Teachers' perceptions of spreadsheet algebra programs as curriculum materials for high school mathematics in Namibia

By

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Licentiate in Education & BEd (Honours)

Thesis presented in partial fulfilment of the requirements for the degree of Master of Education in Curriculum Studies (Mathematics Education)

At

STELLENBOSCH UNIVERSITY

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DECEMBER 2012

DECLARATION

By submitting this thesis I declare that the entirety of the work contained therein is my own original work, that I am the authorship owner thereof (unless to the extent explicitly stated) and that I have not previously submitted it, in its entirety or in part, for obtaining any qualification.

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Date: December 2012

ABSTRACT

The use of information and communications technologies (ICTs) in the form of spreadsheet algebra programmes (SAPs) is important in the professional development of high school mathematics teachers. This is in line with The Namibian government's *Vision 2030* in which ICT skills and competencies are regarded as core elements of living and participating in the 21st century. ICTs are also considered to be fundamental to the development of a dynamic knowledge-based economy (KBE) through the Education and Training Sector Improvement Program (ETSIP). ETSIP's aim is to embed ICT at all levels of the education system. It also aims to integrate the use of ICTs as tools in the delivery of curriculum and learning and in so doing, lead to a marked improvement in the quality of the learning and teaching process across all levels. Education has a key role in achieving *Vision 2030*. The aim of this research was to investigate mathematics teachers' perceptions of SAPs as curriculum materials in selected Namibian secondary (high) schools.

This research adopted a qualitative methodology, which in this instance was a case study. The sample population consisted of five teachers from Okamu (pseudonym) secondary school in the Ohangwena Region of Namibia. Four of them had been teaching mathematics at different levels in the mentioned school for a period of four years, and one of them was teaching physical science. Three methods of data collection were used. The first two were semi-structured interviews and focus group interviews based on teachers' experiences using SAPs. The third method was an audio taped observation of a lesson taught by one of the teachers,.

This research provides evidence about teachers' perceptions regarding time concerns and constraints with regards to the SAPs and the use of the SAPs. The teachers showed willingness and enthusiasm to use SAPs on linear and quadratic functions in their teaching. Some of the teachers became more aware of the epistemic dimensions associated with mathematical and algebraic symbols. Interview data reveal that the teachers had not considered these dimensions when teaching with the usual paper-and-pen format. The research also provides evidence of a teacher's early vision about the use of spreadsheets as an instrument to teach linear functions. This teacher did not consider any epistemic value for the instrumented spreadsheets techniques, or that they might contribute to a deeper understanding of the linear functions. His concern

was focused more on getting the learners to acquire computer skills, such as learning how to use spreadsheets.

It is recommended that in-service professional development about ICT integration into mathematics teaching be offered. This might help teachers to learn how their knowledge and skills could be used in the classroom more effectively in order to save time. It is also suggested that professional development programmes be designed to stimulate and promote teachers' willingness to develop an understanding of the characteristics of ICTs such as SAPs and their uses. Lastly, it is recommended that new SAPs be designed in order to deepen the understanding of algebra at the secondary level.

OPSOMMING

Die gebruik van inligting- en kommunikasietegnologieë (IKT's) in die vorm van sigblad-algebra-programme (SAP's) is belangrik vir die professionele ontwikkeling van hoërskoolwiskunde-onderwysers. Dit is in pas met die Namibiese regering se visie vir 2030, *Vision 2030*, waarin IKT-vaardighede en -bevoegdhede beskou word as kernelemente van die lewe in en deelname aan die 21ste eeu. IKT's word ook beskou as grondliggend aan die ontwikkeling van ’n dinamiese kennisekonomie (KE) deur middel van die Verbeteringsprogram vir die Onderwys- en Opleidingsektore (ETSIP). ETSIP het as oogmerk om IKT op alle vlakke van die onderwysstelsel vas te lê. Dit het ook ten doel om die gebruik van IKT's as hulpmiddele te integreer in die lewering van kurrikulum en leer en sodoende ’n duidelike verbetering in die gehalte van die onderrig-en-leerproses oor alle vlakke heen tot gevolg te hê. Onderwys het ’n sleutelrol te speel by die bereiking van *Vision 2030*. Die doel van hierdie navorsing was om wiskundeonderwysers se persepsies van SAP's as kurrikulummateriaal in geselekteerde Namibiese sekondêre (hoër-) skole te ondersoek.

Hierdie navorsing het ’n kwalitatiewe metode gevolg, in hierdie geval ’n gevallestudie. Die proefgroep het bestaan uit vyf onderwysers van die sekondêre skool Okamu (skuilnaam) in die Ohangwena-streek van Namibië. Vier van hulle het reeds vier jaar lank wiskunde op verskillende vlakke in die betrokke skool gegee en een van hulle het fisiese wetenskap gegee. Drie metodes is ingespan om data in te samel. Die eerste twee was semigestruktureerde onderhoude en fokusgroeponderhoude gebaseer op onderwysers se ervaringe ten opsigte van die gebruik van SAP's. Die derde metode was ’n klankopname van ’n waarnemingsessie van ’n les wat deur een van die onderwysers gegee is.

