

https://dspace.org/

Challenges and opportunities of technology integration into mathematics classrooms in GET/FET phase : teachers' perspectives.

Polokoana, Polokoana Edward

2015-05-27
http://hdl.handle.net/10539/17874

Downloaded from a DSpace repository. https://dspace.org/

CHALLENGES AND OPPORTUNITIES OF TECHNOLOGY INTEGRATION INTO MATHEMATICS CLASSROOMS

IN GET/ FET PHASE:

TEACHERS' PERSPECTIVES

POLOKOANA EDWARD POLOKOANA

STUDENT NUMBER: 510909

RESEARCH REPORT

SUBMITTED AS PART OF THE REQUIREMENTS OF A

MASTERS DEGREE IN EDUCATION

2012

SCHOOL OF EDUCATION

FACULTY/ DEPARTMENT: EDUCATION

UNIVERSITY OF THE WITWATERSRAND

SUPERVISOR: PROFESSOR MARGOT BERGER

ABSTRACT

In tandem with mathematics education reform movements of the past two decades, computer integration into mathematics classrooms has become an issue of concern. This research is intended to understand teachers' perspectives on both opportunities and challenges that mathematics teachers face when integrating computers into mathematics classrooms. Relevant literature is used to background the study and a Vykotskian socio-cultural constructivist perspective anchors and guides the research.

A small non-representative sample of six mathematics teachers from six different schools in Gauteng province is investigated through a case study that comprised questionnaires sent through emails, and a group interview. Related ethical considerations of conducting a research were considered.

Results indicate the following opportunities: Computers in mathematics classrooms may be used as/ for visual representation of mathematics concepts, time saving, up-dated storage devices and cognitive development tools. Similarly, the following challenges were picked up: Firstly, lack of access to hardware and software, no immediate repairs of computers, no obligation from the Department of Education to integrate computers into mathematics lessons and poor time-tabling of computer lessons. Secondly, lack of mathematics technology knowledge may result in teachers not perceiving the usefulness of the technology. Lastly, lack of in-depth professional development in technology integration negatively impacts on teachers' practices such as expertise in planning, classroom technology management and classroom instruction.

In serving its purpose, the study has provided an understanding that computers hold potential opportunities when integrated into mathematics classrooms. However, there are challenges teachers may face pertaining to this integration scenario.

ACKNOWLEDGEMENTS

I want to thank God for His everlasting mercy. Many thanks to my supervisor, Professor Margot Berger for her patience and valuable professional advice. Her critique of my work deserves me to say, “Thank you again, Prof.”

Many thanks to my lovely wife, ‘Mamorapeli who has always stood as an anchor of my strength. I express my heartily gladness to my daughters and sons who spent sleepless nights to help type my work: ‘Manese, Nthabiseng, Rethabile, Khauhelo, Morapeli and Tlhobelo.

Alex, Eugene, Frans, Jacob, Moeti, Mahlodi, Shirley, Vincent and Welile, thank you for all your contributions colleagues. Your time and input is greatly appreciated.

Thank you all.

D E C L A R A T I O N

I, POLOKOANA Edward Polokoana, declare that this research report is my own, unaided work. It is being submitted for the degree of Masters in Education in Mathematics Education in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination at any other university.

Signature:

Date:

DEDICATION

To my wife, ‘Mamorapeli for her love, patience and support.

ACGRONYMS

DoE	The South African Department of Education
IT	Information Technology
ICT	Integrated Communication Technology
SNSA	School Net South Africa
GDE	Gauteng Department of Education
$\in$	Universal set
$L \cap Q \cap I$	L intersects Q intersects I
ZPD	Zone of Proximal Development
ZFM	Zone of Free Movement
ZPA	Zone of Promoted Action
MOD	Maximum Overlap Desirable
GET	General Education Training
FET	Further Education and Training
CAPS	Curriculum and Assessment Policy Statement
HOD	Head of Department
CAS	Computer Aided Software

TABLE OF CONTENTS

ABSTRACT ii
ACKNOWLEDGEMENTS iii
DECLARATION iv
DEDICATION v
ACGRONYMS vi
TABLE OF CONTENTS vii
LIST OF APPENDICES x
LIST OF TABLES x
LIST OF FIGURES x

CHAPTER 1:INTRODUCTION 1
1.1 STATEMENT OF PURPOSE 1
1.2 STUDY CONTEXT 1
1.3 STUDY BACKGROUND 3
1.3.1 Rationale 3
1.3.2 Critical questions that guide this study 4
1.4 AIM OF THE RESEARCH 5
1.5 RESEARCH CONTRIBUTION 5
1.6 CONCLUSION 5
1.7 RESEARCH OUTLINE 6

CHAPTER 2:LITERATURE REVIEW 7
2.1 INTRODUCTION 7
2.2 OPPORTUNITIES PROVIDED BY TECHNOLOGY INTERGRATION 7
2.3 DRAWBACKS OF COMPUTERS IN MATHEMATICS CLASSROOMS 13
2.3.1 Technology Dependence 13
2.3.2 Varied computer literacy 13
2.3.3 Technology Enhanced Academic Dishonesty 13
2.3.4 Reduced Interaction 14
2.3.5 Potential Dangers 14
2.4 INTERGRATION CHALLENGES 15
2.4.1 Environmental constraints 15
2.4.1.1 Hardware challenges 16
2.4.1.2 Software challenges 18
2.4.1.3 Technical support 18

2.4.2 Underdeveloped, but emerging skills of novice teacher 19
2.4.2.1 Experience in working with technology 19
2.4.2.2 Pedagogical knowledge 20
2.4.2.3 Attitudes and beliefs 20
2.4.3 Actions promoted by expert guide 21
2.4.3.1 Lack of technology knowledge 22
2.4.3.2 Poor classroom technology management 22
2.4.3.3 Lack of time for training and avoidance for the need for training and avoidance for the need for training 22
2.5 CONCLUSION 23

CHAPTER 3:THEORETICAL FRAMEWORK 24
3.1 INTRODUCTION 24
3.2 LEARNING THEORIES 25
3.3 WHY CHOOSE THE SOCIO-CULTURAL THEORY 26
3.4 SOCIO-CULTURAL CONSTRUCTIVISM 27
3.5 INTERRELATIONSHIP 30
3.6 CONCLUSION 30

CHAPTER 4:RESEARCH DESIGN AND METHODOLOGY 32
4.1 INTRODUCTION 32
4.2 RESEARCH APPROACH 32
4.3 SAMPLING PROCEDURE 33
4.4 DATA COLLECTION METHODS 33
4.5 MOTIVATION FOR DATA COLLECTION INSTRUMENTS 34
4.5.1 Literature review as a research instrument 35
4.5.2 Questionnaires 35
4.5.3 Group Interview 38
4.6 PILOTING THE INSTRUMENTS 39
4.7 RIGOUR IN THIS RESEARCH 39
4.7.1 Reliability 39
4.7.2 Validity 39
4.7.3 Credibility 40
4.7.4 Use of audio recorder 41
4.7.5 Issues of biasness 41
4.8 ETHICAL CONSIDERATIONS 41
4.9 PRESENTATION OF RESULTS 41
4.10 LIMITATIONS OF THE STUDY 43
4.11 CONCLUSION 44

CHAPTER 5:FINDINGS AND DISCUSSIONS 45
5.1 INTRODUCTION 45
5.2 BIOGRAPHICAL DETAILS OF THE PARTICIPANTS 45
5.3 ANSWERING THE RESEARCH QUESTIONS 48
5.3.1 What potential opportunities do the integration of technology in mathematics classrooms offer? 48
5.3.1.1 Visual representation of mathematics concepts 49
5.3.1.2 Time saving 50
5.3.1.3 Up-dated storage device 51
5.3.1.4 A cognitive development tool 51
5.3.2 What school structures and constraints influence the integration of technology into mathematics classrooms? 53
5.3.3 How do teachers' knowledge and beliefs affect the integration of technology into mathematics classrooms? 59
5.3.4 Does professional learning affect teachers' integration of technology of technology in mathematics classrooms? 64
5.4 A SAMPLE RELATIONSHIP BETWEEN JULIUS'S ZFM, ZDP AND ZPAs AS AN EXPERIENCED TEACHER 65
5.5 CONCLUSION 67

CHAPTER 6:RECOMMENDATIONS, LIMITATIONS AND CONLUSION 68
6.1 SUMMARY OF ANSWERS TO THE CRITICAL QUESTIONS 68
6.2 LIMITATIONS OF THIS STUDY 70
6.3 REFLECTIONS 70
6.3.1 Introduction 71
6.3.2 Reflection 71
6.3.2.1 The short-falls of this Research 71
6.3.2.2 Goodness of this Report 72
6.3.2.3 Short-falls versus goodness of this Report 72
6.4 RECOMMENDATIONS 72
6.5 CONCLUSION 73

REFERENCE LIST

LIST OF APPENDICES

Appendix A The flagpole problem
Appendix B Questionnaire Schedule
Appendix C Interview Schedule
Appendix D Consent and Confidentiality (Teachers)
Appendix E Transcription from Group Interview

LIST OF TABLES

TABLE	MAIN HEADING
1.1	Research outline
2.1	Internet usage and population statistics in South Africa
3.1	Different zones, types of challenges and factors within each challenge
4.1	Research instruments
4.2	Advantages and disadvantages of closed-ended versus open-ended questions
4.3	How instruments gathered information for the research
5.1	Biographical details of the participants
5.2	Opportunities from the participants from the questionnaires
5.3	Opportunities picked up from the group interviews
5.4	Results analysis from Section A of the questionnaire schedule
5.5	Results analysis from Sections B and C of the questionnaire schedule
5.6	Summary of the results from questionnaires and interviews

LIST OF FIGURES

FIGURE	MAIN HEADING
3.1	How the three zones are related to each other
4.1	A set of research instruments
5.1	Relationship between Julius's ZFM, ZPD and ZPAs

Chapter 1: Introduction

1.1 Statement of purpose

By technology integration in mathematics education context I refer to the incorporation of computers and/ or laptops into the teaching and learning of mathematics. The purpose of this study is to understand mathematics teachers' perspectives regarding opportunities and challenges of this integration scenario.

1.2 Study context

Mathematics education globally has undergone great changes (reforms) in the past three decades. In particular there has been a concern to develop learner and/ or teacher mathematical thinking from the traditional teaching methods of drill and practice (rote-learning) to new methods of learner-centeredness (Davis, 1997; Hufferd-Ackles, Fuson & Gamoran Sherrin, 2004; Lobato, Clarke & Burns, 2005; Brodie, 2007). Mathematics educator academics elaborate learning theories through research based activities and these theories help to inform mathematics teaching and learning practices in classrooms. For example, the theory of constructivism: this has a long history from Piaget and Vygotsky (psychologists of the 20th centuries). It is used to support the notion that teachers' roles in mathematics classrooms are facilitators and/ or mediators to help learners to construct new knowledge from prior knowledge. This theory is of major importance in classrooms today. Sfard (1998, p.4) in her opening remarks of one paper states, "The idea that new knowledge germinates in old knowledge has been promoted by all theoreticians of intellectual development, from Piaget, Vygotsky to contemporary cognitive scientists."

In tandem with the mathematics education reform movement around developing learner and/ or teacher mathematical thinking abilities, education researchers express high expectations for the potential of computer technology integration to improve the teaching and learning of mathematics (Kendal & Stacey, 2002; Zbiek & Hollebrands, 2008; Wachira & Keengwe, 2010). Dunham and Hennessy (2008) when viewing how information technology (IT) has become a part of mathematics education, and the dramatic growth in access to personal computing power, cite Heid's (1997, p.5) assertion that information technology is "the single most important catalyst for today's mathematics education reform movement". This suggests that computers are

semiotic (psychological) learning tools (Meadows, 2004) that can be used to facilitate, mediate, and catalyse mathematics learning and teaching.

However, to merge mathematics reforms and integration of computers simultaneously into teaching stands as a challenge to curriculum developers, policy-makers and classroom teachers. Studies both within and beyond South Africa indicate that there are overarching challenges towards computer integration into mathematics classrooms. For example, lack of infrastructure in some schools, teachers' beliefs and attitudes towards the use of technology and not enough training on technology integration in mathematics instruction (Wachira & Keengwe, 2010). Some of the integration challenges may be so crude that in some schools teachers may abandon integrating computers in their mathematics classrooms and resort to their traditional ways of pen and paper or chalk and talk teaching methods.

In line with global reforms, the Department of Education (DoE.) in South Africa while introducing, revising and re-visiting curriculum 2003 has not divorced the integration of Integrated Communication Technology (ICT) into learning and teaching to achieve the nationally-stated curriculum goals: learner-centered learning (active, exploratory, inquiry-based learning), collaborative work among learners and teachers and creativity, analytical skills, critical thinking and informed decision-making (DoE, 2003). For instance, DoE (2003, p.10) in one of the scopes within the mathematics curriculum states, "…use available technology (the minimum being a modern scientific calculator) in calculations and in the development of models".

If the minimum technology can be a calculator, then the maximum can be any available technological tool that a particular school can afford. Therefore, the NCS document offers room to use computers for calculations and development of mathematical models. Similarly, the DoE (2011, p.6), although it does not specifically say computers should be used in mathematics, states through the Curriculum and Assessment Policy Statement (CAPS) document that the envisaged learner should be able to:

- Communicate effectively using visual, symbolic and/or language skills in various modes
- Use science and technology effectively and critically showing …

Based on these two aims from the CAPS document I suggest that computers if integrated into mathematics can serve as good communicative tools that may also offer effective visual representation of mathematical models. The findings of this report will support my argument. Hence, the Department of Education in South Africa neither does restrict nor exempt the use of computers in mathematics learning in classrooms. Some other educational policies in other different countries share a stronger focus on the use of ICT in their education systems. For example, in Australian schools teachers are integrating ICT so as to support experiential constructivist learning in schools and across learning sites (Kozma, 2003).

1.3 Study background

A new framework for the professional development of South African teachers as well as guidelines to enable teachers to use ICT has been developed by the National Department of Education (Isaacs, 2007). Isaacs indicates that teachers are provided with training, professional development and ICT integration programmes and some non-governmental organizations, like School Net South Africa (SNSA), provide teachers with professional skills in technology integration into schools.

Modern computers support a variety of mathematics software. This can be used to draw swift and accurate graphs (for example, GeoGebra), to provide online discussion boards (e.g. Facebook) and Java tools. There is ample important information that both teachers and learners can make use of when integrating computers into mathematics classrooms. Reports from the international communities of mathematics practitioners point to the opportunities afforded by computers for the advancement of mathematics understanding by learners. This may well inspire South Africa to deliver the same experience in her classrooms.

1.3.1 Rationale

For the past two and a half decades I have had an opportunity to use a range of mathematics technological tools (artifacts) to teach mathematics. These range from an abacus, slide rule, and figure tables to a scientific calculator. Some of these artifacts help to reduce the tedious arithmetic manual computations such as finding the square-root of a non-perfect square number. One of the challenges that I have experienced is that in order to teach learners how to manipulate

an artifact properly one has to be conversant and familiar with it else learners will have trouble in understanding and using the tool efficiently.

With the advent of computers I have considered computers as a further improvement to the already existing mathematical technological artifacts that hold potential opportunities to enhance learners' mathematical thinking skills. However, very few mathematics teachers use computers for instructional purposes even though there may be computer laboratories in schools (Stols & Kriek, 2011). Thus I feel challenged to understand the opportunities and challenges of integrating computers into mathematics classrooms.

For instance, the Gauteng Department of Education (GDE), as early as 2002, invited major companies in the South African ICT industry to provide all Gauteng schools with computers through the Gauteng Online project (Isaacs, 2007). According to Isaacs (2007) Gauteng Online project is one of the leading technology access programs that serve the schools in Gauteng with computers. One of the goals of this program is to "contribute towards building the human resource capacity through the provision of quality education" (p.12). Human resource capacity building may mean empowering teachers with skills on how to integrate computers into their teaching; this in turn may help learners at state schools have similar access to computers, e-mail addresses and information on the internet as do many learners in the South African private school sector and elsewhere in the world. The project is expected to equip the 2500 Gauteng schools with computers by 2013 (Gauteng Online, 2011). But, what are the potential opportunities and challenges underlying the use of a computer for mathematics instruction?

1.3.2 Critical questions that guide this study

The critical questions are as follows:

(1) What are some of the potential opportunities that the integration of technology in a mathematics classroom offers?
(2) What are some of the school structures and constraints that may affect the integration of technology into a mathematics classroom?
(3) How do teachers' knowledge and beliefs affect the integration of technology into a mathematics classroom?
(4) Does professional learning affect teachers' integration of technology into a mathematics classroom?

1.4 Aim of the research

The aim of this study is two-fold: first, to understand some of the opportunities that may be offered by integrating computers into mathematics classrooms; secondly, to understand some of the challenges that may emerge from school infrastructure, teachers' knowledge and beliefs, and professional learning due to computer integration. This is a small-scale non-representative study that focuses on six mathematics teachers from the Gauteng Province.

1.5 Research contribution

While referring to noteworthy roles in understanding mathematical knowledge, Michener (1978, p.377) elucidates that:

> … understanding an item in a deep way, one ought to know about the item itself …understanding involves knowing the "pros" and "cons" of items: which items are good for what; which items are appropriate and when; how to use them; what their limitations are …

This research may serve to reveal some of the pertinent issues ingrained in computer integration into mathematics classrooms and therefore indirectly inform teachers about the opportunities of using computers and related challenges. Thus, understanding as one of the core purposes of this research may serve to illuminate a theory behind technology integration into mathematics education which may inform productive practices (Lovert & Smith, 1995; Pang & Marton, 2006) in using computers in mathematics education.

1.6 Conclusion

In this chapter I have tried to state the purpose of this research and describe the context of the study by highlighting very briefly some opportunities and challenges faced when integrating computers in mathematics classrooms. For instance, 'insufficient technology-qualified teachers' is one of the challenges. These challenges will be elaborated more in the literature review section. I have also stated the study background with a rationale and a set of critical questions that guide my study. I have also indicated the aim of the research, and anticipated research contributions.

