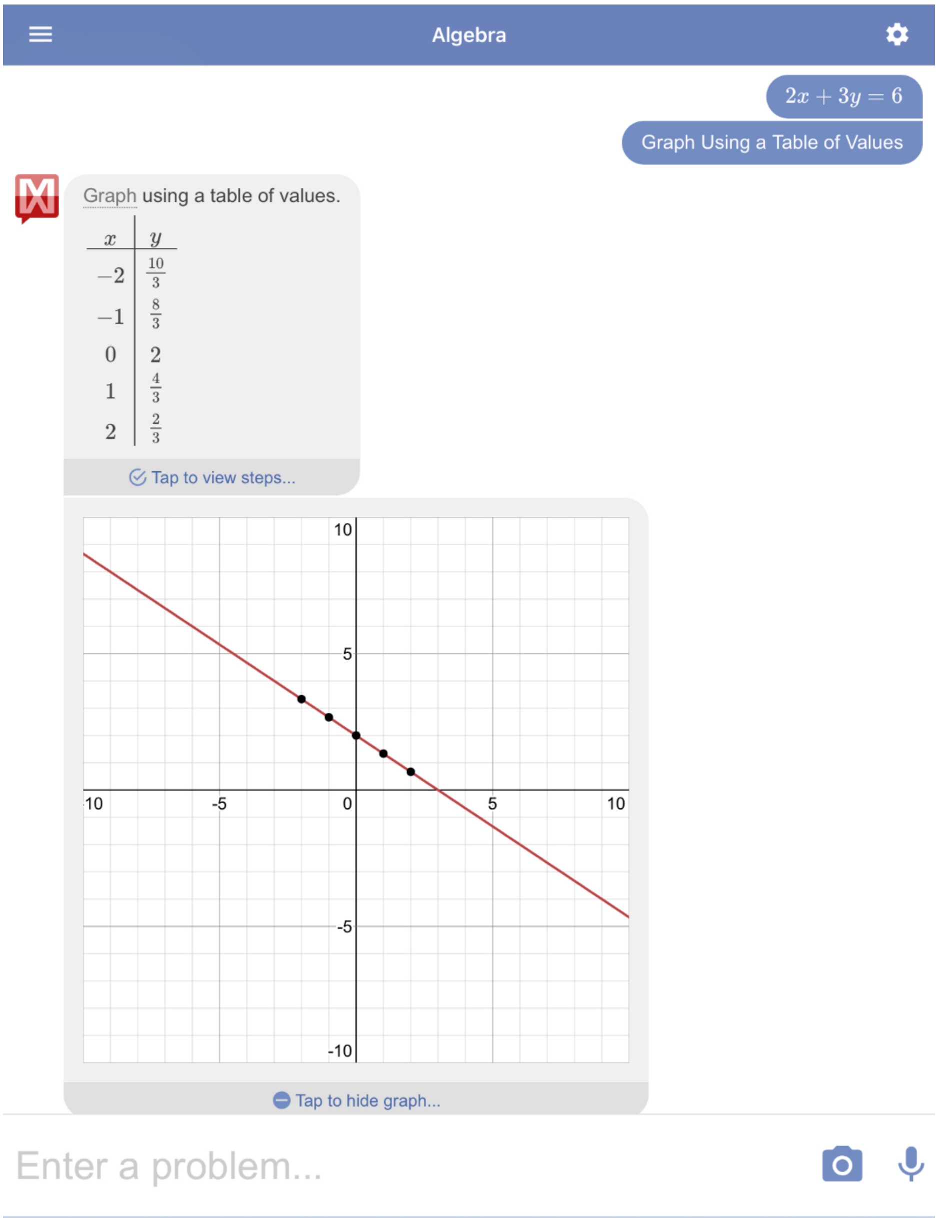

Figure 4.15 Solution based on the choice, *Graph Using a Table of Values*

In all the three workshops described here, the main issue was simulation, which mathematical apps afford teachers and students to carryout. Simulation is extremely important in the classroom because it allows for better understanding of complex concepts that would ordinarily be difficult for a teacher to explain. Simulations have the advantage of replacing and amplifying "… real experiences with guided ones, often 'immersive' in nature, that evoke or replicate substantial aspects of the real world in a fully interactive fashion" (Lateef 2010, 348). The teachers were really immersed in the activities covered in the three workshops and by their admission, 'learning was fun'.

By the time the third workshop took place, eight participants unfortunately indicated that they had to withdraw. On inquiry, they indicated that they were unable to continue because they could not afford the cost of data. The eight did express their gratitude for the invitation to participate and learning about mathematical apps that they had never been exposed to before. At the completion of the third workshop, each teacher participated on a one-on-one interview with the researcher. The teachers were told that the interviews would be about all aspects related to what they had been exposed to. All the remaining 22 teachers agreed to be interviewed. Their responses are presented in Section 4.5 in the results.

4.3 Data analysis

In this section, an explanation of how data were analysed quantitatively and qualitatively is proffered. Here, quantitative data were analysed using SPSS version 26 (2019). With respect to qualitative data, all interviews were recorded and later transcribed. This made it easy to listen to what was said and quote these directly.

4.3.1 Analysis of quantitative data

About biographical data, frequency distributions including percentages were calculated. Where applicable, for instance in the case of the teachers' ages, central tendency in terms of the mean and median including dispersion, represented by the standard deviation, were computed. Following the biographical data, was the analysis of the Affinity for Technology Questionnaire (ATQ). Initially, the internal consistency of the scores (reliability) obtained from the teachers' responses was determined. This was important because if these scores were not found to be reliable then reporting on and drawing conclusions would not be sensible. In analysing the data, the focus here was on whether teachers agreed or disagreed with statement reflecting their attitudes toward technology. In addition, teachers rated their phobia to technology on a four-point scale anchored by Highly Technophobic to Not Technophobic. In reporting the results here, cross-tabulations of the ratings by gender, age and years of experience were computed using (SPSS, 2019).

4.3.2 Analysis of qualitative data

An advantage of the Microsoft Teams platform is that it allows for the recording of a meeting. The one-on-one interviews were recorded, therefore. To analyse the data, all the interview session responses by each teacher were initially transcribed. The intention was to establish whether themes or categories of sorts would emerge from what they had said. This approach is consistent with the view that in interviews the aim is "… to produce a detailed and systematic recording of the themes and issues addressed in the interviews and to link the themes and interviews together under a reasonably exhaustive category system" (Burnard 1991, 461 - 462). As much as practicable, teachers' responses were grouped together in an endeavour to link themes that seemed to express a particular view. The next section deals with how ethical issues were addressed in this study.

4.4 Ethical considerations

With respect to ethical considerations, a researcher from the onset should reveal underlying interest, agenda, epistemological and ontological perspective (Hitchcock & Hughes 1995; Griffiths 1998; Mason 2002). Ideally, there was need to write to relevant parties requesting necessary permissions to work with teachers. Had everything gone according to the originally intended plan, the relevant parties would have been the education department authorities as well as school principals of selected schools. This is also consistent with TUT's ethical protocols and guidelines. The onset of COVID -19 and subsequent government sanctioned lockdowns meant that alternative methods of even contacting possible participants had to be found. The alternative was to meet teachers online. The researcher managed to contact 30 mathematics teachers, to whom teaching with mathematical apps, the workshops and the research process was explained. Fortunately, all were enthusiastic and agreed to participate.

Literature points out that participants should be made aware of what a study entails, and they should also know what their rights are when agreeing to participate (Bell 2010). In this developmental study, the teachers were informed that the study was conducted only for research purposes and that all information they supplied would be treated with confidentiality. They were further informed that the one-on-one interviews would be recorded. In this regard, it was explained that the recordings were meant to keep an accurate account of what was said only and that after transcription they would be deleted. It was also stressed to the teachers that their participation was voluntary. That is, they could withdraw at any stage if they so wished. In this regard, 30 teachers started with the study. Following a lack of data, eight withdrew without any repercussions.

As the teachers were expected to submit responses to the questionnaire through WhatsApp or SMS, it was stressed that they should not write their names on the document. It was also explained to the teachers that their responses would be quoted *verbatim* in reporting the qualitative data, however, pseudonyms would be used instead of their actual names.

4.5 Summary

In this chapter the study design was outlined where it was indicated that a mixed methods design was used to encourage the use of smartphones in teaching high school mathematics. Following this, an explanation of the collection of quantitative data as well as qualitative data including the procedures was advanced. The next section presented the methods used to analyse the collected data. The chapter closes by touching on ethical issues. It was shown here that ethical issues are important in according respect and due ethical conduct in dealing with the participants. The implementation and outcomes emanating from the data collected here are presented in the next chapter.

5 Implementation and outcomes

5.1 Introduction

In this chapter the implementation and outcomes of both the quantitative and qualitative data are presented. The presentation begins with a description of the characteristics of the participants, in terms of variables such as gender, age, teaching experience and qualifications. This is followed by the results of the affinity for technology aspect of the quantitative data. In this instance, graphic representations of the responses to the Affinity for Technology Questionnaire (ATQ) provide a visual picture of whether teachers were 'technology optimists' or 'technology pessimists.' After the graphic representations, the results reveal the teachers' self-ratings in terms of the different levels of technophobia. The last section here covers the qualitative data. Here, excerpts from the one-on-one interviews are provided as illustrations of the views of the participants to the different questions they had to respond to.

5.2 Biographical data

Table 5.1 Characteristics of the participants (N = 22)

Characteristics		**n**	**%**	**M (SD)**	**Median**
Gender	M	15	68		
	F	7	32		
Age	≤ 29 years	5	23	41.6 (10.1)	45.0
	30 - 45 years	6	27		
	≥ 46 years	11	50		
Teaching experience	≤ 5 years	3	14	11.9 (4.6)	13.5
	6 - 10 years	4	18		
	≥ 11 years	15	68		
Qualification	Diploma	3	14		
	Degree	7	32		
	Degree + Diploma	2	9		
	BEd	5	23		
	BEd (Hons)	4	18		
	Hons Degree	0	0		
	Hons + Diploma	1	4		
Own a smart phone	Yes	22	100		
	No	0	0		

Table 5.1 shows the biographical information of the 22 teachers who completed the research process. The table shows that the majority of the Grade 12 teachers were men (68%) with half of them aged 46 years and older. Specifically, the teachers' ages ranged between 23 years and 53 years (M = 41.6 years; SD = 10.1) with a median of 45 years. In addition, a majority had teaching experience of 11 years or more. Their teaching experience ranged between 4 years and 18 years (M = 11.9 years; SD = 4.6) with a median of 13.5 years. In essence, the table shows that 77% of the teachers were more than 30 years old while 86% had been teaching for at least 6 years.

In terms of the highest qualification, it is observable from Table 4.1 that slightly less than a third (32%) of the teachers possessed a degree without a teaching qualification. More than half (54%) however, had a minimum of a teaching qualification degree (BEd) to an Honours degree and a teaching qualification [e.g., BSc (Hons) + HDE]. The table also shows that all the participants owned a smartphone.

5.3 Affinity for technology

Here, the teachers responded to 10 questions that sought to determine their attitudes toward technology (affinity) are presented. In terms of the internal consistency scores obtained from the teachers' responses to the ATQ, Cronbach's alpha was found to be 0.805. The conclusion here was that the scores were reliable considering that Cronbach's alpha values of 0.892 and 0.88 were reported by the developers of this questionnaire (Edison & Geissler, 2003). In addition, this developmental study's alpha value was good when judged against guidelines for clinical significance of fair if $.70 \leq \alpha < .80$; **good if** $.80 \leq \alpha < .90$; and $\geq .90$ excellent (Cicchetti, 1994). Showing that the reliability of this study was good was important because if this were not the case, then a presentation of the results from the questionnaire would not be sensible. Therefore, the results presented here, were interpreted with the understanding that they were at least reliable.

Figure 5.1 reveals that more than half (59%) of the participants agreed with the statement: ***Technology is my friend***. That is, a majority of the teachers reported an affinity or positive attitudes toward technology.