Hierdie navorsing getuig van onderwysers se persepsies ten opsigte van tydskwessies en -beperkinge met betrekking tot die SAP's en die gebruik van die SAP's. Die onderwysers het ’n gewilligheid en geesdrif geopenbaar om by lineêre en kwadratiese funksies SAP's in hul onderrig te gebruik. Party onderwysers het meer bewus geraak van die epistemiese dimensies in verband met wiskundige en algebraïese simbole. Onderhouddata onthul dat die onderwysers nie hierdie dimensies in ag geneem het toe hulle met die gewone papier-en-pen-formaat klasgegee het nie. Die navorsing bevestig ook ’n onderwyser se aanvanklike insig oor die gebruik van sigblaaie as ’n

instrument om lineêre funksies te onderrig. Hierdie onderwyser het nie die epistemiese waarde vir die geïnstrumenteerde sigbladtegnieke in ag geneem nie, of dat hulle sou kon bydra tot ’n grondiger begrip van die lineêre funksies nie. Sy belangstelling was eerder daarop gefokus om die leerders sover te kry om rekenaarvaardighede, soos om sigblaaie te kan gebruik, te verwerf.

Daar word aanbeveel dat indiens- professionele ontwikkeling oor IKT-integrasie in wiskundeonderrig aangebied word. Dit sal onderwysers moontlik help om te leer hoe hulle kennis en vaardighede meer doeltreffend in die klaskamer gebruik kan word om tyd te bespaar. Daar word ook voorgestel dat professionele ontwikkelingsprogramme ontwerp word, ter stimulering en bevordering van onderwysers se bereidwilligheid om ’n begrip te ontwikkel van die kenmerke en gebruike van IKT's soos SAP's. Laastens word daar aanbeveel dat nuwe SAP's ontwerp word om die verstaan van algebra op sekondêre vlak te verdiep.

ACKNOWLEDGEMENTS

I would like to thank my supervisor Doctor Faaiz Gierdien for his assistance, support and critical comments during the process of writing my thesis. Without his guidance this study would never have reached completion.

I wish to express my thanks to Professor Reddy, chairperson of Curriculum Studies, for his moral support during the daunting time it took me to complete my research. To Professor Yusef Waghid, Dean of the Education Faculty of Stellenbosch University, thank you very much for your eminent inspiration. I owe my deepest gratitude to the Research Unit for Mathematics Education, University of Stellenbosch (RUMEUS), especially to Mr Alwyn Oliver, the director of RUMEUS for allowing me to use some of the spreadsheet algebra programs in my study. A special word of thanks goes to the teachers who participated in my study. This study would not have been possible without your involvement. Thank you. You made my research become a very valuable project and a privilege, something which I should have undertaken long ago. I am grateful to the Principal of the school and the Director of Education where I conducted my study. Their hospitality and helpfulness is very much appreciated. Finally, I would like to thank my family especially my brothers Carlo, Emilio and my daughters Wendy and Lopez for their emotional support during my study.

DECLARATION ii

ABSTRACT iii

OPSOMMING iv

ACKNOWLEDGEMENTS v

TABLE OF CONTENTS vi

LIST OF ACRONYMS USED……………………………………………………….xii

Table of Contents

CHAPTER 1 1

1.1 Introduction 1

1.2 Problem statement 1

1.3 Research question 2

How do Namibian high school teachers perceive spreadsheet algebra programs as curriculum materials? 2

1.4 Research aims and objectives 2

1.5 Research motivation 3

1.6 Background to the area of the study 3

1.7 ICT within the context of education in Namibia 4

1.8 ICT use in Namibia's education system with specific reference to school mathematics at secondary level 6

1.9 Research methodology 7

1.10 Thesis outline 8

CHAPTER 2 10

LITERATURE REVIEW 10

In this chapter there is a literature review related to the research question, "How do Namibian high school teachers percieve spreadsheet algebra programs as curriculum materials?" 10