1.7Research outline

Table 1.1: Research outline

Chapter	Main Heading	Summary Content
1	Introduction	Statement of purpose, Study context, Study background, Aim of the research, Research contribution, Conclusion, Research outline
2	Literature Review	Introduction, Opportunities provided by technology integration, drawbacks of computers in mathematics classrooms, Integration challenges, Conclusion
3	Theoretical Framework	Introduction, Learning theories, Why choose the socio-cultural theory, Socio-cultural constructivism, Interrelationship, Conclusion
4	Research Design and Methodology	Introduction, Research approach, Sampling procedure, Data collection methods, Motivation for data collection instruments, Piloting the instruments, Rigour in this research, Ethical considerations, Conclusion
5	Research findings and discussions	Introduction, Biographical details of the participants, Presentation of results, Limitations of the study, conclusion.
6	Answering the critical questions, Limitations, Reflections, Recommendations and Conclusion	
	Reference list	
	Appendices	

Chapter 2: Literature Review

2.1 Introduction

I have indicated that there are high expectations for computer technology integration to improve the teaching and learning of mathematics and also that there are challenges or barriers facing this integration scenario. In this chapter I refer to the relevant literature that contributes towards an understanding of opportunities, drawbacks and challenges of integrating computers into mathematics education and I highlight types of computer-based programs (software) available for teaching mathematics.

The chapter discusses research literature under three main headings: opportunities provided by technology integration in mathematics education, drawbacks of computers in mathematics classrooms and integration challenges (environmental constraints, underdeveloped but emerging skills of novice teacher and actions promoted by expert guide, and their related subcategories). The teachers' perspectives under these headings form the cornerstone of my research.

2.2 Opportunities provided by technology integration

An opportunity in technology integration is that which offers good chances for improvement or progress in mathematics teaching. The teaching and learning of mathematics is an activity that ought to be afforded with favourable conditions conducive to learners` conceptual cognitive development. Stacey and Chick (2000) as cited in Drijvers, Goddijn & Kindt, (2011, p.6) contend that:

> The increased availability of computers and calculators will change what mathematics is useful as well as changing how mathematics is done. At the same time as challenging the content of what is taught, the technological revolution is also providing rich prospects for teaching and is offering students new paths to understanding

This means that the situation created by technology integration not only provides learners with new paths of understanding mathematical concepts but may also broaden teachers' potential instructional strategies. Thus, an opportunity to advance mathematics education is provided.

Research studies in mathematics education world-wide indicate the importance of integrating technology in mathematics learning (Kendal & Stacey, 2002; Guin & Trouche, 1999; Pierce & Stacey, 2004; Goos, Galbraith, Renshaw & Geiger, 2003; Wachira & Keengwe, 2010) to enhance teaching and learners' mathematical understanding. Based on the constructivist philosophy that knowledge is actively built by one from prior knowledge, Guin and Trouche (1999) argue that computers serve the purpose of renewing teaching practices by managing technical computations. By technical computations I refer to mathematical computations that would require a learner, without a computer to spend excessive time on calculations rather than on concepts, and/ or such mathematical problems which learners may not be able to solve (or visualize) by free hand without the use of technological support.

In this way technology may promote more conceptual understanding. Guin and Trouche (1999) also argue that the role of a teacher is to organize and encourage interaction with the computer environment. Such environments aid exploration and construction of concepts. Wachira and Keengwe (2010, p. 10) support Guin and Trouche's (1999) claim that "integrating technology into mathematics lessons is an effective means of supporting students' understanding of mathematics content." I think these two sets of researchers mean that mathematics content is actually made up of mathematical concepts and in the process of knowledge creation, computers may be used as assistive learning tools which enhance conceptual understanding. Technical computations may be able to be done easily. Therefore computers have the potential of renewing teaching practices.

Chronaki and Christianson (2005), when talking about information and communication technologies in mathematics education classrooms mention the following opportunities for both learners and teachers: computers provide dynamic media which enable teachers and learners to manipulate and program visual representations of mathematical ideas. They offer new possibilities for learning mathematics. These possibilities include among others: linking multiple representations, dynamic manipulation of mathematical objects, active construction of mathematical knowledge and programming, testing mathematical hypotheses, informing proof, critical and reflective use of mathematical information in themed activities or modelling and establishing communities of practice.

Chronaki and Christianson (2005) further argue that technology is not a factor that itself enhances or hinders learning but the role of technology develops in close interaction with the roles of teachers and learners within a pedagogic context of classroom communication. This implies that the use of technology in mathematics classrooms is not an end in itself but may provide assistance to the existing means in classrooms depending on how teachers engage with learners and the technology.

The idea of mathematical thinking to which I have already alluded in Chapter One, which entails new methods of learner-centeredness: learners are involved in making conjectures, argumentation and generalization in mathematics. This idea has gained much popularity in current mathematics education and is supported by Goos et al (2003). They (Goos et al, 2003) argue that electronic technologies such as computers may offer new opportunities for learners to communicate and analyze their mathematical thinking. Furthermore computer integration in mathematics classroom may foster conjecturing, justification and generalization by enabling fast, accurate computation, collection and analysis of data. Current researchers define mathematical thinking differently depending on their findings and understandings but often mean the same thing. For example, Kazemi and Stipek (2001) argue that mathematical thinking is supported by explanations that consist of mathematical arguments, by a focus on relations among multiple strategies and by individual accountability to reach consensus through mathematical argumentation. Alternatively, Ball (2002) argues that mathematical thinking is afforded by the use of representations, argumentation, justification and generalization.

Based on these three sets of researchers I argue that mathematical thinking is fostered by an environment (intellectual climate) where learners are free to make conjectures (mathematical guesses), defend (argue/ debate), justify (prove) and hence draw general mathematical understanding of a phenomenon. This exercise of mathematical thinking often takes place in a community of practice. It is dialectical in nature. Both the teacher as an expert of the learning areas and the learners are co-participants (Brodie, 2007). This community of practice works through whole class participation. Through these practices participants learn and develop each other's mathematical thinking skills, with assistance by the more knowledgeable ones. The mathematics community has its own cultural beliefs, practices, artifacts and identities. While the teacher develops professionally, in creating an intellectual climate he/ she simultaneously

develops learners' mathematical thinking through their conjecturing, justifying their claims and generalizing.

One of the important artifacts of a community is the tools that are used to support the culture of the particular community efficiently and effectively. I would like to argue that the uses of computers in mathematics classrooms are such useful tools. Goos et al (2003) affirms that the use of technological tools such as computers not only amplify, but also re-organize cognitive processes through their integration into the social and discursive practices of a community of practice. According to Goos et al (2003), amplification occurs when computers simply supplement the range of tools already available in mathematics classrooms, for example speeding up tedious calculations. Similarly, cognitive re-organization occurs when learners and the teacher interact among themselves using technology as a new semiotic tool that transforms and develops their mathematical thinking. Thus knowledge acquisition in a mathematics community of practice can be enhanced through the assistance of a computer.

To further the debate, Hufferd–Ackles et al (2004) introduce to us what they call whole-class community and explain it as a math-talk learning community. The teacher and learners use discourse to support the mathematical learning of all participants. Hufferd–Ackles et al (2004) further explain that the goal of this community is to understand and extend one's own thinking as well as the thinking of others in the classroom. Goos et al (2003) argue that in a math-talk community the use of technology may mediate, extend and promote peer mathematical understanding through discussion in the classroom. Learners may present and examine alternative mathematical conjectures using computers.

To provide a broader picture of how computer integration may offer opportunities, Mendel (2006) highlights how technology has always influenced how we teach mathematics: not too long ago, hand-held calculators made slide-rules and tables of logarithms obsolete, and simultaneously extended the range of problems accessible to learners. Similarly, powerful computers and exciting software now offer opportunities to explain classical mathematical concepts in a fresh and dynamic way, as well as open up new venues of inquiry. He (Mendel, 2006) provides examples of software of which mathematics teachers need to have a know-how so that they can provide effective instruction during a computer integrated mathematics lesson: computer algebra systems such as *Maple* which can assist practically in all the mathematics

taught in high school and college; Fathom which is uniquely suited to explain statistical concepts such as lines of regression, probability distributions, and *Geometer's Sketchpad* which is software designed to experimentally discover or verify geometric theorems and connections.

South Africa is no exception to the international findings about the importance of computers in mathematics classrooms. Matthee and Jacobus (2007) agree with the international findings that computers can transform classroom pedagogy and learners' understanding of mathematics in a positive way. Moreover, Stols and Kriek (2011) emphasize the fact that dynamic mathematics software such as GeoGebra, Cabri and Geometer's Sketchpad helps improve learners' visualization skills and ability to focus on interrelationships of the parts of geometric shapes.

What implications then may be drawn from the above literature as far as learners' and teachers' roles are concerned, due to opportunities afforded by computer integration into mathematics classrooms? The use of technology in teaching mathematics has the power to change the roles of both learners and teachers (Kieran, 2007; Guin & Trouche, 1999; Farrell, 1996; Goos et al, 2003). Goos et al (2003) emphasize that the use of technology in classroom interactions offers opportunities for learners to engage constructively and critically with mathematical ideas. This is especially so if the learner is guided to shift from using technology as master to using it as an extension to self. Goos explain these two metaphors (masters and extension to self) in terms of teaching: teachers may see technology as a master if their knowledge and competence are limited to a narrow range of operations, especially in situations where external pressures from the educational systems force technological implementation. For example, the work schedule that the department has assigned to the teachers may force the teacher to concentrate on keeping up with the schedule without exploring some of the possible mathematics ideas that can be learned through the computer. Therefore their minds are narrowed by a system that dictates what they are supposed to do. They consider it as an extension of self when seamlessly incorporated into a teacher's pedagogical and mathematical repertoire, such as through the integration of a variety of technology resources into course planning and the everyday practices of the mathematics classroom. It can also facilitate collaborative inquiry either in small group interaction or whole-class discussion where learners share and debate their mathematical understanding. Thus the sharing of knowledge is expanded through the use of technology.

Moreover, Manouchehri (2004) in her case study on the relationship between technologies` enhanced mathematics instruction and group discourse in a senior-level mathematics course reflects that the complexity of the mathematical discourse increased from before the technology was introduced to afterwards. While observing the classes she noticed that the factors that control the construction of useful mathematics classroom discourse are the teacher, the tasks designed and the technology.

Stacey et al (2002) provide the following example of a flagpole problem (Refer to Appendix A) to show opportunities offered by the use of Geometer's Sketchpad:

- Learners can visualize what happens to 'h' and 'd' when point B is dragged along ray AE
- The sketchpad offers fast and accurate drawing
- CAS (Computer Aided Software) requires the entering of different format of variables compared to the conventional written forms and this broadens learners' knowledge of multiple representations.
- Equations can be solved fast and the conjectures which are obtained empirically from geometry and graphs can be verified
- Making use of CAS to expand algebra is both an incentive and an enabler for finding and using a variety of approaches to solve problems.

Most importantly, now that the Department of Education has brought back 'Euclidean Geometry' into the Curriculum and Assessment Document Statement (CAPS) the use of technology, GeoGebra or Sketchpad for instance, may help improve learners' understanding.

In summary, literature on opportunities suggests the potential of technology for broadening and deepening mathematical thinking in communities of practice (for both teachers and learners). It highlights the idea that technology can be used as a discourse participant rather than just a presentation device (Kieran, 2007). Computers as powerful learning artifacts may provide rich prospects for teaching and offer learners new paths of understanding. That is, teachers can use computers with built in mathematics software and access internet sources, to improve their

teaching methods; they can also download mathematical tasks from the internet. So computers may be powerful information providers if teachers can maximize the use of potential resources afforded through computers. However, both international and local research mention challenges facing technology use in mathematics classrooms.

2.3 Drawbacks of computers in mathematics classrooms

Although I have elaborated on a number of pros for using computers there are also cons for using them in mathematics classrooms. However, most research shows that these disadvantages are relatively less important than the advantages (Criss, 2012; Duma, 2012). For instance, Duma (2012) argues that although there are disadvantages of using computers there are numerous advantages. Schreiner (2012) identified about five types of drawbacks of computers:

2.3.1 Technological Dependence

When computers and other technological tools are used constantly, learners develop a dependence upon these tools. Just as pupils who are never required to do math without a calculator lose the ability to solve math problems manually, learners who use computers for nearly every mathematical activity experience a decline in their ability to solve problems manually. Thus, many learners become so dependent on computers that they feel helpless without.

2.3.2 Varied Computer Literacy

Computers present an added challenge to educators because teachers must deal with learners of varying computer literacy levels. Some learners enter the classroom fully versed in the applications of a computer, while others come with no prior experience. It is difficult for teachers to deal with this vast difference and to ensure that they provide learners who need assistance with that assistance while not requiring capable learners to slow their academic progress.

2.3.3 Technologically Enhanced Academic Dishonesty

While cheating is hardly a new phenomenon, computers make academic dishonesty even easier for learners to perpetrate. Learners who wish to plagiarize can simply copy and paste information into their reports, and those who wish to share answers to tests or assignment questions can

transmit those answers digitally. This ease of cheating may tempt more learners to indulge in academic dishonesty.

2.3.4 Reduced Interaction

While computer mathematical games are just as, if not more, engaging than board or card games, they do not afford the same degree of player interaction. Many computer games are individual pursuits. When learners complete these digital games and activities they miss out on the interaction practice that they receive through the playing of traditional games.

2.3.5 Potential Dangers

The use of computers opens learners to potential dangers. Learners can fall victim to Internet predators or become the target of cyber-bullying while on the Internet. Many parents choose to closely monitor their children's Internet usage at home, but at school keeping a close eye on all learners simultaneously can be difficult. When computers are used in school, teachers must be vigilant in their monitoring of learner activity to ensure that they do not become entangled in a dangerous situation.

Also, one can get aches, cramps, and arguably blood clots and impaired vision from excessive use of computer. Not going outdoors, together with physical inactivity can result in ill-health (Duma, 2012). Furthermore, although computers can be used to enhance the curriculum and promote learning, they can also be misused and abused. For example, the fact that much of the software designed for children is appealing to them may not be a positive characteristic: for example, just because a television show holds one’s attention, does not necessarily mean that its use enhances one`s education. Maybe some television shows do, but certainly not all do. Mostly they are just simply entertaining (Criss, 2012).

One of the biggest drawbacks is best illustrated by the expression ‘garbage in - garbage out’. This implies that errors are sometimes much harder to detect when using an electronic computer than when computing manually. Another drawback is that work on a computer can be lost if the machine crashes or somehow loses data that has not yet been saved. Besides, training can be expensive and if staff leaves new staff will need to be trained.

2.4 Integration challenges

In addition to the above drawbacks of computers, Wachira and Keengwe (2010) talk about two major forms of challenges facing technology integration in mathematics classrooms: There are first order challenges which includes infrastructure, the presence of computers, proper housing and network for internet facilities and second order challenges which include administrative issues like school culture, teachers' beliefs and attitudes towards the use of modern technology in their classrooms and teachers' and principals' openness to change. Hew and Brush (2007) mention that a total of 123 challenges to technology integration were found in their review of past empirical studies. They formed six main categories from these 123 challenges. These categories are as follows: resources, knowledge and skills, institution, attitudes and beliefs, assessment, and subject culture.

Goos (2005) provides us with three main forms of challenges facing teachers when they integrate computers in mathematics classrooms: environmental constraints, underdeveloped but emerging skills of novice, and actions promoted by expert guide. I find Goos's (2005) classification most useful for my study which is based in South African mathematics classrooms. This context is characterized by learners and teachers with diverse socio-historical backgrounds and aspirations to use computers for learning mathematics. The classification may help me understand some of the broad variety of challenges that surround computer integration into mathematics classrooms.

2.4.1 Environmental constraints

According to Goos (2005), environmental constraints are synonymous with school structures and institutional constraints which may include one or more of the following: access to hardware, software and laboratories, access to teaching materials and technical support. Hew and Brush (2007) argue that without enough of these external resources there is little opportunity for teachers to integrate technology into mathematics curriculum. Wachira and Keengwe (2010) classify these challenges or constraints as first order and denote them as infrastructural challenges.

2.4.1.1 Hardware challenges

Computers and laboratories that can support a whole mathematics class are very expensive. For those schools which have installed computer hardware one may find that most mathematics teachers are not aware that they can be used for mathematics instruction. Even for those who may be using them one may find that they are not using them to their fullest potential (Childs, Blenkinsopp & Hall, 2005). It is a fact that most mathematics teachers presently at schools in South Africa were trained well before computers were popular. As a result they are imbued in chalk and talk means of instruction and there is not enough information about the different types of hardware that can replace the present tools used in classrooms. The understanding and use of computer hardware itself is a challenge for most teachers in South Africa because during their times of training they were not introduced to computers since computers were very scarce. Even operating a cell phone may be problematic to older teachers and therefore using a computer to teach mathematics may be even more intimidating. Looking at the challenges brought by hardware, Childs et al (2005) comment that overcoming hardware challenges seems to be a dream to achieve.

Furthermore, even if there are computers in a school, there needs to be a minimum package that goes along with the computers (including printers, internet access and access speed) for better mathematics instruction. Matthee and Jacobus (2007) from the South African perspective assert that low bandwidth through which people get access to internet and the geographical nature of South Africa which leads to some schools being in remote, rural areas stands as a challenge to teachers who want to use computers to teach mathematics. Moreover reaching these remote areas is a problem and most of them have no internet connectivity. "Internet connectivity is a measure of the school's technology access," heralds Dunham and Hennessey (2008, p. 352).

To indicate the seriousness of internet connectivity as a challenge in South Africa, Table 2.1 below provides a clear picture of the poor relationship between connectivity and population. It indicates that by the year 2009 only 10.8% of the population had access to internet. Furthermore, looking at the rate of growth of the internet connectivity I would like to argue that it is very low and hence much work has still to be done to improve internet connectivity if the government is serious about providing schools in Gauteng Province with on-line computers by 2013.

Conversely, smart phones which have evolved and proliferated over the past three years are capable of accessing internet. This development may help to alleviate the rather slow rate of internet connectivity depicted in the statistics on Table 2.1.

Table2.1: Internet Usage and Population Statistics in South Africa:

YEAR	Users	Population	% Pen.	Usage Source
2000	2,400,000	43,690,000	5.5 %	ITU
2001	2,750,000	44,409,700	6.2 %	IWS
2002	3,100,000	45,129,400	6.8 %	ITU
2003	3,283,000	45,919,200	7.1 %	Wide World Worx
2004	3,523,000	47,556,900	7.4 %	Wide World Worx
2005	3,600,000	48,861,805	7.4 %	Wide World Worx
2008	4,590,000	43,786,115	10.5 %	Wide World Worx
2009	5,300,000	49,052,489	10.8 %	Wide World Worx

http://www.internetworldstats.com/af/za.htm (Internet World Statistics)

The other challenge concerns the transportability and compatibility of the hardware. The high rate at which computer technology changes sets a challenge to schools that very often use outdated models with limited computing speed, lacking up-to-date external or internal memory devices, CD/ DVD drives, or modems which are compatible with newer software or peripherals (Dunham & Hennessy, 2008). If schools were supported with full fleshed computer laboratories today, in a five year period new hardware and software would be required to replace the outdated systems.