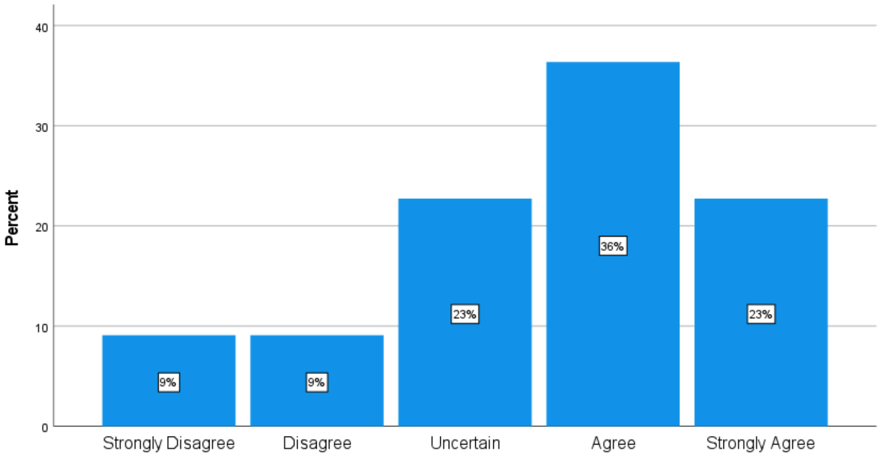

Figure 5.1 Technology a friend

To the statement: ***I enjoy learning new computer programs and hearing about new technologies*** less than half (45%) of the teachers agreed (see Figure 5.2). Here in essence, most teachers revealed negative attitudes toward technology.

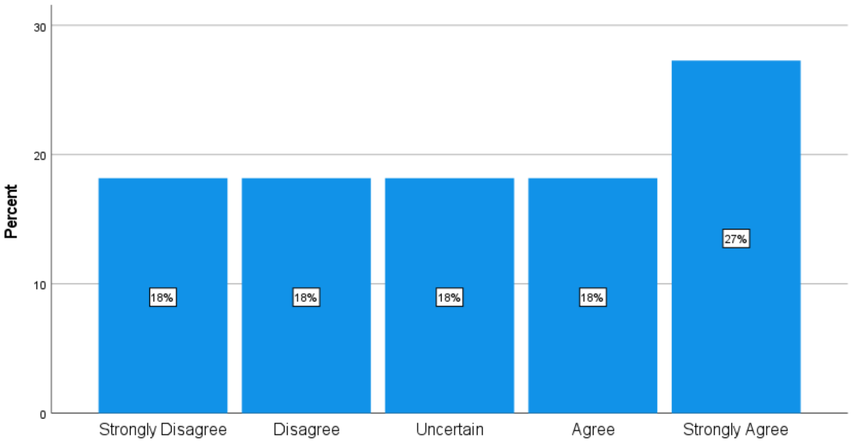

Figure 5.2 Learning new programs and hearing about new technologies

Figure 5.3 shows that more than half (59%) of the participants disagreed with the statement: ***People expect me to know about technology and I don't want to let them down***. That is, the teachers felt that others should not expect them to know about technology.

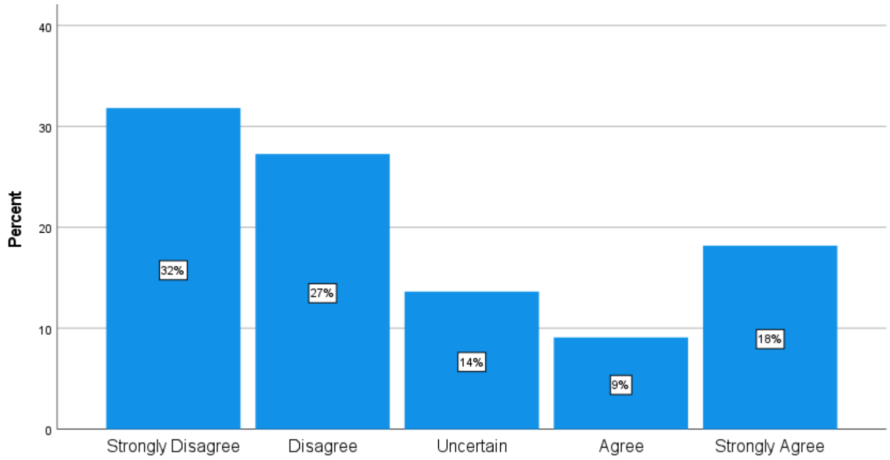

Figure 5.3 Know about technology

To the statement: ***If I am given an assignment that requires that I learn to use a new program or how to use a machine, I usually succeed***. Figure 5.4 reveals that 41% of the teachers disagreed that they usually succeeded while the same number agreed with this view.

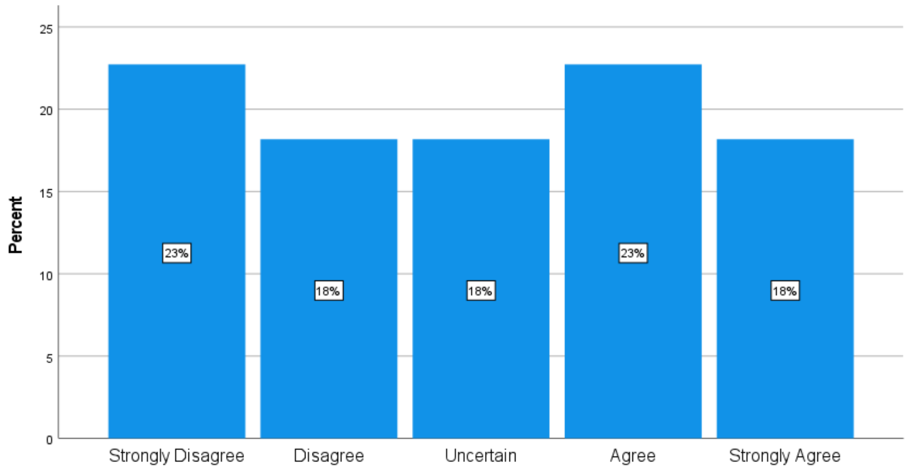

Figure 5.4 I usually succeed

Figure 5.5 reveals that about 45% of the teachers felt that they did not relate well to technology. Meanwhile 41% indicated that they related well to technology.

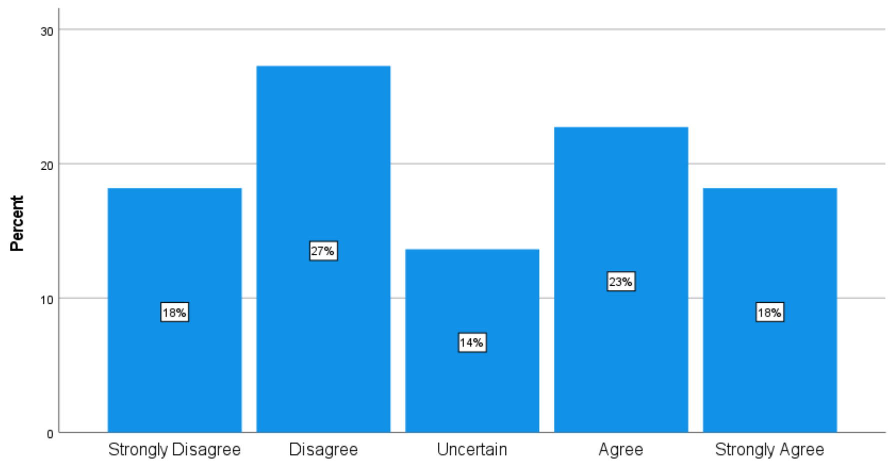

Figure 5.5 Relate well to technology

To the statement: ***I am comfortable learning new technology***, it may be observed from Figure 5.6 that about 46% of the teachers agreed that they were comfortable learning new technology. However, about 41% were somehow not sure that they were that they were comfortable learning new technology.

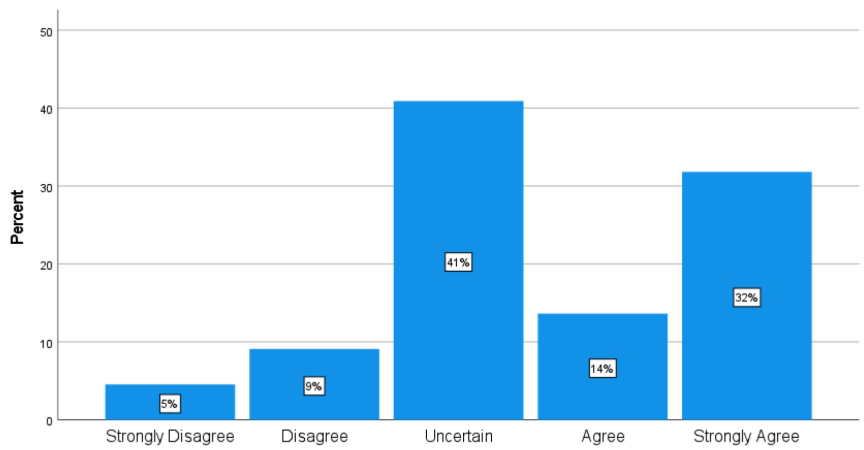

Figure 5.6 Learning new technology

To the statement***: I know how to deal with technological malfunctions or problems***, less than half (46%) agreed that they knew (see Figure 5.7). Around a third (32%) of the teachers somehow felt they were unsure if they knew how to deal with technological problems.

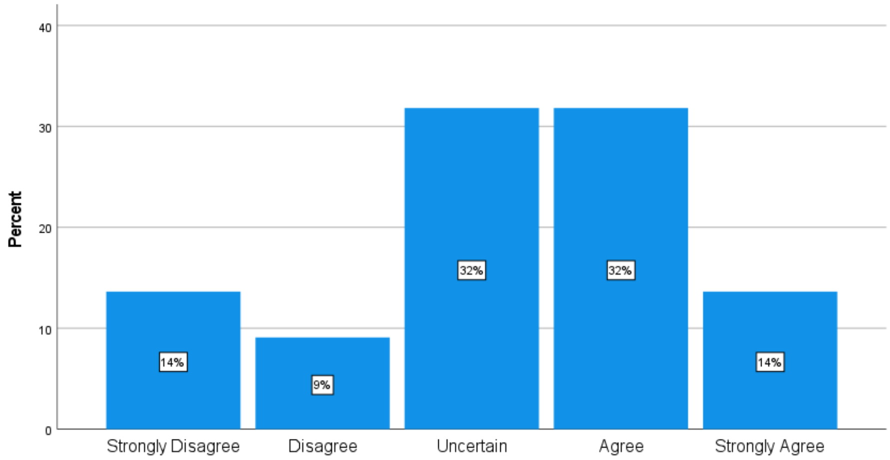

Figure 5.7 Deal with technological malfunctions

Figure 5.8 reveals that less than half (45%) of the teachers were unsure of the view that solving a technological problem was a fun challenge. Similarly, another 41% of the teachers indicated that they felt: ***Solving a technological problem seems like a fun challenge***.

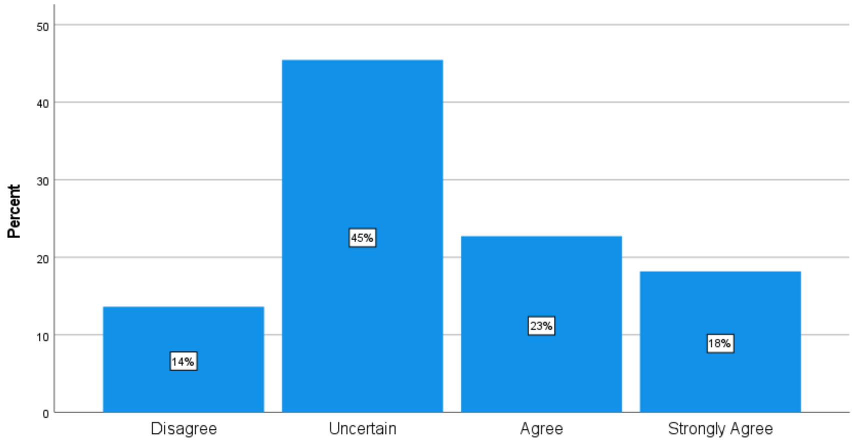

Figure 5.8 Solving technological problem like fun

Figure 5.9 shows that about 41% of the teachers agreed with the statement***: I find most technology easy to learn***. On the other hand, slightly more than one in three (36%) of the teachers were uncertain that they found technology easy to learn.