2.1 Introduction 10

2.2 Perception as a concept and how it relates to ICT integration 11

2.3 Teachers' professional development (TPD) 12

2.3.1 Necessity and importance of TPD 13

2.3.2 Mathematics teachers' professional development in relation to ICT 14

2.3.3 State of TPD in Namibia 14

2.3.4 Teacher professional development (TPD) and ICT 15

2.4 Barriers to integration of ICT in education 16

2.5 Designing professional development programmes for teachers 18

2.6 Role of curriculum materials in TPD and teachers' instructional practices 20

2.6.1 Spreadsheet algebra programs as curriculum materials 23

2.7 ICT-based didactic objects in teachers' professional development 24

2.8 ICT tools in mathematics teaching 25

2.9 Spreadsheet algebra programs as a tool in secondary school mathematics: pragmatic and epistemic values 26

2.9.1 Spreadsheets use in the case of the secondary school algebra 27

2.10 Summary 28

CHAPTER 3 30

RESEARCH DESIGN AND METHODOLOGY 30

3.1 Introduction 30

3.2 Research goal 30

3.3 The chosen paradigm 30

3.4 Research methods 32

3.5 Sampling 32

3.6 Data collection methods 33

3.6.1 Semi-structured interviews 34

3.6.2 Focus group interviews 35

3.6.3 Observation of a teacher using his own spreadsheet algebra program 36

3.7 Research design instruments 36

3.8 Ethical considerations 37

3.9 Description of the spreadsheet algebra programs (SAPs) used in this study 38

3.9.1 Activity 1 (case 1) 38

Using SAP to explore equivalence 38

3.9.2 Activity 2 (case 2) 39

Using SAP on the discriminant of a quadratic function (DoQF). 39

3.9.3 Activity 3 (case 3) 41

A teacher demonstrating the plotting of a linear function using spreadsheets. 41

3.10 Summary of data generation from the various appendices: 43

3.11 Summary 44

CHAPTER 4 45

DATA ANALYSIS AND FINDINGS 45

4.1 Introduction 45

Case 1: The teachers' perceptions with regards to SAPs were influenced by *time concerns and constraints* 46

Case 2: Teachers' showed a willingness to use SAPs on linear and quadratic functions in the classroom; this willingness had pragmatic and epistemic dimensions. 46

Case 3: In a particular instance, a teacher perceived spreadsheets as useful as a curriculum material and used it to teach linear functions to his grade 11 leaners. 46

4.2 Case analysis 48

4.2.1 Case 1 48

The teachers’ perceptions with regards to the SAPs were influenced by *time concerns and constraints.* 48

4.2.2 Case 2 51

4.2.3 Case 3 59

4.3 Summary 67

CHAPTER 5 69

CONCLUSIONS AND RECOMENDATIONS 69

5.1 Introduction 69

5.4 Reflection and future research 73

5.4.1 Self- reflection 73

Why the use of spreadsheets or SAPs in school mathematics teaching? 73

5.4.2 Future research 75

REFERENCES 77

APPENDICES 94

Appendix A 94

Appendix B 95

Appendix C 96

Appendix D 102

Appendix E 105

Appendix F 106

Appendix G 108

Appendix H 109

Appendix I 110

LIST OF ACRONYMS USED

BECTA	British Educational Communication and Technology Agency
BETD	Basic Education Teachers' Diploma
B.ED	Bachelor of Education degree
CAS	Computer Algebra Systems
CERME	Congress of the European Society for Research in Mathematics Education
CPD	Continuing Professional Development
DoGF	Discriminant of the Quadratic Function
DO	Didactic Object
ETSIP	Education and Training Sector and Improvement Programme
ICDL	International Computer Driving License
ICT	Information and Communication Technology
IMTE	Integrated Media in Technology Education
IMTE	Integrated Methods of Technology Education
KBE	Knowledge-base Economy
LF	Linear Function
MAS	Mathematics Analysis Software
MICTSC	Ministry's ICT Steering Committee
MoE	Ministry of Education
NIED	National Institute of Educational Development
NCTM	National Council of Teacher of Mathematics
PoN	Polytechnic of Namibia
PGDE	Postgraduate Diploma in Education
PLGs	Professional Learning Groups
RUMEUS	Research Unit for Mathematics Education, University of Stellenbosch
SAPs	Spreadsheet Algebra Programs
TIs	Time Issues

TPD	Teachers’ Professional Development
TPs	Teacher Perceptions
UNAM	University of Namibia

CHAPTER 1

1.1 Introduction

Worldwide research has shown that Information and Communication Technology (ICT) can lead to improved student learning and better teaching methods (National Council of Teachers of Mathematics (NCTM), 2000). Increasing student exposure to educational ICTs through curriculum integration could have a significant and positive impact on their achievements in all subject areas including mathematics, science and social studies (Hew & Brush, 2007). This study focused on the potential of ICTs used in mathematics teachers' professional development, specifically using spreadsheets in teaching and learning high school algebra.

This chapter provides an introduction to the study. It includes the problem statement and context of the study, the research question, and the rationale and purpose of the study. The chapter ends with an overview of the thesis.

1.2 Problem statement

The teaching and learning of algebra in high schools has been identified as a major problem. These difficulties have been highlighted in several studies. For example, Herscovics and Linchevski (1994) approached the problem in terms of the cognitive gap between arithmetic and algebra. Kieran (1991) and Arzarello (1991) similarly approached the problem in terms of the dialectic between procedural and relational thought. Fischbein and Barash (1993) centred their attention on the significance of errors made by students learning algebra. Kieran (1992), Sfard (1991), and Sfard and Linchevski (1994) highlighted the important sources of students' difficulties with the introduction to algebra. These studies revealed that the students often seemed to have a limited view of algebraic expressions; their notions of the solution of algebraic equations seemed to be associated more with the procedure of the solution process rather than the numerical solution obtained; and they failed to understand the meaning of the operations to be performed on the literal symbols, the algebraic expressions or the equations. Conventional methods of teaching, such as the “pen-and-paper” method, yield limited results in stimulating student interest and enhancing their understanding. This has been partly attributed to the lack of visuals (which improve the retentive memory of learners), the difficulty on the part of educators in explaining complex instructions, and a lack of interactive classes that make the learning process enjoyable. It is proposed that ICTs may address these deficiencies in education.