Computers are very delicate. Any slight falling may cause a great problem; falls are especially likely when learners have to hold and push computers around in their classrooms. They are not durable items and they have to be used with great care. Sometimes minor technical problems with hardware may cause a school to incur high expenses for repairs. Thus mathematics teachers are faced with the challenge of having to have basic technology repair skills and with more responsibility to avoid damage.

2.4.1.2Software challenges

Some of the challenges of the mathematics software are similar to those of the hardware e.g. the cost of software licenses can be so high that poor schools may not be able to afford to buy the relevant software. However there are some very good free software packages, such as GeoGebra. In contrast, the internet may be a disappointment to those hoping to find relevant mathematics materials if they do not know how to effectively search the internet. Even if teachers are knowledgeable about accessing the internet in order to use the free software packages, areas (schools) with poor internet reception (or none at all) are disadvantaged. Furthermore, internet servers are not fully reliable. As such, teachers may fail to access internet any time they wish.

2.4.1.3 Technical support

Literature indicates that the time factor may serve as a technical challenge to the use of computers in schools (Hew & Brush, 2007; Cuban, Kirkpatrick & Peck, 2001; Butzin, 2001). Mathematics teachers need hours to preview web sites, to locate diagrams and relevant mathematics tasks required for learner assignments, or to scan those diagrams and email them to learners to carry out the assignments at their convenience. Thus access to technology is more than merely the availability of computers in a school; it involves providing the proper time-tabling to avoid competition among the rest of the teachers in a school in using the laboratories and reasonably enough time for the individual teacher to access the mathematics. Hew and Brush (2007) warn that even though there is a need for technical personnel to help teachers use different technologies, teachers tend to rely on the technical staff so much that they (teachers) are severely limited in their independent use of the technology. A school needs to employ different staff resources like teacher facilitators, technicians and instructors but this must be done so that the mathematics teachers are supported and encouraged to become technically competent.

The other challenge is the limited awareness on the side of the institution or the mathematics teachers, of the available support materials and of recognition of their usefulness in the curriculum. School administrators may not be aware of how to get or how to inquire about technology supportive materials and available funding to support materials that are provided by either the government or the non-governmental organizations. Thus, Mentz and Mentz (2003) emphasize that the pressure put on schools to perform in the field of technology places demand

on schools' management to facilitate this process. Moreover introduction into and improvement of technology in any organization including schools require a very active leadership in schools. It is clear that the success of technology integration into mathematics classrooms places a heavy challenge on school management to ensure that technical support processes are managed effectively and successfully.

2.4.2 Underdeveloped, but emerging skills of novice teacher

There are three major challenges which are consequent upon the underdeveloped but emerging skills of novice teachers (Goos et al, 2003; Goos, 2005; Stols & Kriek, 2011; Hew & Brush, 2007; Kieran, 2007; Wachira & Keengwe, 2010): skills/ experience in working with technology, pedagogical knowledge, and pedagogical attitudes and beliefs. For example, Wachira and Keengwe (2010) insist that the effective use of technology for instruction depends on the teachers themselves and the beliefs that they hold about technology. For instance, when hand calculators were first introduced many mathematics teachers held a belief that their use in classrooms would inhibit the learners from knowing the basics in arithmetic (although gradually they realized that that is not the case). Additionally, Hew and Brush (2007, p. 229) argue that "teachers' attitudes and beliefs towards technology can be another major barrier to technology integration."

2.4.2.1 Experience in working with technology

Zbiek and Hollebrands (2008) declare that teachers' knowledge, and the use of technology, that is, their experience in working with technology, influences the technologically-based activities that teachers create for their learners. Teachers tend to project their own views about computers onto their learners; these views often depend on the experience that teachers have gained while working with technology. According to Zbiek and Hollebrands (2008) this tendency suggests that teachers who believe that it is necessary, from their own learning experiences with technology to know all the technological steps to be successful, might structure activities for learners that provide them with all the technological steps. This suggests that experience affects beliefs. However experience also affects competence, confidence and technological independence. There are several views based on beliefs that teachers may hold. One of these views is that it is necessary for learners to understand mathematical ideas before exploring them

with technology and therefore technology should only be used with upper-level high school mathematics. Related to this is another view: technology should only be used as a computational tool for doing mathematics it should be used after learners have learned the concepts and skills by hand.

Technologically experienced teachers may hold different views, for example- that technology may be used effectively at all levels neither before nor after mathematical concepts and skills have been learned by hand. Experience usually creates more competence skills and confidence in using an artifact but experience in technological pedagogy differs from teacher to teacher. Experience creates a particular belief. In most cases teachers teach according to the way they were taught not according to the learner needs (Duhaney, 2001). Hence some of the teacher's own experiences may limit learners' attainment in mathematical thinking through computer instruction depending on how each teacher developed experience in technology. However, Duhaney (2001) argues that many teachers lack role models to guide them through the necessary changes they will need to make to be successful in integrating new technology into their classrooms.

2.4.2.2 Pedagogical knowledge

The nature of teaching changes with the integration of technology, as does that of the tasks presented to the learners. To take advantage of the potential of technology requires tasks that are designed to push the learners beyond the limits of their current mathematical thinking and to encourage further development of that thinking (Kieran, 2007). For teachers to design tasks that may help further learners' mathematical thinking using technology is a large challenge. Teachers require in-depth knowledge of mathematical technology to develop appropriate tasks.

2.4.2.3 Attitudes and beliefs

Mathematics teachers' attitudes and beliefs about the integration of computers in classrooms can be another major challenge. Hew and Brush (2007) define attitude as specific feelings that indicate whether a person likes or dislikes something. Thus, in the use of technology for teaching mathematics this may relate to the teachers' willingness or unwillingness to use a computer for mathematics instruction. Beliefs are premises that are felt to be true. Mostly, teachers' beliefs are grounded in their educational beliefs about technology and learning. For example, Kieran (2007)

argues that there is a perception among some teachers that, when technological tools appear to "do all work," there might be little to teach in mathematics. This perception is one of the psychological myths held by many mathematics teachers. Others include: technophobia, computer anxiety, lack of IT confidence (Childs et al, 2005).

Also resistance to the need for change in teaching methods may pose further challenges to the teachers. How can we account for the attitudes and beliefs of each individual teacher?

From a South African perspective, Stols and Kriek (2011) from their exploratory study on teachers' attitudes and beliefs insofar as technology is used in classrooms, pronounce that teachers' actual behaviour is influenced by the perceived usefulness of the technology or by its ability to make their lives in the classrooms easier. However, if teachers do not have the general technological proficiency to use it in the classroom, it will not be used. They further their argument by drawing ideas from Ertmer (2005) who proposes that when considering ways to change teachers' practices, particularly regarding the use of technology, one has to take teachers' pedagogical beliefs into account. If teachers' beliefs and attitudes are taken into account, that may increase their confidence in using technology in mathematics instruction.

2.4.3 Actions promoted by expert guide

This category refers to challenges that are reflected by a lack of teacher professional learning opportunities. Research indicates that further training of teachers besides the formal university degree certification may help teachers understand and do their job productively and more efficiently (Goos et al, 2003; Duhaney, 2001; Hew & Brush 2007). For example, Duhaney (2001) claims that in-depth professional development in technology integration may produce positive results in teachers' practices in classroom instruction. Lack of technology knowledge, poor classroom technology management, and lack of time for training and avoidance of the need for training are some of the challenges that belong to this category of actions that are promoted by an expert guide.

2.4.3.1 Lack of technology knowledge

Goos et al (2003) argue that professional learning and development influence the integration of digital technologies into mathematics teaching. To create future-oriented visions of technology integration they propose the development of theories of practice which could inform teacher education in order to strengthen recommendations about what counts as 'progress' or 'success' in technology integration. Duhaney (2001) insists that without a model of technology integration the feasibility of success if blurred. Hew and Brush (2007) further illuminate how lack of technology knowledge and skills impair teachers' planning to integrate technology into their teaching.

The above debates indicate that the absence of a theory of practice and a model of technology integration are challenges to professional training opportunities. Without theory and a model of technology integration the use of computers for teaching mathematics is unlikely to be a success.

2.4.3.2 Poor classroom technology management

Hew and Brush (2007) argue that lack of technology-related-classroom management knowledge and skill is a barrier to technology integration into the curriculum. Traditionally, classroom management includes provisions and procedures necessary to establish and maintain an environment in which instruction and learning can occur; it involves the preparation of the classroom as an effective learning environment. Classroom management is complex and unpredictable. Then with the inclusion of technology integrated instruction it may be worse. Challenges such as the establishment of rules and procedures and classroom design are some of the inevitable technology related management barriers (Lim, Teo, Wong, Khine, Chai & Divaharan, 2003; Zandvliet & Fraser, 2004).

2.4.3.3 Lack of time for training and avoidance for the need for training

Once teachers have graduated and start working it is very hard for them to go for professional training, and some may avoid taking any training even if there are opportunities to attend such training in technology. Others consider technology as a modern era innovation from which they are exempted due to age. In general, time may be a challenge to mathematics teachers if they hope to integrate technology in their mathematics instruction.

2.5 Conclusion

I have tried to review the literature on the integration of technology in mathematics education. The literature stipulates some opportunities, drawbacks and challenges that teachers and learners face. Goos (2005) has narrowed down the expansive sets of challenges discussed in previous research to three major challenges: environmental constraints, underdeveloped but emerging skills of novice teachers, and actions promoted by expert guide. However, within these three categories there is rich literature that explains technology challenges within each category.

The literature has set a background for my understanding of potential opportunities and challenges brought by technology integration into mathematics classrooms at school level. Furthermore, it has set a platform from which I will engage with the theory that anchors and guides my study. The theoretical framework that I provide below will expand and clarify this scenario.

Chapter 3: Theoretical Framework

3.1 Introduction

Although the above literature has set a background for this study, it is necessary to understand the theory that anchors, drives and upholds the whole study. In Chapter 2, I stipulated that the primary purpose of the literature review is to sharpen and deepen the theoretical framework of the research. In this chapter I provide a brief development of some learning theoretical perspectives and show why I choose Vykotsky's socio-cultural constructivism as my theoretical framework; more especially the zone notion and the use of learning tools. I will discuss how other researchers have elaborated the zone notion and show how they are linked to the research questions and, most importantly, to the above literature. The literature presents three main challenges to computer integration into mathematics classrooms: environmental constraints, underdeveloped but emerging skills of novice teachers and actions promoted by expert guide. The socio-cultural perspective can account for these three sets of challenges in terms of different zones. Each zone is related to each type of challenge. This is elaborated by Goos (2005). See Table 3.1 and discussion below.

Although the ZPD is used very often to describe learners' development, in this research and in line with Goos et al (2003) I talk about a teacher's ZPD in a learning-teaching situation. Why teachers in particular? Jina and Brodie (2008, p.3) when they debate about teachers' questions and interaction patterns in their case study argue that:

> … teachers are unlikely to provide an adequate explanation of concepts if they do not understand them themselves. Teachers will not be able to engage their learners in productive conversations about multiple ways to solve problems if they themselves can only solve it in a single way

In a similar fashion, I think that mathematics teachers need to be conversant with technology integration into mathematics learning if they are to provide adequate computer instruction to learners; moreover they need this knowledge of technology integration if they wish to engage their learners in productive and potentially multiple ways of solving and displaying mathematics

problems within a context of computer use. Thus, learning needs to take place in the ZPD of the teacher if technology is to be successfully integrated into the mathematics classrooms.

The two other zones: the Zone of Free Movement (ZFM) and the Zone of Promoted Action (ZPA) are used to classify the different challenges that teachers face in the technology integration process (Goos, 2005). These three zones are further defined and discussed below.

3.2 Learning theories

The radical developments in education, over the past half-century, have produced such expansive theoretical perspectives that practice within the mathematical arena is infused with theories that attempt to inform, improve and sustain mathematics teachers' instructional approaches. These theories range from Skinner, the behaviourist, whose analysis of learning is based on individual behaviour and a notion of knowledge which is figured from simple to complex, but without structure. In this view, knowledge accumulates as a result of reinforcement and conditioning. Then Piaget, the cognitive constructivist, looked at the individual mind from a biological perspective (cognitive development). He argued that knowledge is structure and knowledge structures the mind. Learning increases through the organization of schemata; this happens as a result of the process of equilibration. Essentially (Piaget, 1964) argues that learning re-organizes prior knowledge.

Vygotsky argues that there is a relationship between knowledge and social activities. Socio-cultural mechanisms infuse knowledge. Learning is mediated through semiotic artifacts such as signs, tools, etcetera, in the zone of proximal development (ZPD). Similar to Piaget's perspectives, learning re-organizes prior knowledge and functions (Vygotsky, 1978). Recently some of the contemporary theorists talk about the intuitiveness of knowledge in a community of practice (Lave & Wenger, 1991; Hanks, 1991; Brown, Collins & Duguid, 1989). For instance, Brown et al (1989) introduced the idea of situated learning and argued that learning is a social practice. In this framework, learning is improved action in context. In order to understand learning one has to understand the context of the learner and the material being learned.

3.3 Why choose the socio-cultural theory

Any of the above theories of learning may be used to understand the challenges and opportunities of technology integration into mathematics classrooms. However, the works of Vygotsky which consider learning as a socio-cultural activity seem to have caught the attention of many current researchers. Even when researchers come up with a new theory, Vygotsky's notion of the 'social' still maintains a high position within the learning arena. For instance, whether one is learning alone on one's own computer, or with others that becomes one's own social world (Goos, 2005). After all, the computer and its software have been designed and built through the efforts and thinking of many others.

I therefore argue that mathematics learning occurs within a social system. Besides Piaget's biological mental systems, a classroom functions as a social system composed of teacher, learners, artifacts and the mathematics. But a classroom system operates within a larger communal school system which also has an impact on what happens in the classroom. For example, if the school administration offers resources for a particular school subject there is a high likelihood that learners will perform well in that subject.

In fact what is the ZPD? The word 'zone' can be associated with territory or section of an area distinct from the surrounding. 'Proximal' can be anything in the neighbourhood or situated nearest the point of attachment. 'Development' may mean the process of getting better gradually. Therefore the ZPD can be defined as a distinct and critical area or space where one is ready and able to acquire unfamiliar knowledge gradually. This happens in a social context where there is interaction among a teacher (or more knowledgeable person), learners, artifacts (such as a computer) and the mathematics.

The Vygotskian notion of the 'zone', as elaborated by Valsiner (1997), may be helpful in analysing different systems within a school that opportune or limit the use of technology in mathematics classrooms. A 'zone' is an imaginary space; it does not exist in reality but can be understood and its 'existence' inferred from occurrences in a learning-teaching situation. Hence Vygotsky's two ideas: the use of artifacts and the notion of a zone persuade me to employ his theory of socio-cultural constructivism as opposed to the other learning theories. For instance, each zone in Table 3.1 shows the main challenge and its associated factors or elements within the

zone that affect the integration of computers in classrooms. These different zones in table 3.1 have been explained under section 3.4 below.

Table 3.1: Different zones, types of challenges and factors within each challenge. Adapted from Goos (2005).

Valsiner's zones	Related challenges	Elements of the zones
ZFM	environmental constraints	.access to hardware, software, and laboratories .access to teaching materials .technical support including colleagues
ZPD	teacher knowledge and beliefs	.skills/ experience in working with technology .pedagogical knowledge .pedagogical beliefs
ZPA	professional learning opportunities	.professional development

3.4 Socio-cultural constructivism

Vygotsky (1978) defines the ZPD as the distance between the actual development and the potential development of an individual. Vygotskian constructivism emphasizes education for social transformation and his theory is a theory of human development that situates the individual learner within a socio-cultural context (Ismat, 1998). A learner's development is derived from social interactions within groups in which cultural meanings are shared and these meanings are internalized by the learner (Vygotsky, 1978). Thus, cognitive development according to Vygotsky acts on two planes: inter-psychological (through interaction with the social world or between people) and intra-psychological (within one's own thinking). In this way, the mastery of the social forms is later united within the individual and internalized (Meadows, 2004). We can see a dialectical relationship between knowledge and the social activity. But, what counts as learning then? Learning is perceived as an increase in the organization of inter- and intra-mental functions; through this increased organization one develops more sophisticated cognitive competencies. The organization is obtained through

guidance by a competent adult (teacher) or peers (Meadows, 2004). Learning is assisted by the learning tools e.g. language, technological tools, etcetera, which mediate within the zone of proximal development (ZPD). Thus learning re-organizes, extends and deepens prior knowledge and functions. The role of an expert or teacher therefore is to function as a mediator of the learning tasks, by taking someone through the ZPD. How?

With a limited degree of understanding from the learner, the teacher offers successive, precise and simple directions which the learner observes or imitates. As the learner becomes able to cope with more components of the activity and has increased understanding, the teacher reduces the assistance given until the learner is competent to perform the activity on his/her own. This is a movement from other (teacher)-regulation to self (child)-regulation or own scaffolding (Meadows, 2004). But, how do all these arguments relate to teachers' integration of computers in mathematics classrooms?

The literature review points to three aspects which Table 3.1 ascribes to the teacher's ZPD: skills/ experience in working with technology, pedagogical knowledge, and pedagogical beliefs. These constitute teacher knowledge and beliefs. The common element within these challenging factors is technology knowledge. For instance, pedagogical knowledge refers to teacher's technological know-how (expertise or proficiency) in a teaching and learning situation. In order to become proficient in using technology in a classroom a teacher needs to be taught or guided by a more knowledgeable someone and this learning process assumes a similar path to that of a learner in a social context, and hence the teacher's ZPD can be defined accordingly. Most importantly these three aspects develop gradually in proximal interaction with instances. For example, experience or skill is a gradual process that one acquires while working on a phenomenon for some time, mostly in social contexts. A similar case applies for beliefs.

I have already indicated that technological experience affects one's beliefs. Since experience is a gradual process, alongside it a teacher may have either negative or positive beliefs depending on the success or failure of the phenomenon. For instance, a teacher may believe in teaching mathematics through computers depending on how frequently she has been successful in using computers as teaching tools.