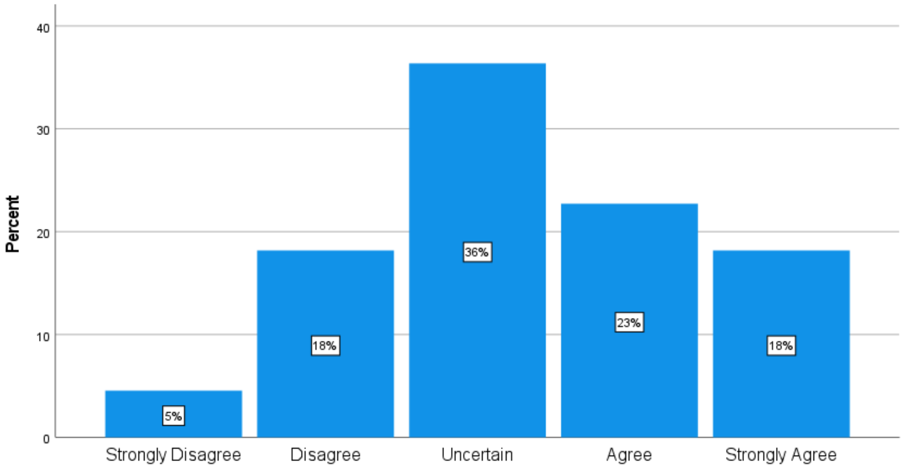

Figure 5.9 Most technology easy to learn

To the statement: ***I feel as up-to-date on technology as my peers***, less than half (41%) of the teachers felt they were not as up-to-date (Figure 5.10). On the other hand, just about one in three (32%) agreed that they kept up-to-date on technology as other teachers.

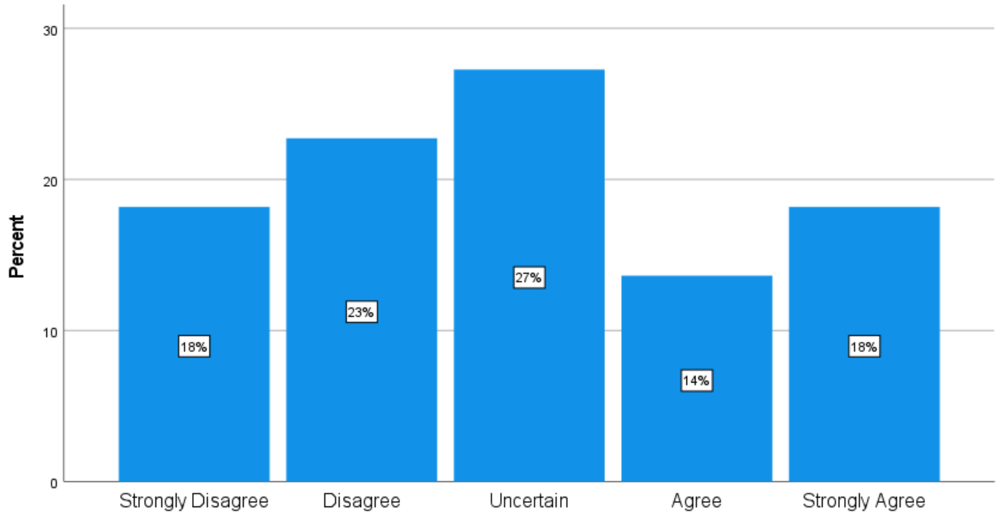

Figure 5.10 Up-to-date on technology as peers

In summary, the results of the ATQ suggest that in many ways the teachers may be categorised as technological pessimists. That is, the teachers may be classified to have had a negative affinity with technology. This result was extremely important for me, because I could not assume that they understood what would be deemed basics in dealing with mathematical apps. For example, this means that during the workshops I could not assume that everyone understood and was conversant if I said ‘Go to the app store and purchase the Geometry app developed by so and so.’

5.4 Global attitude towards technology

Here, the teachers were provided with a definition of technophobia. Following this, they were requested to rate themselves, cognisant of the definition. The results revealed that half (50%) of the teachers [2 women and 9 men] felt high discomfort about computers or any new technology (see Table 5.2). Meantime four (18%) indicated that they were not technophobic. On the other hand, a cross tabulation of the age by phobia revealed that a more than a quarter (27%) of the highly technophobic teachers were those whose age was 46 years and older (see Table A3.1 in Appendix 3). In addition, more than a third (36%) of the highly technophobic teachers had been in the profession for 11 or more years (see Table A3.2 in Appendix 3).

Table 5.2 Self-ratings of the level of technophobia (N = 22)

Phobia	**Frequency**		**Women**		**Men**	
	N	**%**	**N**	**%**	**N**	**%**
Highly Technophobic	11	***50.0***	2	***9***	9	***41***
Moderately Technophobic	6	***27.3***	4	***18***	2	***9***
Mildly Technophobic	1	***4.5***	0	***0***	1	***4.5***
Not Technophobic	4	***18.2***	1	***4.5***	3	***14***

5.5 Qualitative results

The qualitative results reported here are based on the teachers' responses to the questions asked during the one-on-one interviews (see Appendix 2). In order to provide a complete picture or perspective about an individual's response, their biographical information is also included. This, however, is only done when reference was made to a teacher for the first time. In subsequent references, only to the teacher's name appears. For example, if Kgomotso's response was referenced, for the first time this would include the gender, age, qualification, teaching experience and technophobia self-rating. It is worth mentioning that all the names used here are pseudonyms. This was done to fulfil the promise of anonymity that the teachers participated on the understanding of.

The results of the one-on-one interviews seemed to suggest the emergence of three groups of teachers (see Appendix 5). The first, named the ***fear of failure*** group included three women and four men. The second was named the ***early adopters***. This group comprised of three women and eight men. The third was referred to as the ***wait and see*** group that comprised of one woman and three men. As a result of the categorisation, the interview responses are presented in correspondence to the three.

The first question the teachers were asked was: *Have you ever used mathematical apps to teach the subject?* All the 22 interviewees indicated that they had never used a mathematical app to teach, not only mathematics but any subject. Perhaps Katlego's response to this question represented the sentiment and excitement of the teachers. She was a 46-year-old woman who possessed a Bachelor of Education Honours degree and had been teaching Grade 12 mathematics for 11 years. In terms of technophobia, she rated herself as moderately technophobic. She said, ***thank you, thank you very much sir. I would like to start by thanking you for inviting me to be here. I have never used a mathematical app before. … I didn't even know there was something like that***. Complementing this sentiment was Thabo. He was a 41-year-old man who possesses an honours degree in science and a teaching diploma. He had an experience of 8 years in teaching Grade 12 mathematics. He rated himself as not technophobic, however he said, ***I use apps quite regularly … but I have never looked at a mathematical app. In fact, I never ever thought about using apps in my classroom***.

The second question was: *Now that you have attended the workshops how likely are you to incorporate apps in your teaching*? Thabang's response is an apt representation of what the seven teachers (***fear of failure*** group) said. He was a 48 year old man who possesses a Bachelor of Education degree, with teaching experience of 17 years and who rated himself as highly technophobic. Thabang indicated, ***I have seen and appreciated these apps but I think I will need more time and training to familiarise myself with them and be comfortable in using them … Right now, as we speak, I see their value, but I don't think I am ready yet***.

The second response type was given by eleven teachers (***early adopters*** group). Pulane's response typified their enthusiasm, motivation to use mathematical apps and acceptance of these. Pulane, a 27 year old woman, a holder of a BSc degree, with 5 years of teaching experience, who rated herself as not technophobic, with excitement and enthusiasm said, ***I wish there was no Covid … I cannot wait for schools to open and to use these apps. … I am going to practice and practice these … by the time we go back I will be so ready to teach with apps***.

The third response type was from four teachers (***wait and see*** group). A representative interview interaction here was with Gomolemo a 53 year old man. He is a BSc degree holder, with 18 years' teaching experience. Gomolemo rated himself as highly technophobic. He said, ***I do not think I will be able to incorporate the apps in my teaching***. When asked why, he said, … ***please do not think that I do not want to use apps in my teaching, I do … at this stage I don't think I am confident enough and I***

know that the children I teach know how to use cell phones more than I do … they are advanced. In following up he was asked; don't you think that is exactly what you need? … advanced students? He said, ***I never thought about it that way … I know now that I should be ready to use these apps … I promise you sir, I will try my best.***

The third question was: *How likely are you to search for more apps other than the three we used in the workshops*? Neo's response was a fitting representation of what the eleven other teachers in this group said. Neo was a 23 year old man who possessed a BSc degree plus a teaching diploma, with teaching experience of four years. He rated himself as highly technophobic. He said ***… to be honest with you, immediately after the workshops I have looked at and practiced different examples from the apps you brought … later I searched for other apps I could look at … for now I looked at them just to have an idea of what else I could add ...*** On the other hand, Sello, a 53 year old man who possessed a BEd degree with a teaching experience of 11 years and rated himself as highly technophobic, pointed out, ***… not now … we still have Covid now. I think I will start with these apps I know … in fact, I am going to start by familiarising myself with the workshop apps first … I hope to search for others later …*** Meanwhile, Morongoa, a 28 year old woman who possessed a BSc degree with a teaching experience of six years and rated herself as moderately technophobic, indicated, ***… I am not sure I will … if I do, I will have to contact some of the colleagues and work with …*** Asked what if others do not want to search for more apps, she responded, ***… I will try and convince one or two to work with me …***

The fourth question was: *Do you think your use of mathematical apps will make a difference in your classroom*? To this question Mashudu a 47 year old man who possessed a BEd (Hons) degree with a teaching experience of 15 years and rated himself as not technophobic, replied, ***… I cannot vouch for it … my feeling is that I will have to convince the students to learn to use the apps in conjunction with the textbook.*** Thabang, also in the wait and see group said ***… I am not sure you know; I am thinking the apps will be new to them so they will have to adapt to this form of learning***. On the other hand, Pulane with confidence pointed out ***… of course, my students will enjoy learning with apps … I have never used apps with students, but I think in no time they will enjoy working with them and of course the apps will make a difference …*** Meanwhile, a typical response from the fear of failure group was proffered by Lebogang, a 52 year old man who possessed a BSc degree with a teaching experience of 16 years and rated himself as highly technophobic. He said ***… they will have to make a difference …*** asked why he was saying this, he pointed out, ***… because if things don't work it will be wasted time and I may not teach everything in the syllabus …***

The fifth question was: *Do you think teaching using mathematical apps has the potential to enhance learning?* Katlego simply said ***… without doubt.*** Asked why she thought so, she indicated ***… think about it, you bring this technology to children who enjoy fiddling with their phones anyway. I expect them to appreciate working with the apps and so their learning will improve***. A similar answer was given by Kgalema, a 30-year-old man, whose qualification was a teaching diploma. He had teaching experience of seven years and rated himself as highly technophobic. He said ***… of course the apps will enhance learning … I only have to beef up my understanding, thereafter my task will be to make sure my students benefit from using apps***.

On the other hand, Mmabatho's response was a fitting representation of the four other teachers in the wait and see group. Mmabatho was a 44 year old woman who possessed a BEd degree with teaching experience of 13 years. She rated herself as highly technophobic. She answered ***… right now I do not think the apps can enhance learning …*** asked why, she replied ***… I would like to use apps over and over with my students after which I can determine that.*** Meanwhile, Malebo, a 50-year-old woman with a teaching diploma qualification, who had teaching experience of 16 years and who rated herself as moderately technophobic, said ***… I am afraid this may not be so as it appears …*** asked what she meant, she replied ***… I am asking myself what if things don't work out? What if I rely on apps and my students do not have data? It may not end up well.***

The sixth question was: *Do you think mathematical apps have the potential to promote students' self-directed learning?* Masego's response was a typical representation of the early adopters group. She was a 23 year old woman who possessed a BSc degree, with teaching experience of seven years. She rated herself as moderately technophobic. She pointed out ***… definitely … because one of the advantages of the apps is that students can work out problems on their own even at home or whenever they want to …*** This view was also corroborated by the 40 year old Moshidi, a man who holds a BSc degree with 11 years of teaching experience and who rated himself as moderately technophobic. He said ***… as far as I am concerned these apps will promote students' self-directed learning. … I also think that students will even help their friends who do not understand how a solution was reached by showing them the steps followed … so I also see them collaborating and assisting each other.***

Mogale saw things slightly differently. A 47 year old man who possessed a BSc degree plus a teaching diploma with a teaching experience of 14 years, who rated himself as highly technophobic, ***… I think I have to make sure that the students clearly***

understand how the apps work … if I do not do that there may be disaster … asked what he meant by disaster, he said ***… I generally don't like for students to work on their own because they may learn wrong things that I will later need to correct. For me it is better to lead them, then I will be comfortable …*** Malebo who belongs to the fear of failure group as Mogale, in many ways was in agreement with him. She opined ***… I don't think apps have the potential to promote students' self-directed learning.*** Asked why she did not think they would, she said ***… my students solely depend on me in working out mathematics problems … If they were to take over, let me tell you, nothing will be achieved.***

Meantime, the wait and see group seemed to be more circumspect about things. Perhaps Thabang's views epitomised them. He said ***… for me that will depend on whether students will like and buy into the idea of using apps to learn mathematics … I am not sure at this stage …*** Likewise, Mashudu said ***… I am afraid I do not know as we speak … I will find out though as soon as students come back to school***.