Whilst ICTs do exist in Namibian schools they are not integrated into the school curriculum to enhance teaching, even in subject areas such mathematics, where they have been proved to make the teaching process more effective as well as improve the students’ understanding of the basic concepts of mathematics (Ittigson & Zewe, 2003). High school teachers underutilise the potential of ICTs such as *Microsoft Excel* spreadsheets as a medium to foster algebra learning and teaching. In schools, both teachers and learners mainly use computers for non-academic activities and purposes. This study investigated teachers’ perceptions of spreadsheets as curriculum materials for secondary (high) school mathematics, specifically algebra.

1.3 Research question

How do Namibian high school teachers perceive spreadsheet algebra programs as curriculum materials?

1.4 Research aims and objectives

This study investigates teachers’ perceptions of spreadsheet-based algebra programs as curriculum materials in high school mathematics.

1.5 Research motivation

The decision to focus this research on spreadsheets used in relation to algebra in the high school mathematics curriculum was motivated by the fact that almost all schools in Namibia are equipped with computers and Microsoft Excel (which uses spredsheets). Thus, there is a potential opportunity for the use of spreadsheets. Leung (2006) reported that for many countries the problem is not in the access to ICT tools, but in their actual use in mathematics teaching and learning. Cuban (2001: 97) described ICT used in Californian classrooms as “oversold and underused” and reported that teachers made infrequent and limited use of computers in the classroom. This scenario prevailed despite abundant access to ICT, and contradicted the expectations of promoters (Cuban, 2001).

Another important reason for this study was to make a contribution towards the limited literature surrounding this topic, specifically in the case of Namibia. Namibia, like other developing countries, is challenged by a lack of qualified personnel to lead the promotion of ICT, especially in mathematics education. It is hoped that this research will help in some way to improve and address this problem. In addition, this study has the potential to contribute to teachers’ involvement in curriculum decision-making in order to consider ways that spreadsheet-based programs might support algebra teaching.

1.6 Background to the area of the study

Okamu (pseudonym) is a village named after a much-respected bird in the north of Namibia. The village is situated in the Ohangwena Region approximately 700 km north of Windhoek, the capital city of Namibia. Oshikwayama is the main local language that is widely spoken in the region. Communities in this region mainly survive on agricultural means and livestock. Their main crops are omahangu and beans. They also sell traditional beer, meat and other foodstuffs to generate income.

Some of the foodstuffs are well liked and are used during traditional ceremonies and political celebrations.

The school in this study inherited its name from the village of Okamu. The local children from the surrounding areas attend the school. Okamu Secondary School is the cluster center of six schools in the area. The school is at a crossroads that connects surrounding towns; namely Ondangwa, Ohangwena, Oshikango, Eenhana and Olunho. The school has hostel facilities that accommodate around 85% of the learners, which has resulted in an increased influx from other areas. Only 15% of the learners are from the local area. The school has a teaching staff of 25 teachers of which five teach mathematics. In 2010, a new non-promotional subject, Information and Communications Technology Literacy Foundation Level and Computing Fundamentals was introduced in the Namibian curriculum. This non-promotional subject in the upper primary and secondary grades should be assessed through informal continuous assessment methods. This was in line with the Education Training Sector and Improvement Programme (ETSIP, 2007), an initiative from the Namibian Ministry of Education aimed at introducing ICT into all levels of education.

1.7 ICT within the context of education in Namibia

The Namibian Government clearly and positively identified in *Vision 2030* that ICT skills and competencies are to be regarded as core elements of living and participating in the 21st century, and for the development of a dynamic knowledge-based economy (KBE). Recognising the role that education can play in developing technological skills, the Namibian Ministry of Education (MoE) developed a 15 year Education Training Sector and Improvement Programme (ETSIP), aimed at embedding ICT in all levels of the education system and thereby enhancing the quality of teaching and learning in schools.

In order to make ICT an integral part of education, the Ministry of Education through the National Institute for Educational Development (NIED) developed a national Policy for ICT in Education (MoE , 2007a: 6). In 2003 the Ministry's ICT Steering Committee (MICTSC) was formed to coordinate the many ICT initiatives launched in the educational sector (MoE, 2006: 11). The first task performed by the committee was to review and update the policy for ICT in Education (MoE, 2007: 6). The policy was approved by cabinet and adopted in 2005 (MoE, 2006: 37).

The MICTSC developed a detailed implementation plan aimed at translating the Policy for ICT in Education into a cohesive set of interventions embedded within the Education and Training Sector Improvement Programme (ETSIP). In 2008 alone, the MoE was expected to introduce ICT to a minimum of 200 senior schools (MoE, 2006:37).This responsibility entailed providing computers, printers, scanners, televisions and video cassette recorders to schools. Any large-scale initiative requires significant investment, in terms of both financial and human resources that are expended during policy implementation. Questions were bound to arise about the return on such investments once the implementation was underway. National Institute for Educational Development (NIED) has developed a website with very useful resources for teachers. The subject, Integrated Media and Technology Education (IMTE), which includes some ICT literacy, is offered to trainee teachers. Technology-related elective subjects currently offered at school level include Keyboarding, Word Processing and Computer Studies at junior and high school level. At primary school level the non-promotional subject Basic Information Science includes a minor component on ICT literacy. Other initiatives include those of the Polytechnic of Namibia (PoN) and the University of Namibia (UNAM) which offer courses online (ETSIP, 2007).