Additionally, Goos (2005) expands on the work of Valsiner (1997) with regard to the Zone of Proximal Development (ZPD), the Zone of Free Movement (ZFM) and the Zone of Promoted Action (ZPA). Goos (2005) claims that these three zones constitute a system that can account for the dynamic relationship between the contextual constraints and affordances of the teaching environment, the teaching actions specifically promoted and the development of the teacher's pedagogical identity. According to Valsiner (1997) in Goos (2005), the ZFM represents environmental constraints that limit or support freedom of action and thought. Alternatively, Hoyles and Lagrange (2010) describe the ZFM as structuring one's access to different areas of the environment, objects and ways of acting upon these objects. In so far as a mathematics computer integrated classroom is concerned I would like to define the ZFM as comprising of external challenges and supports that a teacher may face while she/ he is supposed to integrate a computer in teaching mathematics. For example, a school infrastructure that has very few outdated computers deprives teachers and learners of access to do mathematics through technology. See more factors (elements) of this zone in Table 3.1.

Similarly, Goos (2005) defines the ZPA as the set of efforts of a teacher educator, supervising teacher, or more experienced teaching colleague to promote particular teaching skills or approaches. One would infer that the ZPA points to teachers' potential development in acquiring professional technology integration skills for mathematics instruction. In relation to the child, Hoyles and Lagrange (2010) describe ZPA as the set of activities, objects, or areas in the environment in which the person's actions are promoted. In the context of my study, actions promoted by an expert guide may be called professional learning opportunities, and such challenges belong to the Zone of Promoted Action (ZPA).

Thus the extended socio-cultural constructivist philosophy elaborated in Table 3.1 serves as my working theoretical framework. As indicated previously it is adapted from the work of Goos (2005) who examines the factors affecting technology use. Her work in turn is based on Valsiner (1997) who shows the relationship between the three zones and related challenges. The critical questions stated in Chapter 1 shall be answered using this framework:

3.5 Interrelationship

To show the relationship among the three zones, Goos (2005) provides Figure 3.1. She argues that the ZPA is within the novice's ZFM because the ZFM suggests the teaching actions possible while the ZPA defines the efforts. In other words, the ZPA is a subset of ZFM. Similarly, ZPD has elements shared with ZPA and lies within the ZFM as well. Goos (2005) argues that the intersection between the ZPD and the ZPA should be a maximum (the maximum overlap desirable (MOD)). In turn, the MOD signals the minimum requirements necessary for creating a conducive environment to integrate technology in mathematics classrooms that affords maximum technology instruction.

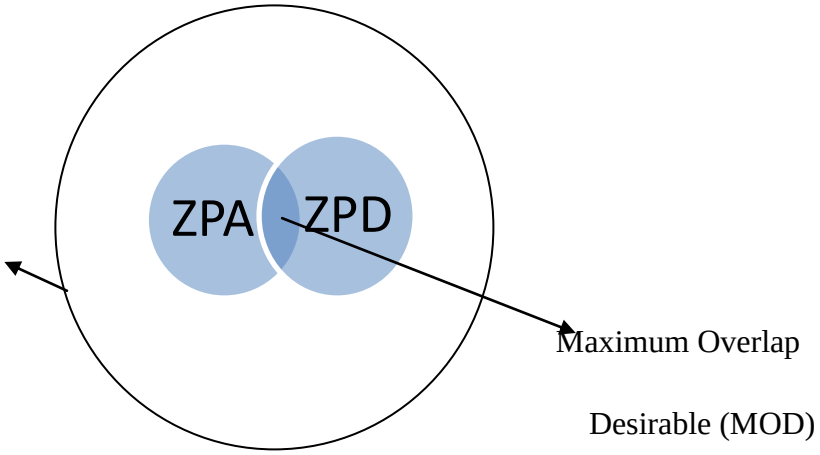

Fig. 3.1: How the three zones are related to each other. Adopted from Goos (2005)

3.6 Conclusion

In this chapter I have provided a brief review of the development of some learning theoretical perspectives and have indicated why I chose Vykotsky's socio-cultural constructivism as my theoretical framework; more especially the zone notion and the idea of learning tools. I have elaborated on different zones from the literature and shown how they are linked to my research questions and most importantly to my background literature above.

> … this socio-cultural model facilitates an analysis of teacher learning and socialization that considers the person-in-practice, and examines how identities develop as involvement in the practice increases. (Goos 2005, p. 28)

Thus this socio-cultural theoretical framework sets signposts for the analysis of the opportunities and challenges that a very small sample of South African teachers, 'persons-in-practice', face when they integrate computers in their mathematics classrooms.

Chapter 4: Research design and methodology

4.1 Introduction

I introduced my report by arguing that there are potential opportunities and challenges that affect computer integration into mathematics classrooms. In order to gather information on teachers' perspectives on these matters I engaged in a case study. The case comprised of a group of mathematics teachers who teach at both GET and FET phases in Gauteng Province. I will say more about this group later. My research is qualitative. The research instruments employed consist of semi-structured questionnaires and an audio-taped group interview. I conclude the chapter with a discussion of issues related to research rigour. These include issues like validity, reliability, credibility, bias, and ethics. I also discuss limitations of this study.

4.2 Research approach

This research report is a case study. What is a case study? Different authors define a case study differently but in this research I have embraced Opie's (2004) definition of the characteristics of a case study. According to Opie (2004) there are two major research paradigms: positivist and constructivist paradigms. The positivist view is based on the ontological belief that reality is there to be studied, captured and understood. Its epistemic beliefs are that the world is really ordered, the researcher is distinct from the known. Methods of approach are through experiments, quasi-experiments, surveys and correlational studies. Usually such studies are quantitative in nature.

Constructivist research posits the ontological belief that multiple realities are constructed. Knowledge is viewed as a human construction. Researcher and participants construct understandings. Hatch (2002) calls data collection methods in a constructivist paradigm 'naturalistic'. Such studies result in case studies, narratives, interpretations and recommendations. They are mostly qualitative in nature. A case study is an approach that focuses just on one instance by conducting an in-depth study of the phenomenon to be investigated. It offers sufficient detail to unravel the complexity of a given situation.

I have chosen a case study because I would like to have an in-depth understanding of the challenges and opportunities faced by teachers who have integrated technology in their

mathematics classrooms in Gauteng province, more especially because Gauteng province is heading on to a full supply of computers in schools from the government by 2013.

4.3 Sampling Procedure

A target group of six skilled mathematics teachers who attend a part-time Masters course in Mathematics Education studies at the University of the Witwatersrand formed a convenient sample for this research. All teachers in this group have access to computers at their respective schools; however they have integrated computers into their teaching to different degree or not at all. See next chapter in which this is discussed. My study was limited to these teachers due to time constraints of this research and the lack of accessibility of other teachers in schools who are very busy at the end of school term with exams and other managerial commitments.

The teachers in the case study group have several characteristics which make them distinct from most other mathematics teachers in Gauteng. They are all studying towards a Masters in Math Education. This indicates a particular interest and skill in mathematics education. They all have access to one or more computers or a computer lab at their schools. These factors are taken into account when interpreting the findings.

Consent was granted by the teachers after I had requested permission from them and I assured confidentiality (refer to Appendix D). More details on the interviewees' biographies and schools are given in the next chapter.

4.4 Data collection methods

The three research instruments that I used in my research are listed in Table 4.1 and described in Figure 4.1 below:

Table 4.1: Research instruments

Instrument	**Brief description**
Literature	Text resources, journals and current literature
Questionnaires	Closed and open-ended questionnaires
Interviews	Group interviews (open-structured)

4.5 Motivation for data collection instruments

The following map represents the set of instruments that I have used in my research

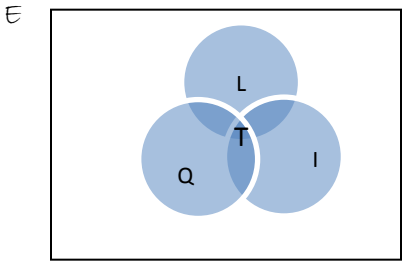

Fig. 4.1: A set of research instruments

Key: ∈= universal set of the set of instruments

L= literature review I= interviews

Q= questionnaires T= triangulation

$L \cap Q \cap I = T$

What is triangulation? Actually triangulation is not a specific research instrument but an approach to research. Opie (2004, p. 72) describes it as "a metaphor in research derived from the practice of surveying; a better map of a landscape can be obtained if one uses more than one line of sight". Figure 4.1 above reflects more than one line of sight in finding out information from the teachers about opportunities and challenges of integrating computers in mathematics classrooms. The three forms of instruments: literature, interviews and questionnaires triangulate this research.

These instruments are used differently to interrogate the concerns of research. Additionally, my use of these different instruments in data collection adds to the validity, reliability and credibility of this research. Moreover, because I would like to have an in-depth understanding of technology integration in a few mathematics classrooms, I think more than one instrument is appropriate.

4.5.1 Literature review as a research instrument

Literature review may provide a theoretical framework for an activity (Opie, 2004; Lichtman, 2006; Neuman, 1997). According to Lichtman (2006) literature review is an accounting of what is out there around a particular topic. It is more than a compilation of individual research studies; it represents a synthesis and critical assessment related to a particular topic. A Literature review clarifies the current state of research: what has gone before and the missing pieces. So it provides the context for a study.

Since literature is so powerful that it is able to relate the past to the present and future I choose it to work for me as a research instrument. Literature allows one to predict the challenges and opportunities offered by integrating technology into mathematics classrooms to date and onwards based on the successive growth of literature findings. I would like to argue that in the future 'technical computations' (computations that need to be worked out fast to save time for understanding concepts) and/ or multiple representations (which need a machine to provide a visual presentation so that learners may understand the mathematics notion better) will still have to be engaged with in mathematics, and if future educators could understand how they were tackled in the past through computers they (educators) may succeed to manage such computations with ease.

Literature allows one to predict the future success or doom of a phenomenon. Furthermore, it provides my report with a synthesized and critical stature because it sets a background to the study. It may also give an analytic framework because one may derive categories for use in and/ or tools for data collection from the existing literature.

4.5.2 Questionnaires

Information from distant interviewees can be obtained through questionnaires and the questionnaires can be used to get a lot of information without too much time having to be spent

delivering the questions (Opie, 2004). I developed a questionnaire (refer to Appendix B) which combine open and closed-ended questions. Before coming up with the questionnaire in Appendix B I had developed a questionnaire which I piloted. Unfortunately it was too long and comprehensive that it was hard for my pilotees to try and answer it. Thus I developed the questionnaire in Appendix B which I delivered through email to the respondents. Some replied electronically while others handed in hard copies. See more information on piloting the instruments below.

Table 4.2: The advantages and disadvantages of closed-ended versus open-ended questions

Closed-ended	**Open-ended**
Advantages	
Enhances consistency of response across respondents	Allows more freedom of response
Easier and faster to tabulate	Easier to construct
More popular with respondents	Permits follow-up by interviewer
Disadvantages	
May limit breadth of responses	Reponses tend to be inconsistent in length and counter across respondents
Take more time to construct	Both questions and responses are subject to misinterpretation
Requires more questions to cover the research topic	Harder to tabulate and synthesize

Adopted from Fraenkel & Wallen (1990, p.339)

Table 4.2 above shows both advantages and disadvantages of each type of closed and open-ended form of a questionnaire. Close-ended questionnaire has the following advantages: It enhances consistency of responses across respondents. If respondents have to choose the answer that they feel is correct among a number of alternatives, the answer they choose is the same among all of them. There is no additional information to supplement the answer. For example in a true or false questionnaire those who choose 'true' as the correct response have answers which are consistent. Responses can be tabulated easily and respondents are likely to answer every question. On the other hand, open-ended questionnaire has an advantage that it allows more freedom of response. That is, respondents may give any answer to a question depending on their

understanding hence there is a high likelihood that one question may have more than one answer. They are easier to construct and they allow the interviewer to probe for further clarification.

Besides these advantages the following disadvantages can be noted: closed-ended questionnaire may limit breadth of responses. Since responses are specific it is not easy to gather more information by a few questions that is why there is need to construct many questions to cover the research topic. Therefore much time is taken when constructing them. Alternatively, open-ended questionnaire has disadvantages that responses tend to be inconsistent in length and counter across respondents. Many answers that may be attributed to one question create inconsistency. Some answers may be longer than others and there may be disagreement among respondents because of the freedom given when answering questions. Questions are more likely to be misinterpreted due to individuals' different understandings. Synthesizing open-ended questionnaire is hard because of a variety of response to each question.

In this research I have chosen a combined form of questionnaire. That is a combination of both closed and open-ended questions. The advantage of a combined form of questionnaire is that where one form is disadvantaging the research data collection exercise, the other may serve as back-up. For instance, since a closed-ended questionnaire requires more questions to cover the research topic and may result in respondents being unwilling to spend time answering the questions, using it minimally by combining it with open-ended questions, may encourage the respondent to answer the questionnaire.

In this study teachers were asked to provide pseudonyms which were used on both questionnaires and in interviews. However it is not easy to ask questions that will need the interviewee to respond to 'why'. Questions that demand a reason from a respondent usually require the respondent to dig deep into their thinking (Opie, 2004). Since my research is a case study, case is formed by a group of teachers that I interviewed using group interview to extract important information. The questionnaires provided an overview of whether there are challenges and opportunities that these mathematics teachers face when they integrate computers into their classrooms or not.

4.5.3 Group Interview

The type of group interview selected for this study is standardized and open-ended, where wording and range of questions are pre-determined and the type of questions are open-ended (Refer to Appendix C). Although Opie (2004) says an interview is similar to a questionnaire in both form and use, the reasons why I chose interviews to supplement the questionnaires is because of the flexibility of an interview (different questions may result from different responses); response rate (many people feel more confident about their speaking than their written abilities); non-verbal behaviour (the interviewer can assess the validity of a respondent's answer by attending to his or her non-verbal behaviour); question order (the interviewer can ensure that the questions are answered in the correct order); and spontaneity (the interviewer can record spontaneous answers, thereby reducing the chance of the respondent retracting his or her first answer). Nevertheless, I am aware that interviews are time consuming. The teachers were interviewed in a group and since they came from different backgrounds I made sure no one dominated the discussion. Everyone during the interview session was given enough time and attention to respond to each question asked. This contributed to the validity of the interview instrument.

However, the interview was conducted after class in the afternoon when teachers were tired and hurrying to go home; this may have had an effect on data collected. The data may lack some of the rich details about computer integration in mathematics classrooms.

Table 4.3: How my instruments gathered information for the research: Summary

Instrument	**Major function**
Literature	Provide study background and instruments which can be adapted for data gathering
Questionnaires	Provide an overview of the challenges and opportunities
Group Interviews	Provide an in-depth understanding of the prevailing challenges and opportunities.

4.6 Piloting the instruments

I piloted my instruments at Wits with some of my colleagues who have integrated computers at their schools. The sample that I used in the pilot is similar to the one in this study because they were also mathematics teachers who teach at FET and use computers to different degrees to teach mathematics. The main purpose of the pilot was to inform the main study about the quality of the questionnaires and interviews that I used. The pilot study indicated the suitability of the instruments used in terms of the clarity in the instruction, structure and context of the questions and whether the questions actually address the challenges and opportunities of computer integration in schools. As a result of the pilot study I had to modify and shorten the questionnaire and interview by getting rid of irrelevant details from the instruments.

4.7 Rigour in this research

Rigour in research relates to the quality of statements and relationships which are defined by aspects such as reliability, validity and credibility. These aspects serve as indicators of 'goodness' or quality in research (Opie, 2004).

4.7.1 Reliability

Joppe (2000) in Golafshani (2003) defines reliability as: The extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology. Opie clarifies the definition "reliability is a property of the whole process of data gathering, rather than a property solely of the results", (p.66). However in this research; according to the definition, I cannot guarantee the reliability of the results because the research study has not been repeated anywhere. Anyhow, the fact that I have defined my data gathering tools and stipulated how they have been used to get relevant data to answer my critical questions sets hope for reliability of my research. Moreover, my claims have been qualified with arguments supported by literature.

4.7.2 Validity

According to Opie (2004) validity addresses issues of whether the instruments used will in fact measure what they are purported to measure. The data presented in chapter five to follow reflects

the validity of the questionnaires and interviews that I have used. I regard the data as valid in as much as has supplied me with information on teachers' perspectives on technology integration in mathematics classrooms.

4.7.3 Credibility

A broader term from which the word 'credibility' is derived from is 'trustworthiness' which involves credibility, transferability, dependability and confirmability. Opie argues that in educational research conducted by new researchers 'credibility' comes into the category of case studies. Since I am embarking on a case study and am a new researcher this is an applicable term. To show whether my study is accurate (credible) I have performed the following:

(1) I have used two forms of validity: content validity and construct validity (Maxwell, 1992). Content validity refers to the adequacy of the questions that I have designed to cover the content being assessed. This refers to information drawn from the teachers about the challenges and opportunities of technology integration in mathematics classrooms. Even though there are limitations in this study, much information has been drawn from this small group of teachers. Construct validity indicates the extent to which the questions measure the theoretical constructs of a study. These refer to the constructs derived from my research questions. I have tried in this study to pose specific critical questions that cover the theoretical aspects of the challenges and opportunities of computer integration into mathematics classrooms.

(2) I have provided accounts of the following:

(a) Data-gathering procedures are explained

(b) Data is presented transparently and in ways that enable ready re-analysis

(c) Negative instances are reported

(d) Where possible biases are acknowledged

(e) My claims have been supported with evidence

(f) My field analysis has been explained

(Adopted from Opie 2004, p. 71)

(3) Figure 4.1 above indicates triangulation in this research. More than one data collection tools have been used.

4.7.4 Use of audio recorder

I used an audio recorder for the interviews which I transcribed and I asked a colleague to check the accuracy of the transcriptions (Refer to Appendix E).

4.7.5 Issues of biases

Being a researcher and a mathematics teacher may affect what I do or say in this study. This may be one of the limitations of this study but in transcribing, probing and prompting teachers I tried to minimize the biases.

4.8 Ethical considerations

I am aware that it is against university regulations to begin research without ethical approval (Wits School of Education, 2011). Accordingly I obtained clearance from Wits School of Ethics Committee which ensures that the right to conduct my research is protected. The Gauteng Department of Education (GDE) as part of ethics clearance has granted me permission to conduct research. I have obtained informed consent from the participating teachers and they have been assured of anonymity and confidentiality of their identities and that their participation in the research is not obligatory. I will keep the data collected from these teachers safely until the results for my research are published and for a further three year period. After that I will then destroy the data by shredding. Furthermore, I have assured the teachers that the research will not have any effect on their normal teaching at schools.

4.9 Presentation of results

The presentation of my results consists of the following:

(a) Biographical details of the teachers and their schools

(b) Feedback from the questionnaires

(c) Analysis of the transcribed teacher utterances from interviews

The purpose of coding, categorizing and interpreting data is to provide explanations of the different phenomena of interest. In this case it is the understanding of opportunities and challenges of technology integration. Therefore the research question that is geared towards understanding of the opportunities is as follows: What are some of the potential opportunities that the integration of technology in a mathematics classroom offers?