Among the early adopters, perhaps a typical answer was provided by Lehlohonolo, a 49 year old man who possessed a BEd (Hons) degree with 15 years teaching experience, and who rated himself as not technophobic. He said ***… most certainly … when students are familiar with how the apps work, they will start learning mathematics on their own and with friends … I think the apps will keep them interested, as a result their test results will eventually improve …*** Moshidi agreed, he said ***… without doubt … mathematical apps have the potential to improve student achievement … apps will increase students' interest in mathematics, it will improve their engagement with the subject, and they will be better at knowledge retention …***

Mmabatho, who was in the wait and see group said ***… the apps may improve or not improve student achievement … I am not sure actually***. Sello was on a similar thought process, he said ***… if the students accept the use of mathematical apps … I think they have a potential to improve achievement … if they don't accept and use them … I am afraid there will be no potential to improve achievement***.

Among the fear of failure group, the 25 year old Itumeleng provided a typical response. She possessed a BEd (Hons) and had been teaching on for four years, while she rated herself as highly technophobic. She said ***… the whole thing depends me …*** Asked, why is that? her answer was ***… it depends on how I handle teaching mathematics with apps ... I must make sure I do it correctly before I even think about student achievement***. Gomolemo meantime simply stated ***… there is hardly any potential if I do not teach them well …***

The final question was*: What would you say is your attitude towards technology – Do you find it easy to learn*? Here the teachers within the fear of failure groups were rather evasive. For instance, Mosebudi was a 44 year old man who possessed a BEd degree and had been teaching for 13 years. He rated himself as moderately technophobic. In answering the question, he said ***… I like to think that I am positive about technology … I don't think I am ready however to fully use this in my classroom …*** Asked to explain what he meant, he continued ***… I always worry that things may not work out and teaching time will have been lost …*** Morongoa simply said ***… I really like technology, but I worry about my students not liking it …*** Asked, what happens if they do not like it? ***… Unfortunately, I will have to revert back to the textbook … at least we all work well with the textbook …***

Among the early adopters, Tebogo's response was perhaps more representative of this group's sentiments. He is a 40 year old man who possessed a teaching diploma. He had 12 years of teaching experience and rated himself as highly technophobic. In answering the question, he averred ***… I always had this negative attitude towards technology. I must admit, the workshops opened my eyes. When I saw how I could use apps to teach geometry I knew immediately I wanted to use them … to cut a long story short, I surprisingly found it easy to learn …*** Pulane on the other hand said ***… I always have had a positive attitude toward technology … that made learning about apps for mathematics much easier for me***. Among the wait and see group Sello said ***… to be honest I don't like technology in the classroom … my fear is that my students will not like it too. I enjoyed the workshops though and I want to try the apps when I meet my students in the near future …*** Meanwhile Mashudu said ***… until the workshops, technology was not something I thought of for teaching purposes … I did not think I would find technology easy to learn actually …***

5.6 Summary

This chapter presented the findings of this developmental study. It was reported here that more than two in three (68%) of the participants were men. The teachers' average teaching experience was about 12 years. In terms of the quantitative questions relating to affinity towards technology, the results revealed that there was no instance where about 50% or more teachers who agreed or disagreed with given statements. This meant that on the main, the teachers had negative attitudes toward technology. About technophobia, only four teachers indicated they were not technophobic. Surprisingly, two of the four were in the age group less than or equal to 45 years and the other two were 46 years or older. Concerning the one-on-one interviews, the teachers' responses fell into three groups, namely, the ***fear of failure*** group; the ***early adopters*** group; as well as the ***wait and see*** group. In fact, the responses of most of the teachers complemented the quantitative findings in that they seemed to confirm negative attitudes toward technology. The next chapter focusses on the discussion of the results, the recommendations and conclusions of this developmental study.

6 Discussion and conclusion

6.1 Introduction

In this chapter, a discussion of the findings follows. As the main objective of this developmental study was to improve Grade 12 mathematics students' performance in South Africa, a process of developing a study guide including a proposed module is addressed. The module and study guide are proposed for the School of Education at TUT so that the process of change and introducing technology in the mathematics curriculum could start with pre-service teachers. A business canvas covers the value proposition in respect of the introduction of the module about teaching mathematics using different applications. Also included in the chapter, are the identified limitations of the study. Following the limitations, is a narrative of some of the researcher's personal reflections regarding the entire study programme. The chapter concludes with a summary of the study.

6.2 Discussion

It is perhaps worth pointing out that the 22 teachers who participated in this developmental study had an average age of about 41 years. They were also fairly experienced mathematics teachers whose average teaching experience was 12 years. This is important because it shows that these were mature teachers with extensive experience of teaching Grade 12 mathematics. That is, one would have to trust their views as opposed to if information was from inexperienced novices. Further, in terms of the findings from the Affinity for Technology Questionnaire, these should be acceptable as it was shown that the scores from the questionnaire were reliable.

In the quantitative aspect of the study, about six in ten (59%) of the teachers indicated that technology was their friend. That is, they had an affinity or positive attitudes toward technology. Meantime, only four teachers identified themselves as not technophobic. Similarly, about 46% of the teachers indicated that they were comfortable with learning new technology. Yet, teachers such as Thabang in contradiction said, ***… I think I will need more time and training to familiarise myself with them and be comfortable in using them … I don't think I am ready yet***. Once more, teachers were asked about their attitudes toward technology. In this instance, Mosebudi said ***… I like to think that I am positive about technology … I don't think I am ready however to fully use this in my classroom …*** Similarly, Morongoa indicated ***… I really like technology, but I worry about my students not liking it … Unfortunately, I will have to revert back to the textbook …*** This is not surprising because literature reports that people have a tendency to overrate their abilities and actually believe it (DeAngelis 2003). In fact, literature shows that overestimation by incompetent individuals and underestimation by competent ones is a result of the same psychological processes (Kim, Kwon Lee & Chiu 2016).

The one-on-one interviews also revealed the emergence of three groups of teachers that were named the ***fear of failure***, the ***early adopters*** and the ***wait and see*** group. The emergence of the three groups was not surprising because literature points out that there are differences in how teachers actually perceive themselves as professionals (Van Veen, Sleegers Bergen & Klaassen 2001) and even about the tasks that they feel responsible for (McKenney & Visscher 2019). In terms of technophobia virtually all the groups comprised of technophobic teachers. In both the ***fear of failure*** and the ***wait and see*** groups there was only one teacher who indicated that they were not technophobic. Essentially by their own admission most of the teachers, in some way, had an aversion towards new technologies, especially cloud technology, mobile applications, the use of Internet as well as of coding (Rungta 2016).

The one-on-one interviews in many ways complemented what was reported from the quantitative data. The one-on-one interviews were more revealing. For instance, the results revealed that the teachers had never used apps in their teaching. Here, Katlego for example indicated ***… I have never used a mathematical app before. … I didn't even know there was something like that***. Even a teacher, who indicated he had used apps privately, revealed that he never thought of them for teaching purposes. In fact, Thabo said ***… but I have never looked at a mathematical app. In fact, I never ever thought about using apps in my classroom***. This view was complemented by the responses to the statement, ***I enjoy learning new computer programs and hearing about new technologies****.* In this instance more than half (55%) of the teachers felt they did not enjoy hearing about new technologies or were unsure.

In this developmental study, teachers were introduced to workshops on mathematical apps. Here, the researcher believed that knowledge gained would help improve their teaching. This is because the information gained from the workshops would give the teachers an opportunity to restructure and redesign their classrooms to create learning environments that promote higher-order thinking skills (Kurt 2010). In addition, literature posits that teachers are provided with information about technology however, they receive no guidance on the use of the technologies that can support their work (McKenney & Visscher 2019). It was exactly for the reason of ensuring that the teachers received guidance on the use of the technologies that can support their work, that the workshops were organised.

To the question, *Do you think teaching using mathematical apps has the potential to enhance learning*? Mmabatho indicated ***… I do not think the apps can enhance learning …*** Similarly, Malebo felt ***… this may not be so …*** The findings reported here are in fact contrary to what literature reports. Literature suggests that incorporating technology in the classroom indeed enhances student learning (Krentler, & Willis-Flurry 2005). This is consistent with the view that interactive technology in the classroom helps enhance mathematics learning (Miller, 2018). On a similar question about technology having the potential to improve student achievement, most teachers did not think this was the case. Mmabatho, for instance said ***… I am not sure actually***. While Itumeleng felt ***… there is hardly any potential if I do not teach them well …*** Literature however shows that indeed technology has the potential to improve student achievement (Protheroe 2005). Other researchers report that technology has the potential to improve student achievement if learning is designed around different educational and psychological theories (Schacter & Fagnano 1999). Regarding the potential of technology, a conclusion advanced is that teachers "… should make every effort to incorporate the use of technology in their instruction" (Krentler, & Willis-Flurry 2005, 320).

It is sometimes easy to blame teachers for not thinking about or using apps in their classrooms however, this is mainly as a result of lack of knowledge than deliberately ignoring apps. In fact, literature points out that inadequate professional development and training is the most commonly cited reason for non-implementation of technology in classrooms (Ertmer, et al. 2012). This suggests that technology is not implemented perhaps because of technophobia or lack of awareness of its effectiveness. The findings reported here are vital because among factors identified to strongly influence classroom practice, are teachers' understanding and beliefs (Ball & Cohen 1996). The following section deals with developing a study guide proposed to be included in the School of Education curriculum at TUT. The study guide could also be used for capacity development for in-service teachers.

6.3 Recommendations

The results of this developmental study have shown that the participants were fairly experienced Grade 12 mathematics teachers. In spite of the experience, all the teachers had never used mathematical apps to teach the subject. Almost all but four, rated themselves as not technophobic. The quantitative results showed that largely, the teachers had a negative affinity with technology. Similarly, in the qualitative results the teachers revealed negative attitudes toward technology. In fact, they did not think technology had the potential to either improve student learning or student achievement.

Technology is extremely important in the teaching and learning context because of what it allows. For instance, it allows for abstract situations to be brought to life and thereby make it easier for students to think about and understand. About the importance of technology in the mathematics classroom, it is pointed out that it is essential because it also influences the way mathematics should be taught while enhancing what students learn (NCTM 2000). In addition, teachers who teach with technology are known to "… help students organize information, support investigations, and develop decision-making, reflection, reasoning, and problem-solving skills" (Ittigson & Zewe 2003). The results of this developmental study therefore point to an opportunity to train high school mathematics teachers to be able to integrate mathematical apps in their teaching. If South Africa is to produce Grade 12 students with good mathematics passes, the recommendation is that government should look at reskilling the teachers teaching this subject. This could be done by universities offering in-service training to teachers. For the future, it is critical for universities such as TUT to incorporate teaching with technology in the curriculum for teacher training. In that regard, a proposed module (see Appendix 7) and study guide (see Appendix 8) for the School of Education are included here.