Despite the achievements to date, Namibia still faces many challenges in realising its policy on integrating and using ICT effectively in the education system and in reducing the digital divide among all communities. Curriculum is one such challenge. Currently there is almost nothing in the curriculum for mathematics at secondary level which addresses the use of ICT as a cross curricular tool. A rigorous review of the curriculum to strengthen opportunities for practical use of ICT is necessary. A developmental framework of ICT skills and competencies at all levels is required as teachers are unclear as to what skills and competencies are needed. In addition, the provision of relevant digital content to support and realise the potential of the revised curriculum for both teachers and students, is essential.

1.8 ICT use in Namibia's education system with specific reference to school mathematics at secondary level

As a whole, we know very little about ICT use in Namibian schools. In a doctoral study titled "Adoption of ICT at Schools in core and Peripheral Settings of Namibia: Exploring Innovation, Technology Policy and Development Issues" Matengu (2006) evaluated, critiqued and developed an understanding of factors involved in the adoption of ICT in schools in Namibia, particularly in Windhoek and Katima Mulilo. He noted that schools were provided with computers on the basis that they did not have them, and cautioned against the assumption that schools with ICT would necessarily use them. He called for a critical review of ICT policy goals and the implementation process. His study also found that the availability of technology infrastructure in schools did not guarantee their usage by learners and teachers. In addition, Katulo (2010) researched the role of school principals on promoting and managing computer usage in selected schools in the Caprivi region in Namibia. The study found that principals were often the initiators of the acquisition of computers. Some schools were more resourced than others. Accessibility and maintenance of equipment depended on the kind of school (advantaged or disadvantaged) and the way the computers were acquired rather than on the role of the principal. The schools that acquired their computers through ministerial distributions received more technical support than the schools that acquired their computers from other sources. School principals that demonstrated the qualities of transformational leadership promoted the usage of computers by taking part in the training offered to teachers.

Another study undertaken in Namibia looked at the integration of ICT in the preparation of teachers at the colleges of education. Iipinge (2010) revealed that whilst teachers expressed interest and willingness to integrate ICT in the teaching situations, there was a lack of infrastructure and digital learning material. ICT was used more in the Integrated Methods of Technology Education (IMTE) and to a lesser extent in mathematics and natural sciences. On the courses offered in the colleges of education, most of the integration activities encouraged practices related to the common Microsoft office (MS office) program.

1.9 Research methodology

This research was oriented by an interpretivist paradigm for the following reasons:

1. Firstly, teachers' perceptions of curriculum materials such as spreadsheet-based programs are important; this is because such programs can influence their teaching in the case of secondary school algebra.

2. Secondly, using a medium such as spreadsheets programs in algebra at secondary school level has potential in terms of algebra learning. Haspekian (2005) discussed these potentialities.

3. The interpretivist paradigm makes it possible to gauge the teachers' perceptions in the case of interventions and conversations around spreadsheet algebra programs.

Throughout the study I sought to interpret the meaning, understanding and experiences of mathematics teachers using spreadsheets as an alternative medium to improve school algebra teaching and learning. Qualitative research is interpretive, focusing on gaining meaning and understanding and building concepts and theories. It does so through the intuition of the researcher, who works to become an insider (Miles & Huberman, 1994). Qualitative researchers gather detail through multiple, usually interactive methods, identifying and systematically reflecting on their role in the inquiry and acknowledging and accommodating personal biases, values and interests (Creswell, 2003). This was a qualitative study that adhered to a constructivist paradigm (Mertens, 2005: 15). The basic assumptions guiding the constructivist paradigm are that people active in the research process socially construct knowledge and that the researcher should attempt to understand a case from a point of view of those who live it (Schwandt, 2001).

This study used a case study design (Yin, 1994: 13) and attempted to understand and describe in depth the challenges and opportunities that spreadsheet algebra programs (SAPs) could bring to Namibian high schools. In educational research, case studies are examples of qualitative research methods. Yin (1994: 13) defines a case study as an "empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundary between phenomenon and context are not clearly evident".

A set of spreadsheet-based algebra activities and programs were used as a medium and material means to interact with the mathematics teachers selected for the study. The aim of the spreadsheet-based activities was not to demonstrate that spreadsheets can be used as better tools in solving algebra problems, but rather to gauge the teachers' perceptions of spreadsheets used as a medium, i.e. as a curriculum material in relation to understanding of school algebra.

There are ethical issues involved in the qualitative methods that were used. Ethics has to do with what is right and what is wrong (Fraenkel & Wallen, 1996; Cohen, Manion & Morrison, 2000). It is the sole responsibility of the researcher to make sure that participants are fully protected by not revealing information that leads to exposure of their identity. According to Fraenkel and Wallen (1996), the most important ethical consideration of all is that the researcher should protect participants from any harm. To ensure that ethics were considered in this research the following was undertaken:

Letters were written to both the Director of Education for the Ohangwena region and the School principal of the secondary school selected for the research, requesting permission to conduct the research within the Ohangwena circuit. In the letters, I indicated the rationale for doing this study, the goals of the research, the target group, the sample size, research site and criteria used in selecting the study sample as well as criteria for selecting interview participants.