The challenges of integrating computers into mathematics classrooms at GET and FET phases that will also be reflected in the results section are addressed through the following critical questions: What are some school structures and constraints that may affect the integration of technology into a mathematics classroom? How do teachers' knowledge and beliefs affect the integration of technology into a mathematics classroom? Does professional learning affect teachers' integration of technology into a mathematics classroom?

In Chapter 2 above, literature points to a number of opportunities that could be afforded by integrating computers into mathematics classrooms. For example, computers as powerful learning medium artifacts can provide rich prospects for teaching and offer learners new paths of understanding. Similarly, in response to the three critical questions that address challenges brought by integrating computers into mathematics classrooms; literature has provided the following examples:

Institutional constraints which may include one or more of the following: access to hardware, software and laboratories, access to teaching materials and technical support. These are challenges because without enough of these external resources there is little opportunity for teachers to integrate technology into mathematics curriculum. Secondly, the effective use of technology for instruction depends on the teachers themselves and the beliefs that they hold about technology. This means that attitudes and beliefs of teachers are a challenge to computer integration into mathematics classrooms. Lastly, actions promoted by expert guide may be a challenge. These are reflected by lack of teacher professional learning opportunities. Due to the absence of in-depth professional development in technology integration it is possible that teachers are not able to integrate computers effectively into mathematics classrooms. Thus professional learning stands as a challenge.

In answering these critical questions the findings of this research will illuminate the opportunities and challenges of technology integration into mathematics classrooms.

4.10 Limitations of the study

I think this research design fall within the limits of the scope of M.Ed. Research Report in the Faculty of Humanities and will contribute to the stated aims in the introduction chapter:

- To understand some of the opportunities that may be offered by integrating computers into mathematics classrooms.
- To understand some of the challenges that may emerge from school infrastructure, teachers' knowledge and beliefs, and professional learning due to the computer integration.

I also think this study is manageable and focused. Issues such as research rigour and the organization of the study have been addressed. However, since information was gathered mainly from a very small non-representative sample of six mathematics teachers all from different schools in the Gauteng Province, this study is not generalizeable. But the fact that it is not generalizeable does not blur its importance. Moreover, during the design discussion I alluded to some other limitations such as: time constraints for conducting this research, the state of teachers during the group interviews and bias. All of these may affect the quality of this study.

For instance, since the questionnaire was conducted through email some of the information that I requested from the informants for further investigations was not easy to get because they did not reply to the email. Furthermore, in response to questionnaires some of the answers may not be truthful. This limitation reflects well in 5.2 in the next chapter: Lexis's answer supports the assertion that:

> research which proceeds from the epistemological assumption that knowledge is experiential and subjective will usually place a considerable emphasis on the accounts given by the informants … In response to questionnaires … the whole issue of how words can actually reflect 'reality' and experience is, in itself, complex and problematic Opie (2004, p.22).

Here we see an example of one of the limitations of questionnaires: some of the answers may not be truthful. To reflect reality from words is complex and problematic. Hence triangulating the research tried to improve the reliability of the responses of my informants.

4.11 Conclusion

This chapter has indicated my ontological belief is that multiple realities are constructed. Knowledge is a human construction. Therefore I chose a qualitative research methodology. Data collection instruments for this case study including the piloting of the study have been discussed. Reasons for rigour (or its lack) in this study have been presented. The methodology and phrasing of relevant questions were informed by the focus of the research: to obtain information about teachers' perspectives on technology integration in mathematics classrooms. Ethical considerations and presentation of my results have been discussed. Lastly, I have provided a brief discussion on strengths and limitations of my study. I will return to these in the final chapter. The next chapter focuses on the findings and discussion of the study.

Chapter 5: Research findings and Discussions

5.1 Introduction

This chapter presents the research findings from the data collected through the qualitative tools of questionnaires and a group interview. I provide the biographical information of the six mathematics teachers who took part in this research. The findings on teachers' perceptions about technology integration in mathematics classrooms will be presented in four main sections relating to each of the four critical questions that guide the study. A discussion about the data, the relevant literature and the appropriate theory is included for each section. Lastly, a summary is given with an example of the relationship between the three zones within one teacher from the group.

The critical questions are as follows:

(1) What are some of the potential opportunities that the integration of technology in a mathematics classroom offers?

(2) What are some of the school structures and constraints that may affect the integration of technology into a mathematics classroom?

(3) How do teachers' knowledge and beliefs affect the integration of technology into a mathematics classroom?

(4) Does professional learning affect teachers' integration of technology into a mathematics classroom?

5.2 Biographical details of the participants

The table below presents biographical details of the participants. The participants were six mathematics teachers who taught at six different FET schools in Gauteng Province in South Africa. The information in the table is in response to questions (i) to (iv) in Section D of the questionnaire in Appendix B.

Table 5.1: Biographical details of the participants

Name	**Pite**	**Khalala**	**Anonymous**	**Mosikili**	**Julius**	**Lexis**
Age range	50-above	40-49	30-39	30-39	30-39	30-39
Mathematics teaching without computers	More than 16 years	11-15 years	11-15 years	11-15 years	1-5 years	6-10 years
Mathematics teaching with computers	1-5 years	1-5 years	none	None	6-10 years	none
Highest level of education	Post graduate	Post graduate	Post graduate	Post graduate	Post graduate	Post graduate
Detail of the schools	Township	Old Location Township	Township	Township	Model C Urban	Township

Synthesis: Biographical details of the participants

The table above shows that none of the participants was below the age of thirty. Also, they all had a reasonable number of years as mathematics teachers. All the teachers except Julius had more years of teaching experience without computers than teaching with computers. And among them, three had no experience of teaching mathematics with computers. Why was Julius's case different from the rest? Probably one of the answers may be picked up from his answer to question 3 in Section B:

3. Do you think you need additional ICT skills to help you use computers in teaching mathematics? Yes No

(a) If yes, which skills do you think you need? ……

(b) If no, why don't you think you need skills? …I did a Bachelor of Commerce Degree in Information Technology.

The possession of an IT degree was an opportunity for Julius. During the era of the integration of technology in mathematics he stands a better chance to do this integration exercise with ease. Therefore Julius' background qualification offered him the opportunity of having more teaching experience with computers than without computers.

Of the three teachers who answered 'none' to question (iii) 'Your experience in teaching mathematics with computers' in Section D, two when answering question 4 in Section C 'If yes, which ones do you use in your mathematics teaching?' had indicated that they used Microsoft math (Lexis) and Geometer's Sketchpad, Power Point, GeoGebra and Thutong (Mosikili). An email message was sent to Lexis and Mosikili to explain their contradictory responses to Question C4 and Question D (iii) or to explain what they understood by computer integration into mathematics classrooms. An email reply from Lexis read thus:

I only do my personal planning and setting questions with Microsoft math and other software but never taught a lesson in class with a computer.

Mosikili did not reply to the email. Possibly, he used computers in the same way as Lexis, for planning and setting questions. This illustrates a limitation of conducting a questionnaire through email and hence one limitation of this study. That is, some of the important information may not be captured from the informants when using emails.

Table 5.1 further shows that five respondents were teaching in township schools and only Julius taught in a Model C school. What is the difference between these two types of schools? Some of the differences between these schools as far as education is concerned are as follows: During the apartheid era township schools were made for Blacks, Coloureds and Indians. They were poorly resourced. At such schools the use of computers was very scarce. On the other hand Model C schools were mainly for the white people, well-resourced and managed. The use of computers at such schools was common.

5.3 Answering the research questions

This section is in four parts based on the four critical questions that guide the study. Each section states the critical question, draws information from the findings and then discusses the findings. Literature and the theoretical perspectives underpinning the study are used to support or interpret the answer to the question.

5.3.1 What are some of the potential opportunities that the integration of technology in mathematics classrooms offers?

Findings: The six teachers pointed to a variety of opportunities that using computers for teaching mathematics could offer. Their ideas were picked up from Section C (1.a) of the questionnaire (Refer to Appendix B):

1. Do you think computers can be used as effective mathematics teaching tools?

Yes No

(a) If yes, why? …….....

All the six respondents answered "yes 'to this question and their responses were as follows:

Table 5.2: Opportunities from the respondents from the questionnaires

Respondent	Example of an opportunity
Khalala	To connect visuals with subject matter and save time
Anonymous	Using a sketch pad to do geometry and (graphs and functions) will enhance a lot of confidence in the learners' geometry. Use Fathom to do statistical representations
Pite	Increase learners' understanding of concepts like statistics, graphs, transformation geometry clearly and faster (time saving)
Julius	Students are early adopters of technology and if properly integrated they could combine technology with mathematics
Lexis	Compare geometric features easily and quickly
Mosikili	Math accessible and learners are interested in technology

Similar responses were picked up from the teachers' utterances during the group interviews. Table 5.3 below shows the respondent's name and his/her utterance that implied an opportunity of using computers.

Table 5.3: Opportunities picked up from the group interviews

Respondent	Utterance
Julius	we can communicate any time; submit assignments electronically and we can mark electronically; kids are so technologically enabled.
Khalala	becomes faster, easily stored or saved, to the learners and also to myself [Both the teacher and learners who have integrated computers in math, computers have built in mathematical formulae that can be retrieved faster than deriving them manually. Computers also have storage devices which can store mathematical data safely for future use]
Pite	make learners able to computerize what they're talking about.
Anonymous	children cannot lose work anymore; finish the syllabus on time and have enough practice.

Discussion: A number of important issues concerning the opportunities offered by computer integration into mathematics classrooms emerged from the above extracts of both questionnaires and interviews findings. These issues may be summarized into four main headings: visual representation of mathematics concepts, time saving, up-dated storage devices and a cognitive development tool.

5.3.1.1 Visual representation of mathematics concepts

From the questionnaire schedule Khalala pointed out that computers may be used to connect the subject matter visually and Pite added that using computers increases learners' understanding of mathematics concepts. I suggest that although Pite did not use the term 'visual', it was implicit in her statement and the context in which it occurred.

According to socio-cultural learning theory, learning is assisted by the learning tools, for example, language, technological tools, etcetera, which mediate within the zone of proximal development (ZPD). A computer is a technological learning tool which according to those two respondents mediates or facilitates the understanding of mathematics because learners and

teachers are able to see and access different properties of a particular mathematical concept. Computers may provide a visual reinforcement of the theoretical ideas described in words during a lesson. Moreover, Lexis commented that geometric features may be compared easily through visualization.

Furthermore, Chronaki and Christianson (2005) emphasize that computers provide dynamic media which enables teachers and learners to manipulate and program visual representations of mathematical ideas. Stols and Kriek (2011) further elaborate that dynamic mathematics software such as GeoGebra, Cabri and Geometer's sketchpad help improve learners' visualization skills and ability to focus on the interrelationships of parts of geometric shapes. Refer to Appendix A for an example of a visualization process that is capable of being attained through the use of computers in mathematics classrooms.

5.3.1.2 Time saving

One of the most common responses from both interviews and questionnaires that were given by the respondents was that computers save time when working out mathematical problems. For instance, "Increase learners' understanding of concepts like statistics, graphs, transformation geometry clearly and faster (time saving)," wrote Pite when responding to a questionnaire question above. Lexis suggested that geometric features can be compared easily and quickly. In other words, the appropriate use of a computer saves time for doing other important aspects that may need more time to grasp. Khalala during the interview emphasized the aspect of time-saving by indicating, "...becomes faster ...to the learners and also to myself." This means that both the teacher and learners who have integrated computers in math, computers have built in mathematical formulae that can be retrieved faster than deriving them manually. Furthermore, Anonymous pointed out by saying that learners cannot lose their work when using computers and that the teacher may also finish the syllabus on time giving the learners enough time for practice.

What is the purpose of the learning tools according to socio-cultural theory? One of the importances of Vykotskian tools is to support the understanding process. Besides the use of visual representations (discussed above), this also relates to the speeding up of the understanding processes. Stacey et al (2002) highlight the idea of time-saving by indicating that the use of Sketchpad offers fast and accurate drawings. Furthermore, Goos et al (2003) argue that

computers as amplification tools are capable of speeding up tedious calculations. The crucial issue is that the use of computers may eliminate the drudgery of calculations and allow the learner to focus on the conceptual ideas.

5.3.1.3 Up-dated storage device

Computers not only speed up calculations but also may be used as mathematics storage devices. When interviewed Khalala said, "... becomes faster, easily stored or saved to the learners and also to myself." Meaning that, computers also have storage devices which can store mathematical data safely for future use. The idea that computers have eliminated the need for piles and piles of paper information storage is an indisputable fact in our modern era. For instance, a whole mathematics text book can be safely stored electronically and be made accessible to learners and teachers easily. Hence, computers as socio-cultural artifacts not only mediate learning through the ZPD but are also capable of storing the mathematics to be learned. Khalala further elaborated during the interview on the same aspect of storing, "whatever the lesson you have done is easily stored or saved".

5.3.1.4 A cognitive development tool

Julius during the interview talked about two important opportunities (communication and enabling environment) that computers may offer: "we can communicate any time, submit assignments electronically, and we can mark electronically, kids are so technologically enabled ...," confessed Julius. On the questionnaire, Julius elaborated that learners are early adopters of technology and hence if the technology is properly integrated into mathematics classrooms, learners may easily combine technology with mathematics. So as an enabling tool, a computer can provide means to develop teacher and/ or learner thinking.

One of the philosophies of constructivism is that learning develops more sophisticated cognitive competencies. In this regard, the inclusion of computers in mathematics classrooms helps learners and teachers become technologically proficient and more cognitively competent. Goos et al (2003) affirm that the use of technological tools such as computers not only amplify, but also re-organize cognitive processes through the computers' integration into the social and discursive practices of a community of practice. Similarly, cognitive re-organization or enabling

may occur when learners and the teacher interact among themselves with technology; a new semiotic tool that transforms and develops their mathematical thinking.

As a communicative tool, Julius pointed out that "we can communicate any time, submit assignments electronically and we can mark electronically." This relates to my own experience: I have always liked to communicate with learners after school hours to track if and what they are studying and to exchange ideas on how to do their homework. But I have failed many times because communication is not easy. In this regard the aspect of communicating any time is an extended opportunity that can be afforded through the use of computers even outside classroom situations to keep track of mathematics learning. So learning is within easy reach. Learners and their teacher are able to create a mathematics environment wherever they are. The fact that technology has transformed the world is indisputable. A message can be sent anywhere within a blink of an eye though the use of technology.

Summary

The above findings and discussion on opportunities that may be afforded through integrating computers into mathematics classrooms concurs with research. Computers may work as visual representation tools, may save time by speeding up tedious calculations and aid conceptual understanding of notions underlying those tedious calculations. Computers may also work as up-dated mathematics storage devices, and also act as both cognitive and communicative tools. All these aspects may be achieved within socio-cultural learning environments where the computers mediate through the ZPD in mathematics pedagogical situations.

Kilpatrick, Swafford & Findell, (2001, p.270) put this cogently:

> Research has indicated that the visual and numerical supports provided for symbolic expressions by digital representations of graphs and tables help students create meaning for expressions and equations in ways difficult to manage in learning environments not supported by computers or calculators

In this section I have addressed Critical Question One. In the following section I will address Critical Question Two: What are some of the school structures and constraints that may affect the integration of technology into a mathematics classroom?

5.3.2 What are some of the school structures and constraints that may affect the integration of technology into a mathematics classroom?

To answer this question I mainly use data obtained from the questionnaire sent through emails to the six teachers who took part in the research. This issue was only briefly discussed in the group interview and so my focus is on the data obtained from the questionnaire. Additionally, I use information on Table 5.1 biographical details of the participants; more especially their schools backgrounds.

Table 5.4 below presents results obtained from the questionnaire schedule pertaining to this question. Column one is for the questions from the schedule, column two shows different answers that teachers were expected to choose from, column three is for ideas or teachers' perceptions, column four is the total respondents on each particular question and column five shows the names of the respondents. For example, in response to the question 'Do you have access to computers? Please indicate.' Khalala indicated that he had access to computers only at school, and the rest (five) indicated that they had access to computers at both school and home. No one had access only at home.

Table 5.4: Results analysis from Section A of the questionnaire schedule

Question	Choices	Elaboration	Total respondents	Names
1. Do you have access to computers? Please indicate	School only		1	Khalala
	Home only		0	none
	Both		5	Anonymous, Julius, Lexis, Mosikili, Pite.
2. How often do you use a computer for your personal use?	Always		5	Anonymous,Julius,Khalala, Lexis, Pite
	Sometime		1	Mosikili
	Never		0	none
3. Do you have a computer lab/ room in your school?	Yes		6	Anonymous, Julius, Khalala, Lexis, Mosikili, Pite
	No		0	None
4. If yes, how often do you use the lab and for what purpose?		Hardly use it, I have my personal computer	1	Lexis
		Not use lab for teaching	1	Julius
		Teaching graphs	1	Khalala
		Never use it	1	Anonymous
		Personal purposes e.g. check emails	1	Pite
		Writing my assignments and internet	1	Mosikili

5. In case of technical problems with a computer (in the lab), how fast are the repairs done and by whom?	fast	School IT person	1	Julius
	slowly	Gauteng Online	2	Mosikili and Lexis
		Technician	1	Pite
		Independent technician	1	Khalala
		Technology HOD	1	Anonymous
	never	--	0	None
6. Does the curriculum (i) mandate or (ii) encourage the use of computers/ laptops to teach mathematics?	(i)		0	None
	(ii)		1	Julius
	Both		2	Khalala and Pite
	Not sure		3	Anonymous, Mosikili and Lexis
7. On your school time-table, is there a period for teaching mathematics using computers?	Yes	Five lessons per week	1	Julius
If yes, how many times per week?	No	Zero lessons per day	5	Anonymous, Khalala, Lexis, Mosikili and Pite

At this juncture, I wish to highlight and explicate the responses to Question 5 and Question 7 in Table 5.4 since they are particularly significant in the discussion below. The first part of Question 5 asked, 'In case of technical problems with a computer (in the lab), how fast are the repairs?'Of the six respondents, it was only Julius who indicated that repairs were done fast while the rest responded that repairs were done slowly at their schools. In other words, when there were problems with computers at Julius' school, the school did not take many days before the computers were repaired. With the rest of the respondents their schools took presumably many days before repairing the computers; this may inconvenience learning and teaching through computers.

For the second part of question 5, '…by whom?' Julius specified that the school IT person did the repairs while Pite and Khalala mentioned that they were done by technician. Presumably, those technicians were IT persons. Lexis and Mosikili indicated that Gauteng Online is responsible for repairs. It was only Anonymous who indicated that the school had a technology Head of Department (HOD) who did the repairs.