6.4 Processes for developing a study guide

In this developmental study, the main aim was to develop a technology-based learning environment to improve the teaching of high school mathematics in South Africa. Specifically, the aim was to explore teaching mathematics through apps by using smartphones. Smartphones were the mode of choice because as has been shown earlier, by September 2018 South Africa had a penetration of 82% of these (Gilbert 2019). This suggests that there was a high probability that students and teachers would possess a smartphone. The learning environment specifically focused on mathematical apps because pedagogically they afford individualised and targeted mathematics practice, which supports mastery of mathematical skills (Outhwaite, Gulliford & Pitchford 2019). Pre-service teachers are not trained to use technology in teaching, especially in the area of mobile applications. This is despite the fact that mobile applications offer flexibility, provide immediate learning opportunities, as well as save time for both learners and teachers (Al-Takhyneh 2018). In the US the NCTM (2000) argues that technology has the ability to effectively support mathematics teaching and learning, while it will approximate abstract concepts through simulations and link mathematical information with students by providing direct sensory experiences.

Teachers are the main factor in deciding what and how technology is integrated within their classrooms. Therefore, introducing teaching with technology as early as possible, to pre-service teachers is sensible while it is empowering to those already in-service. This is because technology-integrating education strongly influence teachers' attitudes toward computers (Christensen 2002, 431). In addition, at TUT quality is at the heart of teaching, learning and research. Which explains the motto ***We Empower People***. Compounding the idea of a study guide was the fact that the teachers had indicated that they did not use mathematical apps in their classrooms. Based on the foregoing, developing a study guide that addressed the introduction of mathematical apps in teacher education was of the essence.

6.4.1 South Africa's qualification framework

At this stage, it is perhaps prudent to provide a perspective of South Africa's qualification framework. In doing this, the hope is that such an exercise will show how an addition of a module to a qualification has implications that require both statutory bodies as well as internal university approval. In South Africa, all qualifications fall under a qualification framework that has clearly defined level descriptors. Each qualification has a pre-determined number of credits, which are sub-divided into a number of modules. Each module carries a number of credits which when added up, make up the qualification credits. A brief descriptor of South Africa's qualification framework and all its nuances is presented in Appendix 6.

The qualification framework is the building block on which the development of modules is based. At TUT for instance, all changes to a qualification are initially approved by the Senate. Following this, statutory bodies such as the Council for Higher Education (CHE), the South African Qualification Authority as well as the Department of Higher Education and Training (DHET) approve any changes to qualifications. At this stage the qualification is then accredited. The need for accreditation suggests that any department seeking changes in their offerings will therefore start the process of a new module request. A typical additional module request form is illustrated in Appendix 7. This therefore means that a study guide may be developed following the necessary approvals and accreditation.

6.4.2 The study guide

The study guide presented here is created and adapted based on the template of TUT (see Appendix 8). It is worth pointing out that the study guide as it is was not discussed with all the relevant parties as there has not been an opportunity to because of the lockdown. As soon as all the lecturers who teach pre-service mathematics are back at work my hope is that consensus will be reached, and the study guide will be taken through the university processes pending approval.

The study guide should receive favourable support from the consultation process more so because I will show that studies report for instance, that teachers found iPad apps less threatening and easier to learn from (Calder & Campbell 2016). What is certain here is the fact that with proper training and the usage of technology in the classroom incorporated in the teacher education programme, teachers will embrace as well as maximise teaching with the mathematical apps. About this, Becker (2000) argues

> where teachers are personally comfortable and at least moderately skilled in using computers themselves, where the school's daily class schedule permits allocating time for students to use computers as part of class assignments, where enough equipment is available and convenient to permit computer activities to flow seamlessly alongside other learning tasks, and where teachers' personal philosophies support a student-centered, constructivist pedagogy that incorporates collaborative projects defined partly by student interest—computers are clearly becoming a valuable and well-functioning instructional tool.

While Becker (2000) references computers here, his contention is valid and holds true for smartphones and associated apps too.

6.5 Business canvas in support of module

Literature argues that "… teachers are not graduating from colleges of education with the skills and competencies needed to be successful in the outdated factory model of education that still plagues many classrooms … (Cator, Schneider & Vander Ark 2014, 3). For this reason, the business canvas presented here provides the value proposition of training teachers for the improvement of mathematical achievement. Figure 6.1 shows the teaching with mathematical apps business canvas for the content recommended for implementation in the School of Education. In terms of the gains, the business canvas reveals that teaching with mathematical apps should lead to the improvement of the success rate in school mathematics in South Africa. It also relates to the development of the study guide developed to address critical success factors in the teaching and learning of mathematics. The canvass shows that the School of Education may incur outlay costs in terms of new smart classrooms (which it currently does not have). In addition, there will be a need to provide seamless and less disruptive Wi-Fi for teaching and learning purposes for pre-service teachers. That is, the School of Education should prepare for the cost of pre-service teacher training. The good thing about this is that the School of Education is likely to recoup the outlay costs from the Department of Higher Education and Training's subsidy grant. Over the years this will result in a profit from pre-service student fees, short courses for in-service teachers and the education department's grant.

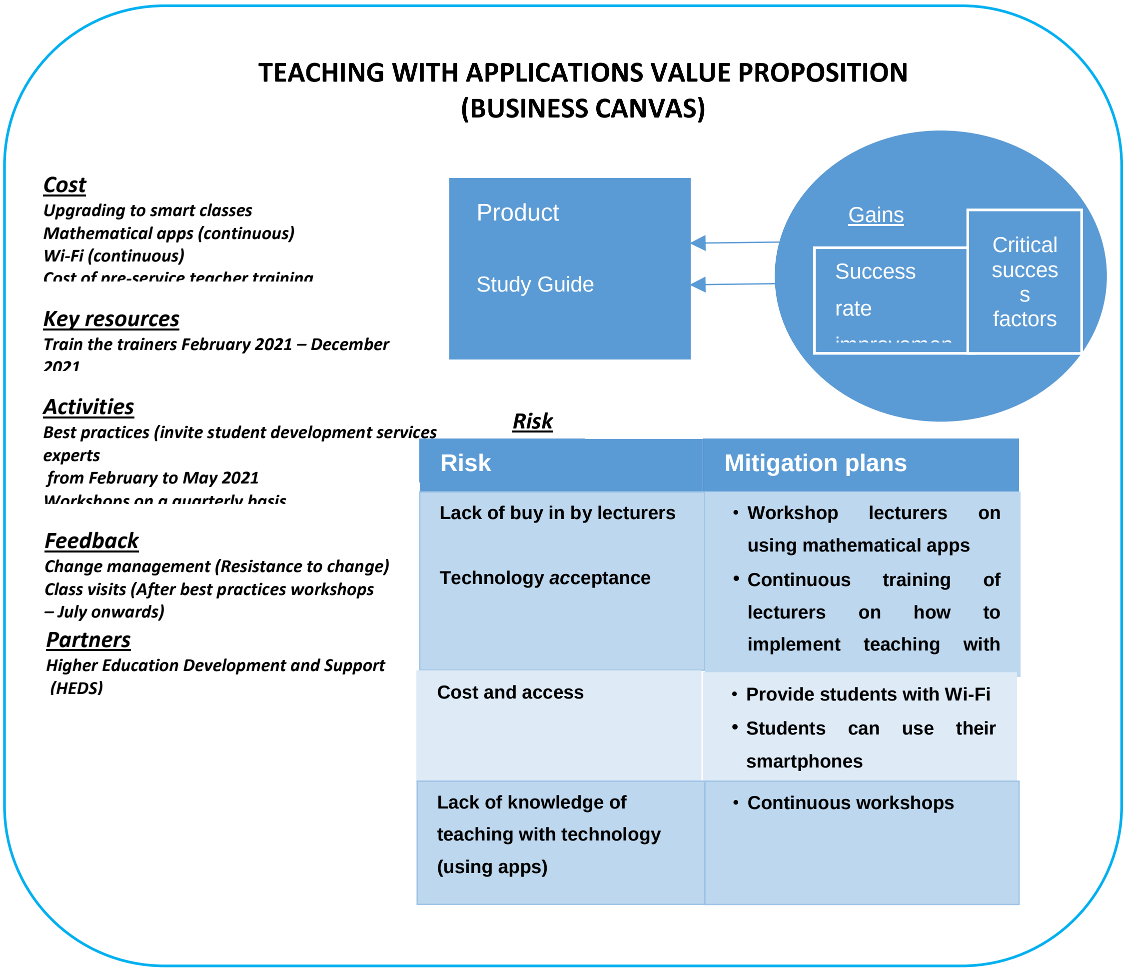

Figure 6.1 Business canvas for the implementation of teaching with apps

In terms of the key resources, the canvass shows that there will be a need to train the lecturers who will implement teaching with apps. In terms of the risk, the canvass identifies this and provide plans for mitigating the risk. For instance, an identified risk relates to the lack of buy in by lecturers. Here, the anticipation is that lecturers in the School of Education at TUT may not themselves be willing to accept the teaching with technology proposal. To address the risk of a buy in by lecturers, the mitigation plan is to workshop them on the importance and value of using mathematical apps in the classroom. What will be important here is that the School of Education will have to conduct a review, say at the end of 2021. The purpose of the review would be to detect any unanticipated issues that may crop up as a result of the addition of a new module.

6.6 Limitations of the study

This study was carried out against the backdrop of Covid-19. The pandemic meant that for more than a year, schools remained closed in South Africa. It became impractical therefore to be in a classroom situation where there would be learning. Ideally, it would have been better to have had an opportunity to observe teachers in situ (teaching in their classrooms) using mathematical apps to teach the subject. In addition, it would be ideal to determine students' attitudes and views about mathematical apps. Because these could not realistically happen, it limited this study to what could be dealt with under the circumstances, which was using Microsoft Teams.

Using apps for learning purposes could be a limitation too from a South African perspective. For instance, sometimes apps are not free but allow a user to a predetermined point where thereafter, there are purchase options to allow for further usage. In addition, there is the extra cost of online access. In South Africa, access to the internet is expensive. In fact, eight of the original participants withdrew from the study because they could not afford the cost of staying connected. While some mathematical apps could be used in the offline mode, they did not however cover the relevant mathematics the teachers taught at Grade 12.

6.7 Reflections

The motivation for undertaking this developmental study was to offer a solution to mitigate the high failure rate among Grade 12 mathematics students in South Africa. Regarding the original plan, the study was first going to determine teachers' attitudes toward technology, thereafter teachers were to be introduced to teaching with technology through workshops on using mathematical applications. Following this, the teachers were to be observed in their classrooms implementing what they had learnt from the workshops. This suggests that the study would also have established students' views about the use of mathematical apps in teaching and learning. The emergence of Covid-19 in many ways both personally and nationally scuppered all the plans. Personally, I lost a number of relatives which affected how and when I commenced with the study. Nationally, government declared a lockdown which meant that schooling came to a standstill in South Africa. With no schooling, this meant that there was a need to re-adjust what had been planned. The re-adjustment was in such a way that a research study could still be undertaken, and the thesis completed under the circumstances. The re-adjustment had its advantages however, in that it brought in new experiences. For instance, the experience of conducting one-on-one interviews online without prior experience. In addition, administering questionnaires to teachers with the expectation for them to send them back, which happened, was a wonderful experience. These are experiences the researcher will certainly build on and coach others on, going forward.

Where the researcher is extremely grateful and appreciative of the benefits derived from conducting this study, is in the area of pedagogy and learning environments. Not only did this mean reading more about these, it also afforded an opportunity to discuss them with the teachers. Such an exercise certainly empowered the teachers too in one way or the other.

Finally, I am much appreciative of the skills and competencies that I have learnt from interacting with all the Haaga-Helia lecturers while undertaking this study. Thank you so much - Kiitos paljon!

6.8 Conclusions

The primary objective in this developmental study was to improve students' performance in Grade 12 mathematics. Due to circumstances beyond the researcher's control, students could however, not participate in this study. Nevertheless, because teachers play a major influential role in how teaching and learning progresses in their classrooms, all activities here focussed on them. Circumstances notwithstanding, the results and conclusions of this study are important in spite of the non-participation of students. To reach the conclusion based on the secondary objectives, the study sought to answer the following questions:

(a) What are the attitudes of teachers about technology in general (**affinity to technology**)?

(b) How likely were teachers to search for mathematical apps and incorporate these in their teaching?

(c) What are teachers' views about the utility of mathematical apps in their classrooms?

With respect to the teachers' attitudes toward technology (affinity to technology), that is how optimistic or pessimistic about using technology, most indicated that they were pessimistic about it. In fact, the teachers even rated themselves as technophobic. Which means they saw themselves as having a fear or dislike of advanced technology or complex devices and especially computers (according to the Merriam-Webster dictionary).