1.10 Thesis outline

Chapter one briefly describes the context of the research, the research methodology, the research site, the research aims, possible significance of the study, research question and objectives**.**

In chapter two there will be a review of literature pertinent to the research question. This literature includes teachers' perceptions in relation to spreadsheet-based programs on secondary school algebra; mathematics teachers' professional development; spreadsheet-based algebra programs as curriculum materials; curriculum material as resources; spreadsheet program use in algebra in secondary schools.

Chapter three describes the research design and methodology employed, sampling procedures and analytical framework.

Chapter four includes data collection, presentation and analysis.

Chapter five concludes the findings, knowledge implications for practices, recommendations and limitations, mathematics teacher education and professional development, suggestionsfor future research and a reflection on the research process.

CHAPTER 2

LITERATURE REVIEW

In this chapter there is a literature review related to the research question, “How do Namibian high school teachers percieve spreadsheet algebra programs as curriculum materials?”

The chapter is structured as follows. Firstly, there is a general overview of literature on ICT use and ICT as curriculum material in schools. Secondly, there is a review of some literature on teachers’ perceptions of ICTs and their professional development. Thirdly, literature specific to the professional development of teachers and high school mathematics teachers in the case of spreadsheet algebra programs as curriculum materials is assessed. The research question informs the sequence and logic of the overall literature review.

2.1 Introduction

Over the past twenty years, the idea that ICT can aid in economic and social development has resulted in governments increasing the diffusion of ICT into schools and restructuring the teaching and learning environments (Brockmeier, Sermon & Hope, 2005). However, there are marked disparities in access to computers between the developing and the developed world; and urban and rural schools. In many developed countries the problem is not access, but rather use of ICTs in the classroom. A study in California, United States, found ICTs to be “oversold and underutilised” (Cuban, 2001). In the developing world, urban schools are relatively better endowed with ITCs than rural schools that lack even the basic infrastructure to facilitate ITC access (Herselman, 2003: 945 in Amedzo, 2007). Namibia has invested in programs aimed at diffusing ICT into schools by installing computers in secondary schools (ETSIP, 2007). Significant progress has been made towards providing Namibian schools with ICT infrastructure and teacher support. However, a lot still needs to be done especially within ICT integration into the Namibian school curriculum (ETSIP, 2007). What is apparent is that regardless of the disparities in access across various locations, teachers make irregular use of ICT in classrooms (Cuban, Kirkpatrick & Peck, 2001: 813).

There are several benefits to the use of technology in the mathematics curriculum (Lefebvre, Deaudelin & Loiselle, 2006). These include: (a) making learning more student-centred; (b) giving students the experience of being mathematicians themselves; (c) providing an opportunity for reflection; (d) making available constant access to the instruction, meaning that the instruction is not limited to lesson time (Dawes, 2001; Hartsell, Herron, Fang & Rathod, 2010; Heid, 1997). Use of ICTs in schools is limited (Hennesy, Harrison & Wamakote, 2010) and various explanations have been proposed for this, including lack of qualified personnel to lead the promotion of ICT, especially in mathematics education. It is hypothesised that teachers' perceptions significantly explain the lack of ICT integration in the teaching of algebra, for example, in high school mathematics.

2.2 Perception as a concept and how it relates to ICT integration

Perception is the extraction and use of information about one's environment (exteroception) and one's own body (interoception) (Audi, 1999). There are two different stages in the extraction and use of sensory information; the early stage which corresponds to our perception of objects or events, and the later stage corresponding to the perception of facts about these objects (Audi, 1999). For example, in the early stage teachers' perceive SAPs as instruments that can help them to solve linear or quadratic equations.

Humans attach meaning to their experiences through the cognitive aspect of perception (Eggen & Kauchak, 2001), which largely depends on acquired background knowledge about the object (Glover, Ronning & Bruning, 1990; Adediwura & Tayo, 2007). Background knowledge is a function of experience and determines how people interpret the present and think about the future (Randolph & Blackburn, 1989: 89-91; Becker & Riel, 1999). Present thoughts are therefore interpreted in the light of past experiences, which influence people's past and future thinking. These experiences when put together, form an individual's beliefs that manifest in behaviour as personal values, judgements, opinions, ideologies, conceptions, dispositions, theories, etc.

(Pajares, 1992). This group of beliefs about phenomena form attitudes and later translate into actions. When connected the beliefs constitute one's values which guide action and behaviour (Ajzen, 1985; Bandura, 1986).