For question 7, Julius indicated that there was one period per day for teaching mathematics using computers. The other five respondents put forward that there were no periods on their time-tables allocated for teaching mathematics with computers and hence zero periods per week.

I return to these responses (and others) in the discussion below.

Discussion

The fact that those teachers had access to computers always used them for their personal purposes (Questions 1 and 2) and that there were computer labs at their schools (Question 3) indicates that some of the basic infrastructural components necessary for computer integration into mathematics classrooms were in place. However, teachers' responses starting from question four showed different challenges at those six schools.

Of the six teachers, it was only Khalala who used the computer lab for teaching graphs (Question 4). The rest seemed to never use the labs at their schools (Question Four). Even though all the teachers replied to question A1 that they had access to computers, question A4 was specific to the school computer laboratories. I have argued from the literature that even in

those schools which have installed computer hardware, one may find that many mathematics teachers are not aware that computers can be used for mathematics instruction and even for those who may be using them, one may find that they are not using them to their fullest potential. However, with these teachers in this study this argument seems not to hold because in answer to question 3 Section C most of them answered that they were aware of the potential for mathematics teaching with a computer.

So what could be the teachers' reasons for not using the school computer labs? Part of the answer may lie in the teachers' responses to Question 5 and in Anonymous' and other teachers' remarks in the group interview.

Anonymous: But I don't think only teachers… I think if also the management…. At my school we've got more than 100 computers but as a math department we're not using them, we're not accessing them; we're not allowed to use them.

Anonymous: *(inaudible)* it's very bad, like we have a lab, it's not used because the computers are always out of order and no one is responsible for fixing the Gauteng online computers.

In essence, I suggest that the teachers in this study had no real pedagogical access to the school computers. Most probably the management at those schools was not aware of the potential of using the labs for mathematics teaching. Having no access to the hardware invariably implies having no access to the software. Thus we see five teachers using the school labs for their own personal needs but not for teaching learners (Question 4). In further support of my hypothesis, five teachers out of six responded to question A5 by indicating that when there were technical problems with a computer, repairs were done slowly. In the interview Anonymous emphasized that, "It's very bad, like we have a lab; it's not used because the computers are always out of order and no one is responsible for fixing".

Furthermore, neither the NCS nor CAPS documents mandate the use of computer for mathematics instruction at both GET and FET phases. Hence there is no obligation for teachers to integrate them into their mathematics instruction. I would like to hypothesize that where there is no obligation people do what they like or are familiar with. Indeed in this study only one teacher had five lessons of teaching mathematics with computers. Amazingly this teacher was not Khalala who used the computer lab for teaching graphs, but it was Julius who never used the

school computer lab. For the rest of the teachers, a math lesson involving the use of computers was not even scheduled.

According to Goos (2005), environmental constraints or institutional constraints include one or more of the following: access to hardware, software and laboratories, access to teaching materials and technical support. I therefore argue that at most of the schools at which these teachers were teaching, school structures and constraints barred the integration of technology into mathematics classrooms because teachers were not given access to computer hardware and software.

In theoretical terms I would like to further my argument: teachers' Zones of Free Movement (ZFM) - the one structuring one's access to different areas of the environment, objects and ways of acting upon these objects - are challenged at these schools. There are external challenges and lack of support that teachers face when they are supposed to integrate computers into their mathematics classrooms. In contrast, Julius's case was interesting: He never used the school computer lab but communicated mathematically with his learners; who owned laptops, through email and a specially designed webpage. This fact emerged during the group interview.

From the constructivist philosophy in my theoretical framework, Lave and Wagner (1991) mention the situativeness of learning. Learning is situated in a community of practice. I am tempted to suggest that such communities of practice are not confined to the 'four walls' (classrooms or in this case, school labs). Rather these communities could be anywhere where learning can take place. Thus Julius had set up a mobile mathematics computer laboratory from which mathematics could be learned and communicated effectively. His class had individual laptops and they had their own website for learning mathematics through the use of technology. This might be the reason why he did not need to use the existing school computer laboratory.

The schools' backgrounds also set a challenge to computer integration in classrooms. Julius was the only teacher among these respondents who was teaching at a Model C school which was well resourced due to its historical background. The rest of the respondents were from poor background schools (Township). The fact that schools' background is a challenge is manifested in Julius' responses in the questionnaire. For example, learners at that school (Model C) owned laptops and there were furnished computer labs which he (Julius) did not even use. This implies

that the Model C schools as compared to Township schools are richer and well resourced, and therefore may provide better education to learners. Most learners from Township schools battle even up to college to own a laptop. It is only currently that they are affording to buy computers. Hence teaching and learning through computers at Township schools is difficult to achieve.

In summary, lack of access to both hardware and software, no immediate repairs of computers, no obligation from the department to integrate computers for teaching mathematics, poor time-tabling and schools' background are challenges that I have found to influence the integration of technology into mathematics classrooms at the six schools.

5.3.3 How do teachers' knowledge and beliefs affect the integration of technology into mathematics classrooms?

Table 5.5 below presents three important aspects of data from the questionnaire schedule. This data concerns possible challenges to technology integration into mathematics classrooms around issues of knowledge, beliefs and professional development. These issues were not explicitly discussed in the group interview and so all data from this section derives from the questionnaire. Table 5.5 will be used to answer the last two critical questions, in this section and the following section (5.3.4).

In this section we look at Critical Question 3: How do teachers' knowledge and beliefs affect the integration of technology into a mathematics classroom?

Table 5.5: Results analysis from Section B and C of the questionnaire schedule

Question	Choices	Elaboration			Total respondents	Names
		Knowledge	**Beliefs**	**Professional Development**		
B1. Have you attended any course(s) at the university/ college/ anywhere on using computers?	Yes				5	Anonymous, Khalala, Mosikili, Lexis and Pite
	No				1	Julius
B2. If yes, was the course useful in your teaching, lesson preparation and presentation of mathematics? Explain.		No. It was about computer skills only			1	Khalala
		Yes, exposed to software and math websites			2	Pite and Mosikili
		Yes, setting questions and tasks			1	Lexis
		Never got chance to practice skills with learners in the school lab.			1	Anonymous,
		No response			1	Julius
B3 Do you think you need additional ICT skills to help you use computers in teaching mathematics?	Yes			yes)- use of other necessary software Skills on how to incorporate in my daily teaching Using a projector A summary of all computer skills Using excel to record marks	5	Anonymous, Khalala, Mosikili, Lexis and Pite (**respondents' answers are given in Section 5.3.4**)

a) If yes, which skills do you think you need? (b)If no, why don't you think you need skills?						
	No				1	Julius
B4 Do you get any help from your colleagues on how to use computers to teach mathematics?	Yes				1	Pite
	No				5	Anonymous, Julius, Khalala, Lexis and Mosikili
C1. Do you C1.Cont. think computers can be used as effective mathematics teaching tools? a) If yes, why? (b) If no, why do you say so?	Yes		Refer to Table 5.1 above		6	Anonymous, Julius, Khalala, Lexis, Mosikidi and Pite
	No				0	

Beliefs: All the six respondents replied "Yes" to question C1 which indicates that they believed that computers can be used as effective mathematics teaching tools. They justified their beliefs with a variety of reasons. For instance, Pite argued that computers increase learners' understanding of concepts like statistics, graphs, transformation geometry "clearly and faster". Her argument was probably based on her experience of 1-5 years teaching mathematics with computers. She had indicated this experience while responding to question D (iii) of the questionnaire schedule –'your experience in teaching mathematics with computers'.

Working from the socio-cultural background I would like to argue that mathematical technological beliefs develop gradually in proximal interaction with instances. Working with a cultural tool for some time creates a certain belief. It may be a positive belief – indicating the importance of the tool, or a negative belief – indicating the disadvantage of using that particular tool. However, beliefs also develop as a result of the context and culture within which teachers operate (as expressed in newspapers, discussion with peers, etcetera). In this research the six teachers reflected a positive belief towards the use of computers in mathematics classrooms.

From a South African perspective and from a exploratory study on teachers' attitudes and beliefs insofar as technology is used in classrooms, Stols and Kriek (2011) pronounce that teachers' actual behaviour is influenced by the perceived usefulness of the technology or its ability to make their lives in the classrooms easier. In my study all the six teachers had indicated the usefulness of computers in mathematics classrooms.

In contrast, the findings on knowledge from these six respondents revealed certain challenges pertaining to their computer technology knowledge.

Knowledge: In response to question B1, five teachers in this study indicated that they had attended courses about computers. But their responses to question B2 indicated that although they had attended courses about computers, some attended courses that were not geared to teaching mathematics with computers. For example, Mosikili responded that the course was about computer skills only. Since the course did not equip him with skills on how to integrate computers into mathematics, his sparse knowledge of using computers for mathematics learning is a challenge. Anonymous, responded that she never had a chance to practice the skills from the course with learners in the computer lab. I suggest that knowledge not used is knowledge

forgotten. This was also a challenge to Anonymous' technology knowledge. Furthermore, question B2 asked the teachers to address three aspects: usefulness in ones' teaching, lesson preparation, and presentation of mathematics. But none of them attempted the three parts. They only gave brief answers. This gives me reason to doubt the usefulness of the courses that they attended insofar as the integration of computers into mathematics classrooms is concerned. So their technological knowledge is challenged.

One of the necessary conditions for teaching mathematics with technology is a good mathematics instructional knowledge. Instructional knowledge comprises content knowledge, pedagogical knowledge and good technology knowledge, including how to work with technological tools such as computers (Lim et al, 2003). This condition, if successfully attained, moulds one's familiarity, experience and behaviour (attitudes and beliefs) in using technology in classrooms. Furthermore, from the theoretical perspective, pedagogical knowledge refers to teacher's technological knowhow (expertise or proficiency) in a teaching and learning situation. In order to become proficient in using technology in a classroom the teacher should first be taught by a more knowledgeable other. This more knowledgeable other is not necessarily a person as such; it may be an on-line course or a text. This learning process works through the teacher's ZPD where the teacher develops gradually in proximal interaction with technology (Vygotsky, 1978; Goos et al, 2003).

So how do teachers' knowledge and beliefs affect the integration of technology into mathematics classrooms? The partial answer is that teachers' lack of mathematics technology knowledge may result in the teachers not perceiving the usefulness of the technology and its potential for making teachers' lives in the mathematics classrooms easy. In addition, without appropriate knowledge, teachers may not be able to successfully use the technology in the classroom.

In the following section I look at Critical Question 4: Does professional learning affect teachers' integration of technology into a mathematics classroom?

5.3.4 Does professional learning affect teachers' integration of technology into a mathematics classroom?

As stated previously, I will mainly use the data in Table 5.5 (obtained from the questionnaire) to answer this question. In particular, the answer may be inferred from questions B1, B2, B3 and B4 and the teachers' biographies.

There is an overlap between the ZPD whose notion I have used to answer question 5.3.3 above and the ZPA which I use to answer question 5.3.4. That is why questions B1 and B2 are repeated to respond to question 5.3.4. This overlap is consistent with my theoretical framework (see Figure 3.1).

Julius' profile indicates that he had spent more time teaching mathematics with computers than without computers while the rest have their profiles the other way round. Julius further had five lessons on the time-table for teaching mathematics with computers. He possessed an IT professional training degree. Therefore, I would like to argue that an appropriate professional training course may offer one the confidence to approach one's work. Indeed Julius' ZPA during university days has advantaged him to integrate computers into mathematics teaching.

The rest of the respondents (teachers) are challenged by not having any formal professional certification from college or university. However, their responses to question B1 had shown that they understood the importance of professional training in technology and in question B2 they also reflected that they had attended some courses on computers. Therefore their school (on job training) ZPAs supported their use of computers to some extent. Interestingly when responding to question B3 five of the teachers showed a need for additional ICT skills that might help them use computers for teaching mathematics. For instance, Khalala mentioned that he needed skills such as using other mathematics software.

Lastly, five out of the six teachers never shared how to teach mathematics with computers with their colleagues. This is a pity since a standard interpretation of Vygotsky (1978) would imply that a teacher's technology knowledge development is largely derived from social interactions within groups in which cultural meanings are shared.

In summary, I have argued from the literature that in-depth professional development in technology integration can produce positive results in teachers' practices (Refer to Chapter 2 on

the Literature section). These include among others: expertise in planning, classroom technology management and classroom instruction. Thus, although all teachers other than Julius showed great interest and willingness to achieve further training on computer use in classrooms, the challenges facing them were on how to employ positive classroom practices. From literature I have also indicated that classroom management is complex and unpredictable. The inclusion of technology integrated instruction adds to the complexity. Challenges such as the establishment of rules and procedures and classroom design are some of the inevitable technology related management barriers (Lim et al, 2003; Zandvliet & Fraser, 2004). Hence, professional learning affects teachers' integration of technology into a mathematics classroom.

5.4 A sample: relationship between Julius's ZFM, ZPD and ZPAs as an experienced teacher

I have used the case of Julius to show how the three zones are related to one another. I have selected Julius since his responses in both interviews and questionnaires seemed to be the most comprehensive and moreover he had integrated technology into his mathematics teaching.

Julius' case: The NCS document from the Department of Education encourages, rather than mandates, the use of technology such as computers. Julius was aware of that. That is why he had marked (ii) for question 6 (Section A) of the questionnaire schedule:

Question A6: Does the curriculum (i) mandate or (ii) encourage the use of computers/ laptops to teach mathematics?

Julius' school was a well-resourced school in Gauteng area with computer labs and each student attending there had their own laptop for their studies. In other words the use of technology was widespread at this school and a compulsory learning tool at that school. Consequently the infrastructure and culture of Julius' school (the ZFM) was supportive of computer integration. Julius had a B.Com degree in IT and this implies that his ZPA from university was an advantage which should help him to integrate technology in mathematics teaching.

However, Julius said he did not need additional ICT skills to help him use computers in teaching mathematics, and he also did not get help from colleagues. Not needing additional skills was a doubtful idea in technology -an industry which is continually changing. New and much

sophisticated hardware and software are likely to crop up any time and hence I think ongoing training is necessary for mathematics teachers' awareness on what is currently there in the market for learning and teaching. Besides that, Goos et al (2003) show that learning in computer education technology may be situated in communities of practice. This implies that professional development of teachers may be enhanced by interacting with more knowledgeable colleagues.

But perhaps Julius as an experienced teacher learned on his own and created his own social learning environment. However, to develop further he might need to interact with others. It should also be noted that the judgment here is based on the upfront information given by Julius (specifically that he did not need additional ICT skills). Probably Julius used internet and books to pick up new skills. But further investigation as to how he managed the new hardware and software that so frequently crops up in technology market is needed.

From the given information Julius's school ZPA is at stake. That is, there is no connection between Julius's school ZPA and his university ZPA because he is not interested in a professional development course while he is teaching. For instance, when answering question B3: Do you think you need additional ICT skills to help you use computers in teaching mathematics? Julius answers, "No". Therefore his school ZPA does not fall within the vicinity of his work place. So, the relationship between Julius's ZFM, ZPD, and ZPA may be represented as follows:

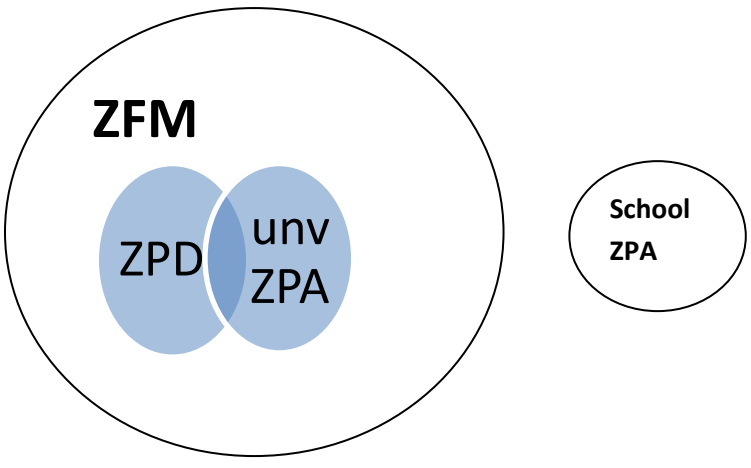

Figure 5.1: Relationship between Julius's ZFM, ZPD and ZPAs

Discussion: The diagram on Figure 5.1 above does not appear to predict a trajectory of development involving technology usage between the three conceptual zones (Goos et al, 2003). According to the theoretical perspectives in this study there is no maximum overlap desirable (MOD) in Julius' integration of technology into his mathematics classroom. Even if Julius may be the most knowledgeable in his school, knowledge is dynamic. That is, even if one may know something well presently, because knowledge frequently changes, one ought to keep updated in current changes.

If Julius was willing to get additional ICT skills and assistance from more knowledgeable colleagues he would undoubtedly achieve the maximum overlap desirable zone/ area, more especially because the rest of his zones have no challenges or problems in so far as computer integration is concerned.

5.5 Conclusion

In my research design I mentioned that I am going to use the following three research instruments to collect and analyse my data: Literature, Questionnaires and Interviews. This chapter analyses data based on these instruments to greater or lesser degree.

I have grounded my study about the teachers' perspectives on opportunities and challenges that they face when they integrate technology into their mathematics classrooms. A socio-cultural constructivist philosophy as a theory that underpins this study has been employed in the analysis and discussions.

The next chapter provides a textual-summary analysis of the findings, study limitations, reflections on the overall research, recommendations and conclusion.

Chapter 6: Answering the critical questions, Limitations, Reflections, Recommendations and Conclusion

This chapter discusses answers to the critical questions supported by theory, relevant literature and research results with special reference to technology integration into mathematics classrooms at GET/ FET phases. Limitations of the study are discussed and reflections on the study are considered. Finally recommendations and conclusions on opportunities and challenges of integrating computers into mathematics education are provided.

6.1 Summary of answers to the critical questions

In the previous chapter the critical questions which guide the study were answered as follows:

What are some of the potential opportunities that the integration of technology in a mathematics classroom offers?

In this study teachers perceived the use of computers in mathematics learning and teaching as tools that can be used to visualize mathematics concepts. Literature supports this perception that dynamic mathematics software such as GeoGebra, Cabri and Geometer's Sketchpad helps improve learners' visualization skills and ability to focus on interrelationships of the parts of geometric shapes (Stacey et al, 2002; Stols & Kriek, 2011). Thus, computers provide dynamic media which enables teachers and learners to manipulate and program visual representations of mathematical ideas (Chronaki & Christianson, 2005). In this and other ways computers can transform classroom pedagogy and learners' understanding of mathematics in a positive way (Matthee & Jacobus, 2007).