About the likelihood of searching for and using mathematical apps in their classrooms, this study found that only the teachers in the *Early Adopters* group looked forward to performing such a task. This group constituted half of the participating teachers, which suggests that the other half did not commit to embracing and using mathematical apps in their classrooms. Similarly, the teachers categorised as falling in the *Fear of Failure* as well as the *Wait and See* groups were more ambivalent with regards to the utility of apps. For example, the teachers while appearing to embrace the technology they tended to doubt its merits in terms of enhancing student learning, collaborative learning and improving students' achievement.

Since by their admission the teachers enjoyed the workshops, it is fair to conclude that the teachers needed training. The conclusion I reached was that the two groups (*Fear of Failure* as well as *Wait and See*) emerged as a genuine call by these teachers for a need for further training. I concluded this because I felt if the teachers did not want to play ball and be honest, they could have pretended they well all tech-savvy. That is, they could have created an impression of being able to use mathematical apps in their classrooms while in fact they did not and could not because of lack of technological nous. The final conclusion of this study therefore was that the School of Education at TUT should consider a module targeting training teachers to incorporate the use of technology in their teaching strategy repertoire.

6.9 Study summary

Chapter 1 was about the overview of this developmental study. It outlined a theoretical framework in which teaching with technology was identified as ideal for improving students' performance in mathematics. The scope and developmental outcomes of this study were outlined. In Chapter 2 relevant literature focussing on the issues this developmental study sought to address were reviewed. Specifically, the review focussed on learning theories, teaching strategies, and teaching mathematics using apps. Chapter 3 outlined the study design. Here the sample of the study was described including the methods of data collection and its analysis. The chapter also dealt with the importance of issues relating to the ethics of conducting this research study. In Chapter 4 the results from both the quantitative and qualitative data of the study are outlined. Chapter 5 presented a discussion of the results. These were followed by recommendations based on the findings. Finally, a conclusion of the study was provided.

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8 Appendices

Appendix 1. Affinity for, and Global Attitudes Toward Technology

Note:
Please note that this questionnaire has three parts. The first part covers the biographical data. The second is the **Affinity for Technology Questionnaire**. The third part is the **Global attitude Towards Technology Measure**

PART 1

Biographical Data

Instructions:

- Please supply the requested information about yourself
- After completion, please take a picture of the questionnaire and send it back by WhatsApp or SMS
- Please note that you are not required to disclose your name or your phone number in your response to this questionnaire

1. I am a woman ☐ I am a man ☐ (Please indicate)
2. My age is ☐ (Please indicate you age in years)
3. I have been teaching for ☐ (Please indicate your teaching experience in years)
4. My highest academic qualification is a (Please select one)
   4.1 Teaching Diploma ☐
   4.2 Degree only ☐ (e.g. BSc)
   4.3 Degree + Teaching Diploma ☐ (e.g. BSc + Higher Diploma in Education)
   4.4 Bachelor of Education Degree ☐
   4.5 Bachelor of Education (Honours) ☐

4.6 Honours Degree only ☐ (e.g. BSc Honours)

4.7 Honours Degree + Teaching Diploma ☐ (e.g. BSc (Hons) + Higher Diploma in Education)

5. I own a smartphone Yes ☐ No ☐ (Please select one)

PART 2

Affinity for Technology Questionnaire

Instructions:

- Please read the statements provided below and register your honest opinion in terms of your agreement or disagreement with each.
- To register your choice, please put an X in the appropriate box.
- Please note that there are no right or wrong answers here instead your choice only reflects your view about each statement

Key:

SD = Strongly Disagree; **D** = Disagree; **U** = Uncertain; **A** = Agree; **SA** = Strongly Agree

1.	Technology is my friend	SD	D	U	A	SA
2.	I enjoy learning new computer programs and hearing about new technologies	SD	D	U	A	SA
3.	People expect me to know about technology and I don't want to let them down	SD	D	U	A	SA
4.	If I am given an assignment that requires that I learn to use a new program or how to use a machine, I usually succeed	SD	D	U	A	SA
5.	I relate well to technology and machines	SD	D	U	A	SA
6.	I am comfortable learning new technology	SD	D	U	A	SA

7.	I know how to deal with technological malfunctions or problems	SD	D	U	A	SA
8.	Solving a technological problem seems like a fun challenge	SD	D	U	A	SA
9.	I find most technology easy to learn	SD	D	U	A	SA
10.	I feel as up-to-date on technology as my peers	SD	D	U	A	SA

PART 3

Global attitude Towards Technology Measure

Technophobia (negative affect towards)

If ‘technophobia’ is defined as feeling discomfort about computers or any new technology, which of the following best describes you:

[Please tick only one box below]

[ ] Highly Technophobic

[ ] Moderately Technophobic

[ ] Mildly Technophobic

[ ] Not Technophobic

OOooo Thank you for your participation oooOO

Appendix 2. A list of one-on-one interview questions asked

Questions relating to experiences with mathematical apps.

Question 1: Have you ever used mathematical apps to teach the subject?

Question 1.1: If yes: Which apps have you used? Can you show me an example of how you have used them?

Question 2: Now that you have attended the workshops how likely are you to incorporate apps in your teaching?

Question 3: How likely are you to search for more apps other than the three we used in the workshops?

Question 4: Do you think your use of mathematical apps will make a difference in your classroom?

Question 5: Do you think teaching using mathematical apps has the potential to enhance learning?

Question 6: Do you think mathematical apps have the potential to improve student achievement?

Question 7: What would you say is your attitude towards technology – Do you find it easy to learn

Appendix 3. Cross-tabulations of levels of technophobia

Table A3.1 Cross-tabulation of levels of technophobia by age range (N = 22)

Phobia	Age					
	≤ 29 years		30 - 45 years		≥ 46 years	
	N	*%*	N	*%*	N	*%*
Highly Technophobic	2	***9***	3	***14***	6	***27***
Moderately Technophobic	2	***9***	2	***9***	2	***9***
Mildly Technophobic	0	***0***	0	***0***	1	***4.5***
Not Technophobic	1	***4.5***	1	***4.5***	2	***9***

Table A3.2 Cross-tabulation of levels of technophobia by years of teaching experience (N = 22)

Phobia	**Teaching Experience**					
	≤ 5 years		6 - 10 years		≥ 11 years	
	N	*%*	N	*%*	N	*%*
Highly Technophobic	2	***9***	1	***4.5***	8	***36***
Moderately Technophobic	0	***0***	2	***9***	4	***18***
Mildly Technophobic	0	***0***	0	***0***	1	***4.5***
Not Technophobic	1	***4.5***	1	***4.5***	2	***9***

Appendix 4. Learning theories*

	Behaviorist	Humanist	Cognitive	Constructivist	Socio-Cultural	Connectivism
What is learning?	Learning is change of behavior happening through trial and error. Students who perform well are rewarded (i.e. reinforcement) and those are not performing are punished. Responses that followed with reinforcement are more likely to recur. Learning is about the changes in the form or frequency of observable performance. Learning is programmed (short tasks with constant feedback to ensure reinforcement). Learning is a science and has general principles. Change in behavior, thoughts and feelings as a result of experience. Learning is passive (I.e. learners do not choose for it to happen and do not have much to do except be exposed to the stimulus for it to occur).	Learning is sensitive and based on affective and cognitive ability of the learner. The goal is to develop self-actualized students in a co-operative and supportive environment. It allows learners to be creative, to think critically and be inquisitive. It is focus based and advocates that with learning comes transformation of an individual.	It refers to an active process involving the acquisition or re-organization of the cognitive structures through which humans process and store information. It involves the study of mental processes such as sensation, perception, attention, encoding and memory. It believes that learning results from organising and processing information effectively. It sees the learner as an active participant in the process of knowledge acquisition and integration.	It refers to knowledge we construct for ourselves as we learn (i.e. teacher can learn from the student and the teacher must be open-minded). It links closely Vroom's theory of motivation (i.e. expectation)	It is the process of acquiring new, or modifying existing, knowledge, behaviours, skills, values, or preferences. It refers to measurable and relatively permanent change in behavior through experience, instruction or study. Sociocultural theorists believe that learning refers to a social process and the origination of human intelligence in society or culture. Furthermore, learning is embedded in social events, social interactions and cultural context. Learning occurs at social level, between people (interpsychology) as well as at individual level,	Learning is a continued process that occurs when knowledge is activated through the process of a learner connecting to and feeding information into a learning community. Learning may be done in a non-human environment (e.g. database, online community and a network). Cognition and emotions are essential in the learning process. It is a knowledge creation, not only consumption. Learning is a cyclical process.

					inside an individual (intrapsychology). Collaborative learning serves as vehicle for sociocultural learning. Collaborative learning refers to an instruction method in which students at various performance levels work together in small groups towards achieving a common goal.	
Where are teaching objectives derived from and how are they expressed?	Mastery learning -. involves the statement of educational objectives and their translation into learner behaviours to generate criteria for assessment grades at various levels in the domain. Example of how learning objectives is expressed: At the end of the learning outcome/objective the learner will be able to define, give an example (comprehension),	It is based on the belief that the students have potential to make appropriate choices and make the most out of it. Teaching objectives are therefore a choice of students as this approach can empower (self-directed).	t is based on what learners know and how they come to acquire it than what they do. The focus is on making knowledge meaningful and helping learners organize and relate new information to prior knowledge in memory. Instruction is based on a student's existing mental structures. A learner should be made aware of his background	The teaching objectives are derived from the learner's experience and the learner's personal interpretation of the world. The teacher helps to negotiate objectives with learners. The learner also helps to develop his/her own goals and assessments.	It is rooted on the notion that when individuals interact physically and socially, they conceptualise and express ideas in which their thinking transforms. It is based on the idea that the way people interact with others and the culture they live in shape their mental abilities. It is further based on the notion that learner's	Learner determines the content of learning. Gaps in learning network are addressed by learner through self-directed active participation in network building and by educator's evaluation of the nature and quality of learning network selected.Students learn from each other and from suggestions offered

	recognise alliteration in context (application), look closely at examples (analysis) and evaluate different learning theories.		knowledge and be exposed to strategies to bridge from pre-requisite skills to learning objectives.		environment plays a pivotal role in his/her learning development. According to Vygotsky the learning process involves culture, language, and the zone of proximal development (ZPD). The focus is not only on how adults and peers influence individual learning, but it is also on how cultural beliefs and attitudes impact how instruction and learning take place.	by the educator or an expert of the subject matter.
What is student motivation based on?	Students should have self-control and should monitor themselves. Students should behavior like late coming, monitor their performance, decide which stimuli is effective, set goals and consider reinforcers. Student must have a drive and students will choose a method that helps them to recall and interpret information (i.e. habit).	Basis of learning are based on: self-belief, self-empowerment, self-confidence; Learning is a lifelong process Developing an awareness of one's own thinking and learning Safe learning environment Critical thinking(inquisitorial	Students are encouraged to explore instructional materials and to become active constructors of their own knowledge through experiences that encourage assimilation and accommodation.	Based on reasoning, imagination and cause-effect relationship. Involvement and active engagement of the learner in the learning process. Allow and encourage students to make connections with previously learned material.	Students adopt a totally self-directed learning approach. In that, they take a role of collaborative community members. They work towards accomplishing a common goal. They listen and engage with one another through brainstorming and discussions.	Learner undertake self-directed learning based on need or inclination. Requires self-reflection by the learner to identify the learning needs. Promote the student to self-correct.

	Students will be surviving and will be motivated to acquire knowledge when their biological needs are satisfied (i.e. hunger, thirst and sleep)	system of learning) and creativity.	Teaching is tailored to the needs, interests, and backgrounds of students. Students learn through interacting with others social interaction, culture and language. Also, students base their learning on the existing/prior knowledge. Therefore, when new information is acquired they either accretion, tune or reconstruct new information in order to make sense of it and fit it within the existing information.		Students/learners get an opportunity to express themselves and take initiative to do certain tasks. Also, students get an opportunity to practice various social skills. Self-efficacy and self-esteem are enhanced. A teacher only creates a conducive environment to foster collaboration. Teachers only intervene if students ask questions or stray off the task.	
Perspective of knowledge	Knowledge is acquired through observable scientific laws governing behavioral associations and patterns. The learner simply responds to external stimuli in a deterministic manner. Knowledge is acquired through trial and error, repetition, shaping and extinction.	Emphasis is that knowledge is acquired from everyday activities and knowledge is self-motivated.	New knowledge has to interact with existing knowledge in order to make sense of the new knowledge. If the new event or situation is encountered individual attempts to reorganize and modify information through assimilation and accommodation.	New knowledge is built-up on prior knowledge. It promotes the idea that there is no definite answer or independent owner of knowledge, a student can create it knowledge as they see it.	Based on the notion that the potential for cognitive development is limited to a "zone of proximal development". ZDP is the area of exploration for which the student is cognitively prepared but requires help and social interaction to fully develop. Students are	It is distributed across an information network.