Teachers have their own perceptions regarding professional practice, which are central to the successful integration of educational innovations such as ICTs (Fullan, 2001; Bitner & Bitner, 2002; Loveless, DeVoogd & Bohlin, 2001; Zhao & Cziko, 2001). Teachers are thus considered as crucial players in bringing about educational change (Van Driel, Verloop, Inge van Werven, & Dekkers, 1997) as their understanding of mathematics instruction translates into practice through the filter of their perceptions (Cooney, 1994; Ringstaff & Kelley, 2002; Sandholtz, Ringstaff & Dwyer, 1997). Therefore, an exploration of the link between teachers' perceptions and practices presents possibilities as to how teachers can make technology integration adoptions (Chen, 2008). However, teachers may be reluctant to embrace technology integration if the change is perceived to replace their current beliefs and practices (Zhao *et al.*, 2001). Teachers must undergo a complete change of mindset and believe that: technology can help them to accomplish higher level goals (rather than interfere with them) more successfully and; they will have acceptable ability and necessary resources to use technology (Heid, 1997).

Next, we examine the literature about teachers' professional development and its importance. The aim is to connect this research literature to spreadsheet use when it comes to teachers' professional development.

2.3 Teachers' professional development (TPD)

Teachers' professional development is realised through experience and reflective review of their teaching approaches (Glatthorn, 1995: 41). This may be achieved through formal experiences, such as (workshops and mentoring), and informal experiences like (reading and watching relevant television documentaries) as stated in Ganser (2000). Traditional in-service teachers' professional development has been described as "ineffective and sorrowfully inadequate" (Ball, 1996; Darling-Hammond & McLaughlin, 1995; Borko, 2004: 3). In-service training is a common form of professional development. This training is not systematic, but conservative and teacher-centred rather than expert-centred, which has been suggested as being more effective, especially if coupled with teacher participation (Beck, Hart & Kosnik, 2002: 191).

2.3.1 Necessity and importance of TPD

Professional development has a significant impact on teaching methods and student achievement (Ferguson & Ladd, 1996; Wenglinsky, 2000, and Darling-Hammond, 2000). High quality professional learning for teachers improves learner success (Greenwald, Hedges & Laine, 1996; Elmore & Burney, 1997; Hawley & Valli, 1999). Professional development deepens teachers' understanding of academic disciplines and pedagogical principles, and enables them to gain the necessary knowledge to integrate rapidly into changing educational technologies (Ganser, 2000). It is also vital that teachers understand learning methods as this has profound implications on what is taught, how it is taught, and how learning is assessed (Bransford, Brown & Cocking, 2000).

Professional development starts with teachers developing an internal drive towards professionalism (Aichele & Coxford, 1994: 3). However, professional development does not necessarily translate into teacher implementation (Maass, 2011), as the practice of change in day-to-day operations may take years to become permanent (Tirosh & Graeber, 2003).

Implementation of change depends on several factors including teacher practice and beliefs, and the context within which a teacher must make change. Context refers to curriculum implementation, external assessment, school head staff support, students' and parents' reactions to innovation, and the school organisation (Joubert & Sutherland, 2008; Manouchehri & Goodman, 2000). Teachers' instructional practice and their underlying knowledge base have been said to be closely related (Gellert, 2008). Some researchers in mathematics teachers' in-service education view the development of knowledge base, including beliefs as a prerequisite for change in practice (Maher & Alston, 1990; Pajares, 1992; Simon & Schifter, 1991). For others, the relationship is more difficult. They observe how teachers can essentially modify and improve their professional knowledge and beliefs whilst they modify their instructional practices (Franke, Fennema & Carpenter, 1997; Prawat, 1992). Gellert (2003 a) views this relationship as “initiator and follower”, where one teacher tries to put new visions of mathematical rich classroom activities into practice; and others emulate (Becker & Riel, 1999; Mudavanhu, 2006).

2.3.2 Mathematics teachers’ professional development in relation to ICT

The positive role of ICT in mathematics teaching and learning is widely acknowledged (Dawes, 2001: 61). Most teachers, whether experienced or inexperienced, have inadequate understanding and experience of how ICT should be or can be integrated into several educational aspects to support teaching and learning (Ertmer, 2005). Preparation of mathematics teachers must therefore go beyond the “how to use” to “how to integrate” domain (Gimbert & Cristol, 2004: 211). Mathematics teachers differ from other teachers in the sense that their focus must be on applying professional knowledge within a meaningful and relevant mathematical context for learner understanding (Aichele & Coxford, 1994: 3).While the potential of ICT in improving mathematics teaching and learning is widely recognised, this may not be easily realised when teachers are expected to implement changes without sufficient support (Dawes, 2001: 61). Technology is a tool that could be used in the mathematics classroom to enhance learning (NCTM, 2000).

2.3.3 State of TPD in Namibia

In many developing countries most teachers have minimal or no ICT skills themselves and therefore cannot develop them in learners. Most of the professional development efforts have been directed at the four teacher training colleges in Namibia, with the idea that instructors would both use and integrate technology with their students, who upon graduation would go into primary and secondary schools and be able to help their learners to use computers (Burns, 2006). However this has not happened. A study recently conducted in Namibia found that professional development is ineffective, as lecturers at the teacher training colleges have not been trained in ICT and therefore are not in a position to train the teachers (Iipinge, 2010).