Furthermore teachers in this study recognized that the use of computers can save time when doing routine procedures. Yet another opportunity is the fact that computers can store thousands of mathematics texts which learners can access. They work as portable libraries. That is why teachers in this study perceived them as updated storage devices. Additionally, computers work as cognitive development tools. Literature, too, recognizes technological artifacts as semiotic learning tools (Meadows, 2004) because the technological tools work as extended psychological aids (Goos et al, 2003). They facilitate, mediate and catalyse (Heid, 1997) the learning/ teaching

exercise in mathematics classrooms. Moreover according to Vygotskian theory of constructivism learning is mediated through these semiotic artifacts in the zone of proximal development (ZPD). Hence re-organization of prior knowledge and functions is attained (Vygotsky, 1978). New knowledge therefore emanates from prior knowledge. That is why Dunham and Hennessy (2008) prophesy that the dramatic growth in access to personal computing power has catalyzed today's mathematics education reform movement.

What are some of the school structures and constraints that may affect the integration of technology into a mathematics classroom?

The extended notion of the Vygotskian zone theory: Zone of Free Movement (ZFM) forms a basis to answering this question. The ZFM describes the environmental constraints which serve as challenges to computer integration in mathematics. Teachers in this study claimed that there was lack of access to hardware and software at schools. This may be because the South African Department of Education does not mandate the use of computers in the mathematics curriculum and most schools that have computer labs lack scheduled computer-integrated lessons. Mostly teachers use computers to learn and teach mathematics using computers at their own discretion. Also computers are not repaired immediately when there are technical problems with them. As a result this negatively affects learning through computers.

How do teachers' knowledge and beliefs affect the integration of technology into a mathematics classroom?

The theory of constructivism describes the Zone of Proximal Development (ZPD) as a distinct and critical area or space where one is ready and able to acquire unfamiliar knowledge gradually. The challenges of integrating technology in mathematics in this area (ZPD) are related to the teachers' knowledge and beliefs. The teachers in this study argued that although they (teachers) attended courses related to computers, those courses were not well grounded in computer integration into mathematics classrooms. So, this is a challenge to their knowledge. However, they believed that computers are helpful resources to teaching mathematics.

Does professional learning affect teachers' integration of technology into a mathematics classroom?

The Zone of Promoted Action (ZPA) according to literature is described as the set of activities, objects, or areas in the environment in which the person's actions are promoted. The challenges set in this zone are related to professional learning opportunities. Even though some teachers in this study showed great interest and willingness to achieve further training on computer use in classrooms, there are very few; if any, courses which help them to incorporate computers into their daily teaching. Most mathematics teachers to date have not got professional computer training geared towards integrating technology into mathematics classrooms.

6.2 Limitations of this study

The following are limitations of this study:

(1) Time constraints and data collection: For a full-time student, working on research concurrently with course work is demanding. Although I gathered sufficient data for my study, the research would have been enriched and deepened had I managed to gather more data (e.g. interviews with more randomly selected teachers).

(2) State of teachers during the group interviews: I have noted that the teachers were interviewed in the afternoon after the last lecture when they were exhausted from their school work and the lecture and this may contribute negatively to the results obtained from their responses.

(3) Bias: Although I have tried to avoid bias, my position as a researcher and as a mathematics teacher will inevitably affect the results of this study.

(4) Conducting research through email: It was not easy to probe responses from respondents by email.

(5) Using questionnaires: some of the responses may have been inaccurate and this may affect the reliability of this study.

6.3 Reflections on this study

Reflecting on one's ideas is not an easy task because one has to take a stance and critically look at one's own arguments and ideas. A tendency to defend oneself without sufficient detachment

may develop. However in reflecting on this research I shall try to minimize such defensiveness in order to try and demonstrate a better picture of the whole research.

6.3.1 Introduction

According to Donclark (2012), reflection is thinking for an extended period by linking recent experiences to earlier ones in order to promote a more complex and interrelated mental schema. When a new mental schema is created or extended, then learning takes place (Piaget,1994; Olivier & Tsujii,1994). According to a socio-cultural philosophy reflection on one's research therefore would mean expanded thinking where one interacts with one's own social world in order to promote learning. On the one hand is one's work or research (in this case) and on the other hand is oneself pondering critically on the pros and cons of the work at hand. Hence through reflection I may be able to learn more and have a better understanding of my research and whether it does contribute to the pool of knowledge.

Thus reflection goes beyond looking at only how well one has performed the research, but at how one could improve the study. Reflection looks for thinking for better further learning in the sense that one has to critically view one's work from a distance. This may mean constructive self-criticism.

6.3.2 Reflection

Reflecting on this research I first look at its short falls, then its goodness and lastly the balance between the two.

6.3.2.1 The short-falls of this research

This study is an opportunistic case study conducted among my colleagues in the Masters' class. It does not provide a broader picture of other teachers' perspectives on technology integration in mathematics classrooms; exclusive of this group, in Gauteng schools. The group interview was used minimally in the analysis section as compared to the questionnaire. Although Kieran (2007) highlights the idea that technology can be used as a discourse participant rather than just a presentation device, seemingly a great percentage of these respondents understood technology integration as Power Point presentation and I have failed to provide enough probing of the respondents to clearly get their understanding of the research topic.

Improvement on triangulating the research could have included class observation because what the teachers say may be reflected well in the actual implementation of the exercise of teaching mathematics through computers. The data collected is rather thin and hence results in thin analysis.

6.3.2.2 Goodness of this report

The report indicates an adequate acquaintance with the methods of research. Almost all parts of the research are well presented and carried out. For example, a thematic literature review rather than summarizing, a competent theoretical framework, the methodology section that includes contextual information about the teachers' schools, an analysis that goes along with discussions based on theory and literature, and a conclusion chapter providing clarity of answers to the critical questions and also reflections.

6.3.2.3 Short-falls versus goodness of this report

Although I have mentioned the short-falls of this research, they do not blur its goodness. I have acknowledged most of the short-falls. For example, in the limitations section I have indicated that it was not easy to probe teachers though emails because some did not respond to the emails. Generally, the research in terms to the answers to the critical questions (see above) does contribute to the pool of knowledge; that integrating technology into mathematics classrooms; in particular, it may contribute to a more nuanced understanding of both opportunities and challenges of the technology integration scenario.

Further improvement of this study may include class observation and a conference paper so that this research can benefit some of the Gauteng mathematics classrooms.

6.4 Recommendations

The following recommendations derive from the findings of this study:

(a) I recommend that teacher training institutions offer a compulsory course for mathematics technology integration to all prospective mathematics teachers.

(b) There should be an awareness campaign directed to school administrators about the potential opportunities that computers hold so that they can encourage and support mathematics teachers in accessing the existing infrastructure in schools.

(c) Teachers should be offered in-service training on computer integration into mathematics teaching. A follow-up should be made to ensure that teachers implement ideas in their respective mathematics classrooms.

(d) The department of education should mandate the integration of computers in the mathematics curriculum.

6.5 Conclusion

The focus or target of any learning-teaching scenario is a learner. Whether it is curriculum development, teacher training, learning resources (e.g. computers), the school or any other related subject, the target is a learner. Although this study is a small non-representative sample of teachers in the Gauteng Province it has served the aims of this research:

Firstly, the research is aimed at understanding the opportunities that may be offered by integrating computers into mathematics classrooms. Secondly, the research addresses the challenges that may emerge from school infrastructure, teachers' knowledge and beliefs, and professional learning with respect to computer integration into mathematics classrooms.

Despite the non-representativeness of the sample used, the study does contribute to the literature. In particular this research reveals some of the pertinent issues involved in computer integration into mathematics classrooms and therefore indirectly may inform teachers about what they have to expect when using computers to teach mathematics in a Gauteng high school.

I have employed analytic tools from literature and socio-cultural constructivism theory to anchor, guide and assist me in responding to my critical questions. In particular I have applied the theory of zones to a select group of teachers of Gauteng schools in order to better understand the problems and opportunities afforded by integration of computers into mathematics classrooms.

Thus, I have gathered understanding of some of the opportunities and challenges facing teachers when they integrate technology (computers) into their mathematics classrooms at GET and FET

phases from this small non-representative sample of participant teachers who teach mathematics in six different Gauteng Province schools.

Reference List

Ball, D. L. (Chair) (2002).*Mathematical proficiency for all students*. Towards a strategic research and development program in mathematics education (DRU-2773-OERI). Arlington, VA: RAND Education, Science and Technology Policy Institute. Section B (pp. 8-11 & 29-41). Chapter 3.

Brodie, K. (2007). Teaching with conversations: beginnings and endings. *For the learning of Mathematics*, 27(1), 17-23.

Brown, S. J., Collins, A. & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, 18(1), 32-41.

Butzin, S. M. (2001).Using instructional technology in transformed learning environments. An Evaluation of Project CHILD.*Journal of Research on Computing in Education*, 33(4), 367-373.

Childs, S., Blenkinsopp, E. & Hall, A. (2005).*Effective e-learning for health professionals and students and their solutions.* A systematic review of literature-findings from HeXL Project.

Chronaki, A. & Christianson, I. M. (2005).*Challenging perspectives classroom communication*. From representations to contexts, interactions, and politics, pages 3-45. Information Age Publishing.

Criss, K. (2012). *Disadvantages of Computers in the Classroom*.Ezine-artice.Ezinearticle. 2 Mar 2006.

Cuban, L., Kirkpartrick, H. & Peck, C. (2001). High access and low use of technologies in high School classrooms: Explaining an apparent paradox. *American Educational Research Journal*, 38(4), 813-834.

Davis, B. (1997). Listening for differences: an evolving conception of mathematics teaching. *Journal for research in mathematics education*, 28, 3, 355-376.

Department of Education (2003).*White Paper on e-Education. Transforming Learning and Teaching through Information and Communication Technologies.* Pretoria: Department of Education.

DoE (2003).*National Curriculum Statement 10-12 (General): Mathematics*: Department of Education, Pretoria.

DoE (2011).*Curriculum and Assessment Policy Statement (CAPS): FET band Mathematics Grades 10 – 12*.Department of Education, Pretoria.

Donclark (2012), http://www.nwlink.com/~donclark/hrd/development/reflection.html

Drijvers, P., Goddijn, A. & Kindt, M. (2011). Algebra education: Exploring topics and themes. In Drijvers, P. (Ed.) *Secondary Algebra Education: Revisiting Topics and Themes and Exploring the Unknown.*Sense Publishers. Rotterdam. Chapter 1 (pp. 5-26).

Duhaney, D.C. (2001) Teachereducation: preparingteachersto integratetechnology. Int J Instr.*Media*28 (1):23–30.

Duma,S.M. (2012). JA Bisplinghoff, DM Senge… - Current Eye …, - informahealthcare.com

Dunham, P. & Hennessy, S. (2008). Equity and the use of educational technology in mathematics. In M. K. Heid& G. W. Blume (Eds.), *Research on Technology and the Teaching and learning of mathematics*: Vol. 1. Research synthesis (pp. 345-415). Charlotte, NC: Information Age.

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technologyintegration? *Educational Technology Research & Development*, 53(4), 25-39.

Farrell, A. (1996). Roles and behaviours in technology –integrated precalculus classrooms. *Journal of Mathematical Behaviour*, 15, 35-53.

Fraenkel, J.&Wallen, N. (1990).*How to design and evaluate a research in Education*. New York: McGraw-Hill.

Gauteng Online: http://www.education.gpg.gov.za/publications/gauteng%20online%20to%20reach%20public%20schools.htm. Retrieved on 8/ 6/ 2011

Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research http://www.nova.edu/ssss/QR/QR84/golafshani.pdf. Retrieved on 31/1/2013

Goos, M., Galbraith, P., Renshaw, P. & Geiger, V. (2003). Perspectives on technology Mediated learning in secondary school mathematics classrooms. *Journal of Mathematical Behaviour*, 22, 73-89.

Goos, M. (2005). A socio-cultural analysis of the development of pre-service and beginning Teachers' pedagogical identities as users of technology. *Journal of Mathematics Teacher Education*, 8(1), pp. 35-59.

Guin, D. & Trouche, L. (1999). The complex process of converting tools into mathematical Instruments: The case study of calculators. *International Journal of computers for Mathematical learning*, 3: 195- 227.

Hanks, F. (1991). Forward to Lave, J. & Wenger, E. (1991) *Situated Learning: Legitimate Peripheral Participation*. (pp. 13-24). Cambridge: Cambridge University Press.

Hatch, J. A. (2002).Chapter 4.Analyzing Qualitative Data. In: *Doing qualitative research in Educational settings*.SUNY. New York. pp. 147-210.

Heid, M.K. (1997). *American Journal of Education*, - JSTOR.

Hew, K.F. & Brush, T. (2007). *Integrating technology into K- 12 teaching and learning*: Current knowledge gaps and recommendations for future research.Education Tech. Research Dev., vol. 55 pp. 223-252. Educational Communications and Technology.

Hoyles, C. & Lagrange, J. (2010).Mathematics Education and Technology-Rethinking the Terrain. The 17th ICMI Study.Springer.

Hufferd-Ackles, K., Fuson, K. C. &GamoranSherrin, M. (2004). Describing levels and Components of math-talk learning community.*Journal for research in mathematics Education, 35(2), 81-116.*

Internet World Statistics.http://www.internetworldstats.com/af/za.htm

Isaacs, S. (2007). Survey of ICT and education in Africa: South Africa Country Report *ICT in Education in South Africa*, pp. 1-29

Ismat, A. H. (1998). Constructivism in teacher education: *Considerations for those who Would link practice to theory*. Eric Digest, pp. 1-7.

Jina, Z. & Brodie, K. (2008).*Teacher questions and interaction patterns in the new and old Curriculum: A case study*. School of Education, University of the Witwatersrand.

Kazemi, E. & Stipek, D. (2001). Promoting conceptual thinking in four upper-elementary mathematics classrooms. *Elementary School Journal*, 102, 59-80.

Kendal, M. & Stacey, K. (2002).*Teachers in transition*: Moving towards CAS- supported Classrooms.ZMD 2002 vol. 34 (5).University of Melbourne.

Kieran, C. (2007). Learning and teaching algebra at the middle school through college levels: Building meanings for symbols and their manipulation. In Lester, F. K. Jr (Ed.) *Second Handbook of Research on Mathematics Teaching and Learning: a Project of the NCTM*.Information Age Publishing. Charlotte. (pp. 707-714).

Kilpatrick, J., Swafford, J. & Findell, B. (2001).*Adding it up: Helping children learn mathematics*. Washington: National Academy Press.

Kozma, B. R. (2003). Comparative analysis of policies for ICT in education.*Center for Technology in Learning*, pp. 1-14.

Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lichtman, M. (2006).*Qualitative Research in Education*.SAGE Publications. Thousand Oaks. London.

Lim, C. P., Teo, Y. H., Wong, P., Khine, M. S., Chai, C. S. & Divaharan, S. (2003). Creating a conducive learning environment for the effective integration of ICT: Classroom management issues.*Journal of Interactive Learning Research*, 14(4), 405-423.

Lobato, J., Clarke, D. & Burns Ellis, A. (2005). Initiating and eliciting in teaching: A Reformulation of telling. *Journal for research in mathematics education*, 36(2), 101- 136.

Lovet, T. & Smith, D. (1995).The origins and nature of curriculum.*Curriculum: Action on Reflection Revisited*. 3rd edition Wentworth Falls, NSW.Social Sciences Press.

Manouchehri, A. (2004). Using iterative algebra software to support a discourse community. *Journal of mathematical Behaviour*, 23, 37-62.

Matthee, M. &Jacobus (Lieb) (2007). *Problems of technology integration in South Africa. Mathematics on the move*: Supporting mathematics learners through mobile technology in South Africa, pp. 149 – 154.University of Pretoria.

Maxwell, J. A. (1992). Understanding and validity in the Qualitative Research.*In Harvard Educational Review*, 62 (3), 279-300.

Meadows, S. (2004). *Models of cognition in childhood*. Metaphors, achievements and problems.The child as Thinker, London and Newyork, Rutledge.

Mendel, G. (2006). Technology in the Teaching of Mathematics: from Excel toMaple.http://www41.homepage.villanova.edu/klaus.volpert/teaching/mat7305/technology-in-teaching06.html

Mentz, E. &Mentz, K. (2003).Managing technology integration into schools. A South African Perspective.*Journal of Educational Administration*, 41(2), 186-200.

Michener, E. R. (1978). Understanding Mathematics: *Cognitive Science* 2, 361-383.

Nueman, W. N. (1997). *Social Research Methods: Qualitative and Quantitative Approaches* (3rd Ed.)University of Wisconsin, Whitewater, USA.

Olivier, P. & Tsujii, J.(1994). Proceedings of the 32nd annual meeting on …, - dl.acm.org

Opie, C. (2004). *Doing Educational Research: A Guide to First-Time Researchers*. SAGE Publications. Los Angeles.

Pang, M. F. &Marton, F. (2006).On Some Necessary Conditions of Learning.*The Journal of the Learning of Sciences*, 15(2), 193-220.

Piaget, J. (1964). Development and learning.In Ripple, R. E. &Rockcastle, V. N. (EDS.). *Piaget rediscovered*. Ithaca: Cornell Univ. Press.

Pierce, R. & Stacey, K. (2004). A framework of monitoring progress and planning teaching towards effective use of computer algebra systems. *International Journal of Computers for Mathematical Learning*, 9(1), 59-93.

Schreiner, E. (2012). The Disadvantages of Computers in Education http://www.ehow.com/list_6562938_disadvantages-computers-education.html#ixzz23cuASgBd

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. *Educational Researcher*, 27(2), 4-13.

Stacey, K., Asp, G. & Ball, L. (2002).Expanding algebra by substitututingCAS.In C. Vale, J. Roumeliotis, & J. Horwood (Eds.), *Valuing Mathematics in Society. Proceedings of the 39th Annual Conference of the MAV* (pp. 348- 364). Melbourne: Mathematical Association of Victoria.

Stols, G. & Kriek, J. (2011).Why don't all maths teachers use dynamic geometry software in their classrooms? *Australasian Journal of Educational Technology* 2011, 27(1), 137-151.

Valsiner, J. (1997). *Culture and the development of children's action: A theory of human development*. (2nded.) New York: John Wiley & Sons.

Vygotsky, L. (1978). *Mind in society.The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wachira, P. & Keengwe, J. (2010).*Technology Integration Barriers*: Urban School Mathematics Teachers' Perspectives.