			Also, based on three principles; general law of genetic development, auxiliary stimuli, and the zone of proximal development (ZPD). The general law of genetic indicate that development states that every complex mental process is first and foremost an interaction between people. The auxiliary stimuli affect the mastery of one's own behavior. ZPD stipulates that learning should be compatible with the child's level of development.		encouraged to take responsibility of their own learning and to share their expertise with others. Students learn to evaluate information and interact with others. A teacher or more experienced peer can provide the learner with "scaffolding" to support the student's evolving understanding of knowledge domains or development of complex skills.	
How does teaching proceed?	Sequential (I.e. easy to complex learning outcomes). It focuses on direct instruction whereby a teacher transmits the knowledge to students in a well-organised manner.	It is based on providing opportunities for empowerment and as a result it should be individualised.	Emphasis on the active involvement of the learner in the learning process (learner control).	The teacher may present a situation to the class, try to identify current knowledge and knowledge gaps on the presented situation,	Teaching takes place through collaborative learning, discourse, modelling, and scaffolding.	In a classroom set-up, the teacher would act more as a facilitator and let the students find out facts and what is fiction.

	The teacher is the authority in the classroom, students do as the teacher instructs.		It uses metacognitive training (e.g., self-planning, monitoring, and revising techniques). It involves use of hierarchical analyses to identify and illustrate prerequisite relationships (cognitive task analysis procedures). Emphasis is on structuring, organising, and sequencing information to facilitate optimal processing (use of cognitive strategies such as outlining, summaries, synthesisers, advanced organisers, etc.) The learning environment should allow and encourage students to make connections with previously learned	group the students, allow students to explain their understanding and do reflections. Students should be subjected to fixing of their mistaken prior knowledge, thus learning new intended skills, knowledge and attitudes. Students can also learn better by interacting with their peers, using their own language and jargon to discuss the learning matter.	These strategies are used to support the intellectual knowledge and learners' skills and facilitate intentional learning. Considerations are also given to how learners are impacted by their peers, and how social scenarios impact their ability to acquire information. The role of a teacher is to facilitate and create a conducive environment for collaborative learning.	Connectivism is based on sharing of information, interrogating and creating new knowledge. As such, mediums that allows for sharing such as cellphones, twitter, blogs etc. can be used.

			material (recall of prerequisite skills) using relevant examples and analogies. Instructional materials should include demonstrations, illustrative examples, and constructive feedback. The teacher is the authority and gives instructions.			
What kinds of teaching methods are favored? ***How are they selected?***	Role playing, simulation and digital tools (i.e. WhatsApp & YouTube video). They are selected based on the learning outcomes and student readiness. They must also be based on Bloom's taxonomy. Digital tools are selected based on the students access to data. Below are the activities that the teacher does in class: Gaining learner's attention Stating session objectives Reminding what was done before Highlighting key features	Creative role playing, practical teaching and applications, pragmatic theory which will encourage a method which works best for a student and his or her environment. Group work/discussions and presentations are encouraged.	Cognitive apprenticeship, reciprocal teaching, anchored instruction, inquiry learning, discovery learning, problem-based learning.	Since it is learning by fitting new information with what learners already know, thus eliminating teacher power and knowledge, it is advisable to use examples with scenarios that students are familiar with. The following learner-centered methods can be used: multimedia/teaching aids Scaffolding Case studies Role playing	Problem-based teaching methods are recommended as they promote learner responsibility, group communication, and individual contemplation to solve problems. Students should be required to work in groups or pairs in the problem-solving processes. Progressing from basic to advanced skill acquisition, the student can interact with other students and	Connection-forming The use of technology.

Structuring learning Encouraging activity Providing feedback Evaluating progress Enhancing attention and signaling future learning		Story telling Group discussions/group activities (reciprocal learning). Probing questions. Project based learning. Critical thinking, problem solving and information processing. Coaching, modelling, articulation, reflection and exploration Students often learn in groups.	instructors to solve problems. By putting into practice what they have learned in the formal classroom setting, students maintain high motivation levels. By applying the knowledge, students are better able to understand and retain the information for later use. They are highly motivated to achieve because they know that these skills are critical to succeed in the field. Approaches such as jigsaw, reciprocal model, collaborative peer groups (peer group problem-based learning and peer group resources-based learning) can be used. With the Jigsaw model emphasis are on small group discussions, which are divided into experts and novices

					group members. Experts learn the material and teach other group members. With the Reciprocal model students are scaffolded and supported using strategies such as questioning, feedback, summarising and reflecting With the Collaborative peer groups peers learn in groups and share ideas. Two approaches that can be useful are; problem-based learning and resource-based learning.	
How and on what basis are the learning outcomes assessed?	Learning outcomes are based theory. Affective (i.e. discriminating, comparing, enumerating & organising), cognitive (i.e. responding, answering &	Assessment be evidence based as learning is more than cognitive, but it also involves emotional	Assessment is based on taxonomy and it is based on the level of students' cognitive stage Students are assigned to groups and presented.	Assessments are qualitative in nature. They are based on real-life tasks and performance.	As part of the assessment process, systematic and corrective feedback is provided on regular basis to allow for the	Peer assessment. Meaning making. Contribution and involvement. After engaging on a topic, the learner

Who does the assessing?	signaling) and psychomotor domains (i.e. following instructions, acting with smooth and effortless). They are expressed in behavioral terms. The teacher does the assessment.	exposure and state of mind. Student assessment be guided by both the teacher and the learner and his or her peers (self-evaluation). The teacher facilitates the discussions and presentations	with a problem to resolve. Students conduct research on different issues and gather the resources. Peer and self-evaluations are conducted.	Most of the time, the student is expected to do a presentation.	construction of knowledge and the application of that knowledge. A gradual transition toward a more comprehensive approach to assessment can occur through careful analysis of the learning objectives and the implementation of more active strategies, such as case studies, peer questioning, and cooperative learning. Competency-based assessment and learner-centered assessments such as role playing, case studies, and narratives are used. Problem solving should also be incorporated into competency-based skills assessments.	connects to a network to share and find new information. The learner will modify beliefs based on the new learning The learner connects to a network to share these realizations and find new information once more.

Advantages	Based on empirical scientific ethos or philosophical principles (i.e. empiricism and rationality. Through experiments behaviors through learning is shaped, extinct, modified and generalised. Positive reinforcements to enhance learning. Even negative reinforce has been experimented, it is not encouraged. Hence, in recent times corporal punishment is not encouraged in the learning environment. As per Bloom's taxonomy, it argued that behaviors progress from basic subject knowledge to the stage where the learner is able evaluate information. It encourages systems thinking.	Transformational, as it encourages self-introspection, reassessment of the structure of the existing knowledge which frames the way of thinking, feeling and actions. It is holistic as positive regard and attention to feelings is fundamentally central. Promotes personal responsibility and active participation (learning) A teacher is a facilitator and does not dictate how learning must be conducted thus promoting one to work at his/her full potential. Students judgement of own progress becomes vital as the learning process is intertwined to one's emotional investment (or consequence)	It enhances critical learning and creative to solve the problem. It is learner-centred.	Students can support each other during the learning process. Embraces diversity Students enjoy- learning is active rather than passive. It is based on thinking and understanding, not rote learning. Learning is transferable- can be applied to other learning settings. Students acquire prestige in ownership of learning. It engages and stimulates natural curiosity to the world. It promotes collaboration and social communication skills. It enables learners to be aware of their modern view of the world or lack thereof, based on their existing knowledge and experiences.	It is based on collaborative learning. Collaborative learning allows students/learners an opportunity to "think out loud". Being able to think and talk about what one is doing. It assists in clarifying own thinking. Focused on achieving task, most of the time is spent working on the task as a group than an individual. Group interaction allows for more engagements and higher order of thinking skills such as application, learning process. Sense of community is created and knowledge is considered to be located in the community.	Learning is not limited by time and place (I.e. fewer access barriers compared to other learning theories). Learning is open to a wide range of students. Information is readily available.

				It also closes the gap left by behaviourism by explaining the reasons behind reinforced repeated behaviour	Technology may be used to support collaborative learning.	
Critique, need for improvement	It is more teacher-centred. Little attention is on how knowledge is stored or recalled for future use. It does not account for anything that is not an observable behaviour (i.e. neglects cognitive (thinking) activity). Limits human behaviour to stimulus response High possibilities of learning without understanding. Indoctrination Focuses on external learning.	Teachers and institutions are not fully equipped nor empowered to facilitate such rounded holistic method of teaching and learning. Lack of student-confidence by teachers which consequently turn to try to spoon-feed students instead of having them become artists in their own right (meaningful learning). Emphasizes consciousness.	Learners can access information that is not authentic and peer reviewed. Learner can copy and paste without understanding.	Lack of structure (student often lack direction). No grading. It requires teacher to be experts and may be costly for an institution to send the teacher to be trained. There is no evidence that suggest that abilities and skills acquired in recent child development in human history like reading, writing and the use of computers, are part of childhood development as opposed to language, which learners use as a precursor to learn under constructivism	ZPD is unclear in that it does not account for a precise picture of a child's learning needs, a child's present capability level, or a child's motivational influences. ZPD also does not explain the process of development or how development occurs. It disregards the role of the individual but regards the collective. It does not seem to apply to all social and cultural groups. That is, social groups may not be whole and equal with all learners being able to gain the same meaning from engagement.	Teachers are not well-versed enough with IT skills Connections are required to facilitate continued learning. Retention of information is not necessary. The abundance of ambiguous information.

Collaboration and participation vary from one learner to another, hence the inequality for each learner.
As well, there are differences in skill set for each learner, which produces learning constraints. Learners with learning disabilities or learning difficulties, for example, might not be able to take away the same meaning from group interactions as those learners without learning disabilities or learning difficulties

* Adapted from: (a) https://miriamcalvoblog.wordpress.com/comparing-learning-theories/
(b) https://griffl.org/comparing-learning-theories/

Appendix 5: Representatives of the three response groups

Fear of Failure Group

Name	Biographical description	Technophobia rating
Gomolemo	A 53 year old man. Possessed a BSc degree. Teaching experience of 18 years.	highly technophobic
Morongoa	A 28 year old woman. Possessed a BSc degree. Teaching experience of six years.	moderately technophobic
Lebogang	A 52 year old man. Possessed a BSc degree. Teaching experience of 16 years.	highly technophobic
Mogale	A 47 year old man. Possessed a BSc degree plus a teaching diploma. Teaching experience of 14 years.	highly technophobic
Mosebudi	A 44 year old man. Possessed a BEd degree. Teaching experience of 13 years.	moderately technophobic
Malebo	A 50 year old woman. Possessed a teaching diploma. Teaching experience of 16 years.	moderately technophobic
Itumeleng	A 25 year old woman. Possessed a BEd (Hons). Teaching experience of 4 years.	highly technophobic

Wait and See Group

Name	Biographical description	Technophobia rating
Thabang	A 48 year old man. Possessed a Bachelor of Education degree. Teaching experience of 17 years.	highly technophobic
Sello	A 53 year old man. Possessed a BEd degree. Teaching experience of 11 years.	highly technophobic
Mashudu	A 47 year old man. Possessed a BEd (Hons) degree. Teaching experience of 15 years.	not technophobic
Mmabatho	A 44 year old woman. Possessed a BEd degree. Teaching experience of 13 years.	highly technophobic

Early Adopters Group

Name	Biographical description	Technophobia rating
Katlego	A 46-year-old woman. Possessed a BEd (Hons) degree. Teaching experience of 11 years.	moderately technophobic
Neo	A 23 year old man. Possessed a BSc degree plus a teaching diploma. Teaching experience of four years.	highly technophobic
Thabo	A 41-year-old man. Possessed a BSc (Hons) degree in science and a teaching diploma. Teaching experience of 8 years.	not technophobic
Pulane	A 27 year old woman. Possessed a BSc degree. Teaching experience of 5 years.	not technophobic
Kgalema	A 30 year old man. Possessed a teaching diploma. Teaching experience of seven years.	highly technophobic
Masego	A 28 year old woman. Possessed a BSc degree. Teaching experience of seven years.	moderately technophobic

Tebogo	A 40 year old man. Possessed a teaching diploma. Teaching experience of 12 years.	highly technophobic
Lehlohonolo	A 49 year old man. Possessed a BEd (Hons). Teaching experience of 15 years.	not technophobic
Moshidi	A 40 year old man. Possessed a BSc degree. Teaching experience of 11 years.	moderately technophobic
Dipholo	A 53 year old man. Possessed a BSc degree. Teaching experience of 17 years.	mildly technophobic
Mokgaetsi	A 28 year old man. Possessed a BEd degree. Teaching experience of 14 years.	highly technophobic

Appendix 6: A brief descriptor of South Africa's qualification framework

A single qualifications framework for a diverse system

The Higher Education Qualifications Framework (HEQF), which was promulgated in October 2007 (Government Gazette No 30353 of 5 October 2007), provided for the establishment a single qualifications framework for higher education to facilitate the development of a single national co-ordinated higher education system, as envisaged in Education White Paper 3, A Programme for the Transformation of Higher Education (1997). Its key objective was to enable the articulation of programmes and the transfer of students between programmes and higher education institutions, which the then separate and parallel qualifications structures for universities and the erstwhile technikons (now Universities of Technology) were perceived to preclude.

The implementation of the HEQF – since 1 January 2009 all new programmes submitted to the Higher Education Quality Committee (HEQC) for accreditation have had to be compliant with the HEQF – confirmed that despite the robust nature of the design of the HEQF, there remained, as the CHE advised the then Minister of Education in April 2007, "unresolved concerns about the number, nature and purposes of the qualification types" set out in the HEQF. In addition, the accreditation process also revealed a number of inconsistencies and gaps in the HEQF, which had an adverse impact on meeting national policy goals and objectives.

The revised Higher Education Qualifications Sub-Framework (HEQSF):

The HEQSF establishes common parameters and criteria for qualifications design and facilitates the comparability of qualifications across the system. Within such common parameters programme diversity and innovation are encouraged. Higher education institutions have a broad scope within which to design educational offerings to realise their different visions, missions and plans and to meet the varying needs of the stakeholders and communities they serve.

The HEQSF thus operates within the context of a single but diverse and differentiated higher education system. It applies to all higher education programmes and qualifications offered in South Africa by public and private institutions.

Level Descriptors - for the South African National Qualifications Framework

A level descriptor is a statement describing learning achievements at a particular level of the National Qualifications Framework. It provides a broad indication of the types of learning outcomes and assessment criteria that are appropriate to a qualification at that level.

Notional learning hours

A level descriptor is a statement describing learning achievements at a particular level of the National Qualifications Framework. It provides a broad indication of the types of learning outcomes and assessment criteria that are appropriate to a qualification at that level.

A level descriptor is a statement describing learning achievements at a particular level of the National Qualifications Framework. It provides a broad indication of the types of learning outcomes and assessment criteria that are appropriate to a qualification at that level.

Notional Learning Time

The number of hours, which it is expected a learner (at a particular level) will spend, on average, to achieve the specified learning outcomes at that level. It includes all learning relevant to achievement of the learning outcomes e.g., directed study, essential practical work, project work, private study and assessment.

Credits

Credits are the number of notional study hours required for achieving the learning outcomes. Notional hours include study time, assignments and examinations. The credit rating system rates 10 notional hours as equivalent to one credit.

For example: A Higher Certificate has 120 credits consisting of a 10 x 12 credit module. A module consisting of 12 credits equates to 120 notional hours. It therefore requires at least 8 hours of study per week in a 15-week semester.

Qualifications require a certain number of credits, broken down into smaller units. At Unisa, undergraduate modules are usually 12 credits. Each module is pegged according to a specific NQF level. A bachelor's degree of 360 credits, for example, consists of 30 modules of 12 credits each.

A bachelor's degree may consist of

- between 8 and 10 modules of 12 credits each at NQF level 5
- between 10 and 12 modules of 12 credits each at NQF level 6
- 10 modules of 12 credits each at NQF level 7

These levels follow on from one another. When choosing a module, you must first have passed the module at the lower level. Before you can be awarded a qualification, you must have completed the required number of credits. The modules must be completed at the required NQF level.

Table A6.1 South African national qualification framework levels

NQF level	Vocational	Professional	General
10		Doctoral degree	Doctoral degree
9		Master's degree	Master's degree
8	Postgraduate diploma	Postgraduate diploma Bachelor degree	Honours degree Bachelor degree
7	Advanced diploma	Bachelor degree Advanced diploma	Bachelor degree
6	Diploma (240 credits and 360 credits)	Diploma (360 credits)	
6	Advanced certificate (120 credits)		
5	Higher certificate (120 credits)		

Note: the information provided in Appendix 6 and 7 was obtained from different websites such as the SAQA, and Universities [TUT, UNISA, UWC, and Stellenbosch]

Appendix 7. Module descriptor: Example

Tshwane University of Technology
We empower people

TSHWANE UNIVERSITY OF TECHNOLOGY

MODULE DESCRIPTOR: NEW MODULE

Name of new module	Teaching Mathematics with Technology

Rationale for introduction of new module

To facilitate the amendment, re-alignment and upgrading of the current Bachelor of Education (BEd) specialisation – Mathematics Education for Senate approval

Programme (s) where module will be offered

Programme	Faculty	Core/Elective
Bachelor of Education (BEd) specialisation – Mathematics Education	Humanities (School of Education)	Core

Department	Mathematics, Science and Business of Education
Module name	Teaching Mathematics with Technology
Code	To be determined

Credit value	15
Duration	Semester
Outcomes	At the end of the module, students will be able to: • Demonstrate a detailed knowledge and comprehension of teaching with technology • Use smartphones or tablets to access the internet • Choose relevant mathematical apps by being able to identify relevant sections covered in the high school mathematics syllabus • Identify appropriate methods and techniques for solving appropriate grade level problems • Demonstrate the necessary communication and practical skills to participate meaningfully in learning activities involving appropriate grade level mathematics • Demonstrate more effective mathematics problem solving skills through improved working out of solutions • Demonstrate knowledge of different areas of mathematics covered at grade level mathematics • Show an ability to find and use mathematical apps in a classroom setting.
Main content	Students will • Through using mathematical apps understand the foundations of the subject • perform basic computations in appropriate grade level mathematics • read and understand appropriate grade level geometric proofs • write and understand basic algebraic rules and geometric proofs at the appropriate grade level • As much as possible identify and apply learnt mathematics in everyday life contexts

Appendix 8. Teaching with technology study guide

FACULTY OF HUMANITIES

DEPARTMENT OF MATHEMATICS, SCIENCE AND BUSINESS EDUCATION

Tshwane University of Technology

We empower people

STUDENT COURSE GUIDE

NAME OF COURSE: BACHELOR OF EDUCATION			
NQF LEVEL	***NQF CREDITS***	***QUALIFICATION & SAQA ID***	***COURSE CODE***
7	**15**		

COMPILED BY: A. Mji (2021)

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FACULTY OF HUMANITIES

Tshwane University of Technology

Private Bag X680

Pretoria

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SECTION	A	ORGANISATIONAL COMPONENT

1. Welcome

Welcome to the learning with technology module. This module is offered in each semester in a year. The module should expose you to different mathematical applications intended to equip you with skills for teaching mathematics with technology. We want you to enjoy the module. it will be interactive and hands on. We therefore expect you to find it interesting and informative.

The mode of presentation for this module will be mainly through:

- Contact sessions
- It will also be available online through MyTutor – TUT's learner management system
- The module covers approximately 15 hours to complete
- Social media platforms, such as WhatsApp, will be used to facilitate communication
- Collaborative learning will form the basis of learning activities including individual and group presentations

Teaching and learning strategy

A combination of learning and teaching approaches will be followed here. All teaching and learning activities will be learner centred

2. Staff availability

For consultation purposes, your lecturers will indicate their availability and consultation periods. You are expected to use these times whenever you need assistance. You may contact your lecturers on created WhatsApp groups.

3. Requirements, resources and recommended material

The prescribed textbook for the mathematics course will be used also in this module. More than anything, you will need a smartphone for your personal learning. In class all activities will be projected while the lecturer's presentation will be projected and connected to the tables found in the smart classroom.

4. Rules and regulations

Please note that he following rules and regulations are over and above the university's rules for students.

4.1 Attendance

It is compulsory for students to attend lectures whenever scheduled. Absence may affect students' performance in terms of continuous assessment.

4.2 Classroom behaviour

All students are expected to be on time for lectures and scheduled practicals. You are expected to be respectful to your lecturers and your fellow classmates at all times. No disruptive or disorderly conduct will be tolerated in lectures. Please treat others as you would like them to treat you.

4.3 Usage of smartphones in class

As the module is about using mathematical apps, smartphones and tablets will be permitted in class. Please use these for academic purposes and avoid taking calls or responding to messages that are not part of the teaching and learning process. Note that the electronic gadgets will not be permitted during tests and examination. Breaking the rules will result in disciplinary proceedings that may adverse consequences.

4.4 Responsibilities of students

It is your responsibility to make a success of your learning in this module. To this end you are encouraged to attend class and avail yourself to all activities assigned to you and others.

It is your responsibility to make sure that you acknowledge all sources you cite in your assignments and any other works not written by you. That is, avoid extracting information from books, articles, websites or any other sources without acknowledging the authors by pretending you are the author.

Avoid submitting work you did not attempt including that of your friends, as yours. In addition never let others to copy your work for submission.

SECTION	B	LEARNING COMPONENT

1. Overview of the course

The purpose of this module is to enrich students' knowledge so that they are able to teach mathematics using technology. The module lays the strategic foundation for selecting best teaching strategies appropriate for high school mathematics. That is, to equip students with the applied competence that demonstrates an ability to use technology to acquire skills for solving mathematics problems.

2. Outcomes

2.1 Critical outcomes

Students will:

- Identify and solve problems and make decisions using critical and creative thinking
- Working effectively with others as members of a team
- Organise and manage themselves and their activities responsibly and effectively
- Collect, analyse, organise and critically evaluate information
- Communicate effectively using visual, symbolic, and/or language skills
- Demonstrate an understanding of the world as a set of related systems by recognizing that problem solving does not exist in isolation

2.2 Specific outcomes

Students will:

- Understand and apply mathematical apps to solve mathematics problems
- Access, process and use apps to address problems in algebra, geometry and trigonometry
- Demonstrate an understanding of how different students adapt and find mathematics solutions using apps

- Demonstrate an understanding of the impact of apps in the teaching and learning context

2.3 Developmental outcomes

- Reflect on and explore a variety of strategies to learn more effectively
- Explore education and career opportunities
- Develop and acquire entrepreneurial opportunities

2.4 Objectives

The learning objectives described in the syllabus, focus on problem solving, understanding and stating theorems as well as determining angles and trigonometric functions

3. Assessment

3.1 Assessment methods and criteria

The module will be assessed through formative and summative methods. Throughout the semester students will be given tasks for individual and group work, assignments to complete as well as written tests. All this will add to their continuous assessment aspect which will be complemented by a summative component at the end of the module term. Continuous assessment will be used in order to encourage mastery and skills acquisition of the mathematics topics covered in the apps. Student will receive assessment criteria for each part of their assessment components.

3.2 Assessment rules

The general rules regarding assessment will apply. Students are advised to familiarise themselves with the rules which are published in the relevant university documents. No special arrangements will be accommodated for defaulting students unless in cases of extenuating circumstances. Incomplete practical work will not be accommodated for assessment.

3.3 Marking

All projects, assignments, tests, and collaborative work will be marked following criteria students will be made familiar with. Where applicable rubrics will be used and students will be given an opportunity to understand how these are applied. Criteria will be made available for students including mark schedules for them to familiarise themselves with.