Wits School of Education (2011). Master of Education (M Ed): *Programme information*. University of the Witwatersrand, Johannesburg.

Zandvliet, D. B. & Fraser, B. J. (2004). Learning environments in information and Communications technology.Tecnhnology, *Pedagogy and Education*, 13(1), 97-123.

Zbiek, R. M., & Hollebrands, K. (2008). A research-informed view of the process of incorporating mathematics technology into classroom pracice by in-service and prospective teachers. In M. K. H. G. W. Blume (Ed.), *Research on technology and the teaching and learning of mathematics: Research synthesis* (Vol. 1, pp. 287 -344). Charlotte, NC: Information Age.

APPENDICES

Appendix A

Flagpole problem

A flag of width h is hoisted to the top of a flagpole. You have a wooden 30-60 degree right triangle and a wooden 45-45 degree right triangle. When you stand at A', which is some unknown distance away from the flagpole, you can use one of the triangles, with one side held parallel to the ground and the other held towards the flagpole, to sight along the hypotenuse from your eye, which is at point A, to point C, the top of the flag. When you walk a distance d in a straight line towards the flagpole to B' you can again sight along the hypotenuse of the same triangle from your eye, now at point B, to the top of the flag. However, this time the positions of the two sides of the triangle are interchanged. With your eye at point B, you can also use the other right triangle to sight along the hypotenuse in a similar manner to point D, the bottom of the flag. What is the relationship between the width of the flag h and the distance d that was walked in moving from point A' to B' ?

Procedure

Demonstrate sighting along a hypotenuse of a right triangle with a wooden board triangle commonly found in school mathematics departments. Have both triangles available, or if necessary construct them from cardboard. Get a member of the class to use the triangles and act out the movements involved in the problem. From a discussion of this have the class determine the angles of elevation at points A and B and develop a static diagram (Figure 1) that models the problem and shows the given information.

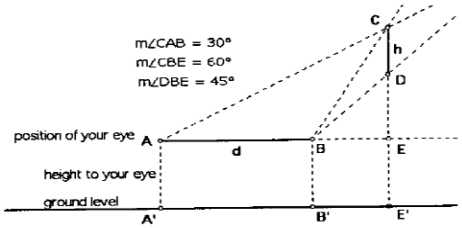

Figure 1. Diagram for the flagpole problem

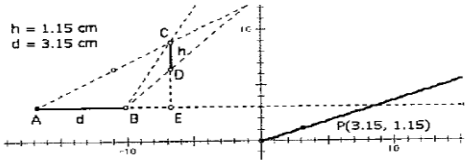

Figure 2. Locus of P(d,h) as B moves on ray AE

Construct a "dynamic" diagram of the static diagram using Geometer's Sketchpad or Cabri, fixing the angles. Use it to show what happens to h and d when point B is dragged along ray AE. Measure h and d, plot as a point P(d,h), and construct the locus of this point as point B moves along ray AE. The resulting graph (see Figure 2) appears to be a straight line passing through the origin, which suggests that the relationship between the two variables h and d is a linear one of the form $h = kd$.

Now have the students use their CAS to verify this conjecture with algebra. With DE = g and BE = f, they use the fact that Δ CAE and Δ CBE are right triangles to formulate and enter these equations into their CAS, in this case a TI-89 calculator.

$$\frac{h+g}{d+f} = tan\,30^\circ \qquad \frac{h+g}{f} = tan\,60^\circ \qquad \frac{g}{f} = tan\,45^\circ$$

From the resulting output (shown below) the students see that the exact value of each tangent has been assigned and that the CAS has changed the order of the variables from what was entered. These differences between conventional written forms and the forms produced by CAS need to be discussed – this is well recognized to be a feature of CAS that puzzles students.

$$\frac{g+h}{d+f} = \frac{\sqrt{3}}{3} \qquad \frac{g+h}{f} = \sqrt{3} \qquad \frac{g}{f} = 1$$

Students now use CAS to solve the first two equations knowing, from the third equation that $g = f$. For example, to solve the first equation for f they could enter:

solve((g + h)/(d + f) = $\sqrt{3}/3$, f) | g = f

Solving in this manner gives $f = \frac{d(\sqrt{3}+1)-h(\sqrt{3}+3)}{2}$ *and* $f = \frac{h(\sqrt{3}+1)}{2}$. Again using CAS students solve the equation that results from equating the right hand sides of these equations for h, and obtain $h = \frac{d(\sqrt{3}-1)}{2}$. This verifies the conjecture, which had been empirically obtained from the geometry and graph, that there is a linear relationship between h and d with $k = \frac{\sqrt{3}-1}{2}$. This result suggests that when the three angles of elevation are known, the value of h can be determined from the value of d by multiplying it by a number whose value is linked to and determined by the known angles. In order to see this more clearly have the students consider the general case of three angles which fit the constraints of the problem. This time they enter these equations in their CAS.

$$\frac{h+g}{d+f} = a \qquad \frac{h+g}{f} = b \qquad \frac{g}{f} = c$$

They solve for h, but in a different way to that done previously, by entering

solve((h + g)/(d + f) =a and (h + g)/f = b, h) | g = c*f

to obtain $h = \frac{-a(b-c)d}{a-b}$. They now know that for any three angles of elevation where a = tan∠ CAB, b = tan∠ CBE and c = tan∠ DBE with $a < c < b$ that $h = kd$ with $k = \frac{-a(b-c)}{a-b}$. Students should use CAS to find h when $a = \sqrt{3}/3$, $b = \sqrt{3}$ and $c = 1$ and confirm that this general equation gives the same equation previously obtained when the angles were 30°, 60° and 45°. To get a result for h in terms of the three angles of elevation θ1, θ2 and θ3 students enter:

h = (– a(b – c)*d)/(a – b) | a = tan θ1 and b = tan θ2 and c = tan θ3

This produces $h = \frac{-d\sin(\theta 1)(\cos(\theta 2)\sin(\theta 3)-\sin(\theta 2)\cos(\theta 3))}{(\cos(\theta 1)\sin(\theta 2)-\sin(\theta 1)\cos(\theta 2))}$, a valid but most surprising result when students would expect the solution to include tans. Perhaps in some instances things are better done without CAS! This offers another opportunity for useful discussion about algebraic equivalence and an opportunity to develop students' 'algebraic insight' (Pierce & Stacey, 2001). Without CAS, this problem could probably only be solved for specific numerical instances in Years 9 and 10. With CAS, it is possible to see the generality of the result – the width of the flag (CD) is a multiple of the distance between the two sighting points (AB). The dynamic geometry program has been used to make the link between the spatial problem and numerical answers and to provide the conjecture which motivates the algebraic problem solving.

Finally, it is instructive for students to also solve the same general case above in a different way by using Cartesian geometry and the equations of straight lines. They need to link the tangent of an angle to the gradient of a line and consider a line not passing through the origin as a translation of a line passing through the origin. Placing the origin of a set of axes at the point A in Figure 1 gives the equations of the lines AC, BC and BD as

$$y = ax \qquad y = b(x-d) \qquad y = c(x-d)$$

The problem can now be solved by finding the point of intersection AC and BC, then using the x-coordinate of this point to find the y-coordinate of the third point D, all done by manipulation of equations using CAS. The new dynamic Euclidean geometry packages are also being linked more strongly to Cartesian geometry, and it is even possible to drag the diagram in Figure 1 onto a set of Cartesian axes and have the software identify the equations in a specific instance. Making use of CAS to expand algebra is both an incentive and enabler for finding and using a variety of approaches to solve problems.

Appendix B

Research Questionnaire 2011

Please put a cross in the box (if answering by hand) or **highlight in red** (if answering on computer) the box for the answer you think most appropriate. Include the written answers in the spaces provided for the following questions:

Section A

1. Do you have access to computers? Please indicate [School] [Home] [Both]

2. How often do you use a computer for your personal use? [Always] [Sometimes] [Never]

3. Do you have a computer lab/ room in your school? [Yes] [No]

4. If yes, how often do you use the lab and for what purpose? ……..

…….

……

5. In case of technical problems with a computer (in the lab), how fast are the repairs done and by whom?

[Fast] [Slowly] [Never] By whom ……

6. Does the curriculum (i) mandate or (ii) encourage the use of computers/ laptops to teach mathematics?

[(i)] [(ii)] [Both] [Not sure]

7. On your school time-table, is there a period for teaching mathematics using computers?

If yes, how many times per week? ……..

Section B

1. Have you attended any course(s) at the university/ college/ anywhere on using computers?

Yes No

2. If yes, was the course useful in your teaching, lesson preparation and presentation of mathematics?

Explain:

……

……..

……

3. Do you think you need additional ICT skills to help you use computers in teaching mathematics?

Yes No

(a) If yes, which skills do you think you need? …….

……

(b)If no, why don't you think you need skills? …….

……

4. Do you get any help from your colleagues on how to use computers to teach mathematics?

Yes No

Section C

1. Do you think computers can be used as effective mathematics teaching tools?

Yes No

(a) If yes, why? …….....

……

(b) If no, why do you say so? …….

……..

2. Underline any of the following technological materials that you use in your mathematics classroom: a printer, overhead projectors, external speakers, scanners, probes sensors, power point, none.

3. Are you aware of mathematics teaching and learning software programmes available from your computer/ laptop and the internet?

(a) computer Yes No

(b) Internet Yes No

4. If yes, which ones do you use in your mathematics teaching? ……..

……..

5. On your school time-table, is there a period for teaching mathematics using computers?

Yes No If yes, how many times per week? ……..

Section D

Please **highlight in red** the appropriate response

i. Your age range	20-29	30-39	40-49	50-above
ii. Your previous experience in teaching mathematics without using computers	1-5 years	6-10 years	11-15 years	16 years and above
iii. Your experience in teaching mathematics with computers	none	1-5 years	6-10 years	11 years and above
iv. Level of education as a teacher	certificate	diploma	degree	post graduate

THANK YOUR FOR TAKING YOUR TIME TO FILL THIS QUESTIONNAIRE

Pseudonym: ……

School name: ……..

Cell No. or Email: ……..

Appendix C:

Interview Schedule

As a mathematics teacher, could you answer the following questions:

(a) Tell me about the advantages or opportunities of using computers in your school for teaching mathematics

(b) What barriers/ problems or challenges do you face when you or learners are using the computers for teaching/ learning mathematics at your school?

[Prompt- State why you think there are barriers at your school for integrating computers into the mathematics classrooms]

Appendix D:

Consent and Confidentiality- participants

Briefing guidelines for Teachers

Introduction

My name is PolokoanaPolokoana and I am completing my Masters Degree in Education at the University of the Witwatersrand and as such I am conducting a study on teachers' perspectives on challenges and opportunities of computer integration into mathematics classrooms at GET and FET phases.

Participation

As a mathematics teacher, you do not have to participate. Your participation is totally voluntary. Interviews will be conducted which will be audio-taped and transcribed. The research will require you to offer your opinions, feelings, experiences and perceptions about computer integration into mathematics classrooms. You can refuse to answer any question or offer any information at any point in the research process. This study will be conducted after school hours, at a convenient time and place for you.

Benefits

Firstly, research findings will be used in my M.Ed. Research Report. Your participation and input could help with future planning on computers use in mathematics education.

There are no risks involved for the participants.

Confidentiality

Any information that you exchange in this research is confidential. To ensure confidentiality, no identifying information about you will be recorded in the research findings. Pseudonyms will be used for the participants. Research records will only be used for the purposes of this study and for the writing up of my M.Ed. Research Report. These will be destroyed after I have completed my report and the examinations have been published.

Concerns

If you have any questions about this study or your rights as a research participant, you may contact:

- PolokoanaPolokoana on 0737378206
- Professor Margot Berger, School of Education, Wits

Part A: Consent from the participants

I …….have consented to participate in Polokoana Polokoana's Master of Education studies. I understand that the data collected and analyzed as a result of the research will form part of the main body of his Master's Research Report to be submitted to the School of Education at the University of the Witwatersrand. I also understand that his studies will be used for educational purposes. I understand that I will be guaranteed anonymity during the actual research process as well as in the final research report.

By signing this, I consent to the following- [Tick the relevant block/s]:

☐ To be interviewed by the researcher

☐ To be audio-taped by the researcher

I expect to be given a copy of this consent form to keep.

……. ……..

Participant's signature Date

……. ……..

Researcher's signature Date

Part B: Guarantee of Confidentiality

I, Polokoana Edward Polokoana, hereby guarantee anonymity and confidentiality to.....

in his / her participation in my Master of Education research.

Confidentiality will be guaranteed both, during and after the research process as well as in the final research report.

……. …….

Participant's signature Date

……. …….

Researcher's signature Date

Appendix E

Portion of Transcription from Group Interviews

Researcher:like I said I am looking at how technology can be integrated into our teaching of mathematics at GET
phase and FET phase so there are two parts that we are looking at; opportunities and challenges. Challenges such that there can negative or positive challenges or what can be noticed as the problems. I would like us to start with the opportunities that you can come across in your teaching, that is may be you have used computers at your school or that you anticipate should happen in the using of computers as a tool for teaching mathematics. I would just like to hear from everyone of you and I shall be taking the voice.

Julius:I think in terms of what we have we are very lucky than most. My classroom has got a smart set up with
a dedicated computer for the whole classroom. We have got a wireless everywhere and the kids do have their laptops that they bring in or anything that can be used to pick up lesson notes and they can drop on other school's internet,they can do research inside the classroom if they want to.I email my my lessons at the end of each lesson from the smart board directory so all the kids in my classroom have my email address, the kids then can respond my email so we can communicate any time, they can submit assignments electronically that we can mark electronically, also I mark workflows of exams, attendance registers; this is done digitally online and I can do them from home or from school so we actually very very lucky <*inaudible*>everything I have, my entire teaching for ten years has been on my laptop, if they want to come and see my files my HOD will have some left on my laptop,I don't have a paper based file anymore, so everything in me has a voice, everything that I have done I can scan (inaudible)

Researcher: Ok, in terms of the…,is there any way of comparing that the use of these computers has done much impact on the learner's ability to do math better on…

Julius

The kids are so technologically enabled, I mean, every one of them has some kind of digital devices and cell phones and for them it's such a second age for them to do things electronically

I: So let's get the input from others about the opportunities of using computers for teaching mathematics

Khalala: Sometimes the opportunities that I can cite are when we use computers for teaching it becomes faster sometimes there are opportunities for the manners for whatever the lesson you have done is easily stored or saved for the manners of the data usage so I think it's one of the things that is also giving the opportunity to the learners and also to myself

I: Mmh, ok

Pite: May also make learners able to computerize what they're talking about like when I use the (*inaudible)*

Researcher: In other words the technology makes them to understand more?

Pite: Mmh, yah

Researcher: Ok I get that, I understand. Any other one opportunity that you've seen with technology

Julius: (*inaudible)*

Anonymous: And I think the other opportunity will be I mean children cannot lose work anymore if they are technologically advanced I mean if the teacher is absent they won't lose anything coz the teacher can send them whatever is necessary for them to learn even if the teacher is caught up somewhere maybe doing some research or whatever it is that the teacher can do in his absence and then they can carry on with whatever is required for them. So I think technology makes it easy to finish the syllabus on time and have enough practice as my other colleagues have alluded

Researcher: So in other words you can communicate in this school, even if you are not at school but you can communicate with them and they can do work

Anonymous: Yes so absenteeism is no longer in reach

I: Now let me change to the challenges coz infect there should be challenges that you meet on the way, the barriers or the problems that you come across as far as integration of computers is concerned. What challenges have you come across so far?

Pite: No computers at our school and no technician or there is one (*inaudible)* and there are two computers working and the rest

Researcher: So in other words if there is a technical problem with the computers it is not easy to repair them so that work can go on. That's a problem

Khalala: And the issue of lack of mathematical software's

Researcher: Ya!Lack of mathematical softwares

TEACHER B: And teachers are not competent enough to work on (*inaudible)*

Researcher: Oh the teacher's competency

Anonymous: But I don't think only teachers I think if also the management. At my school we've got more than 100 computers but as a math department we're not using them, we're not accessing them; we're not allowed to use them. So there's a I don't know, a certain line set that a…I met such a big school where we've got learning areas like electrical technology that give a chance to do some other things on the computers. We've got CAT, we've got IT. And so those people are given preferences with all the computers that are in the school. They are only used, the labs are only used by the CAT people and the IT people mostly and the electrical technologies mechanical technology peoples not the math people.

Researcher: Ok, that is a problem

Khalala: Another challenge is, maybe it is linked to the previous one. The time tables for these computer labs. You will find that the management is not willing to sit down to make a time table, a complete time table for accessing the lab. And also when I'm looking at the… because the lab that we have is sponsored by (*inaudible)* and for you to put any software on it, you have to apply to them first. First they are the ones to restore that software. And if the person who is put in charge for the computer lab does not understand what you have, they will not even apply for that. Then you will find that the computers are there but you don't have specific time to go to them. There is no software in those computers, what you will find are those lessons on the internet that are of a very low level. Sometimes you will have to access the internet for you to get the mathematics. If there is no internet that day you can't get the internet, whereas if the software were there you would have the internet anytime if there is electricity at school and you will have mathematical lessons.

Anonymous: *(inaudible)* it's very bad, like we have a lab, it's not used because the computers are always out of order and no one is responsible for fixing the Gauteng online computers. One time they send a certain guy to be there as their consultant, but the problem is the consultant at the place of work cannot do anything if they are not fixing the computers digitally. So he was there for the whole year but it's like the whole year the computers have not been used.

Julius: (inaudible)

Researcher: I know at school you may find that we are five or six or seven math teachers, what about helping each other by the use of the software or any other things, how to teach mathematics using a computer. Is there such link at school?

Pite: Yes at my school we don't have a problem we had a math department and we don't have a problem. If anyone has something new that person will share with everyone.

Researcher: Basically using a computer?

Pite: Yes

Frans (Mosikili): In my case the problem is people are not willing especially; they have a work shop and we have been expecting teachers from department of science including those ones doing mathematics but the number of people who attended there was disappointing. So seemingly there is no interest from the level of the teachers to use the software that are available in school for teaching manners. One could just say although there are some of the things the little thing will be there is no interest in the computerizing them. That is one cannot know it is not per say the lack of the training because training was about to be given free of charge but people were not willing to attend that particular training.

Researcher: The other thing that I would like to ask is that the technology is changing very fast. The computer that I am using now in a year's time is outdated and it is not easy that I can find parts for it, so is there such a thing that you come across where find out there is a computer here in the classroom and is from Gauteng online probably but now it's going though the year and I am not using it then what is going to happen next year because that one will be outdated, I need a new computer, can you foresee something of that nature?