Teachers need to be prepared for ICT integration into their teaching by being educated in the use of ICT effectively and creatively. In many developing countries including Namibia however, most teachers have minimal or no ICT skills themselves and therefore cannot develop these in learners (Hennessy, Harrison & Wamakote, 2010). Venezky (2004) found that two of the most important forms of support for ICT integration into teaching and learning are: effective Initial Teacher Education (ITE) related to ICT and Continuing Professional Development (CPD). Both have the greatest impact on the beliefs and practices of teachers. This study considered the actual importance of the use of ICT in mathematics teaching and learning. It showed that teachers' interaction with SAPs can be considered as an example of TPD. Consequently this has contributed towards learners' deeper understanding of the algebra concept, and has integrated traditional mathematics into the technological environment.

2.3.4 Teacher professional development (TPD) and ICT

A broad range of sophisticated ICTs, such as Mathematics Analysis Software (MAS) like scientific calculators, function graphics, Computer Algebra Systems (CAS), lists and spreadsheets, statistical packages and geometry packages are now available to teachers (Pierce & Ball, 2009). Traditionally, using pen-and-paper was the method of doing or teaching mathematics. Given the different choices of technologies available, one could ask what are teachers' perceptions of the transition from the pen-and-paper approach to using technology in the teaching of mathematics.

It can be argued that TPD is necessary for ICT adoption and integration into teaching curricula in schools (Ngololo, 2010). For example, teachers and school managers need to be trained in technological skills that will enable them to perform their duties effectively and efficiently in the advancement of teaching and learning. The educational ICT policy implementation has been reported as comprehensive in many regions worldwide, but teachers need education on the "how to" including specific skills and tasks to use in their everyday classroom practices (Howie, 2010; Kozma, 2008; Matengu, 2006).

The following have been found to be the ingredients for a successful implementation of ICT: (1) review types of activities such as forming teacher networks (Kajander & Mason, 2007); (2) allow sufficient time for each activity; (3) encourage cooperative interaction between teachers from the same school, region or cluster; (4) enable active learning opportunities; (5) introduce context focused teaching strategies and (6) ensure coherence of activity to school goals and standards (Strudler & Hearington, 2008, in Ngololo, 2010)

2.4 Barriers to integration of ICT in education

In most of the African developing countries, including Namibia, there are many challenges to bringing ICT into the education process. Researchers, for example Anderson, (1997) and Hennessy, Harrison and Wamakota, (2010), have recognised a variety of important factors that affect ICT use by teachers. These include lack of reliable access to electricity, limited technology infrastructure (especially internet access, bandwidth, hardware and software provision), language of instruction and available software. Geographical factors such as country size, terrain and communications as well as demographic factors such as population size, density and dispersion have to be considered too.

Due to the importance of ICTs in the future of education it is necessary to identify some of the possible obstacles to its integration, in order to improve quality of teaching and learning. Some studies have categorised barriers into teacher (micro) level such as lack of time, lack of confidence and resistance to change; and school (meso) level such as lack of effective training in solving technical problems and lack of access to resources (BECTA, 2004; Balanskat, Blamire & Kefala, 2006). Balanskat *et al*., (2006) proposed an additional category: the macro level, which are system-level barriers, including those matters associated to the wider educational framework. Barriers also vary from region to region depending on several factors including socio-economic development.

A large body of literature identifies lack of proper teacher training as a major obstacle toward teachers using technology in the classroom (VanFossen, 1999: Williams, Coles, Wilson, Richardson & Tuson, 2000). Pre-service and in-service courses have been shown to improve the likelihood of altering teachers' perspectives and enhancing technology adoption in classroom teaching (Lee & Hollebrands, 2008). Lack of training is closely related to lack of teacher confidence, which has been identified as a key factor inhibiting adoption of ICT for teaching purposes (Dawes, 2001; BECTA, 2004). This lack of confidence has been attributed to fear of failure and lack of knowledge on the part of teachers (Beggs, 2000; Balanskat *et al*., 2006). Educators can be anxious to reveal their shallow knowledge of the application of ICT in front of learners. In a study conducted in Australia, Newhouse (2002) found that many teachers lacked the knowledge and skills to use computers and were not enthusiastic about the changes and integration of supplementary learning associated with bringing computers into their teaching practices. In another study conducted in Scottish schools, Williams *et al.,* (2000) found that a lack of skills in using databases and spreadsheets was seen as a limiting factor by more than 10% of elementary school teachers. This scenario is worse in developing countries where access to ICT is limited (Pelgrum, 2001; Al-Oteawi, 2002). Equipping teachers with indepth knowledge right from the start gives them a wealth of experience and confidence, thus they are more motivated to demonstrate it (Cox, Preston & Cox, 1999 b; Osborne & Hennessy, 2003; Balanskat *et al*., 2006). This culminates in a positive perception of ICT and its values in mathematics teaching; hence, adoption may meet very little resistance (Cox, Preston, & Cox, 1999 b). However, competence to use the computer is one thing, but ability to integrate it into classroom pedagogical practice is another. Therefore teachers also need to be equipped with techniques related to how to integrate ICT into their classroom.

Much of the research conducted on the barriers to integrate ICT into education found that teachers' attitudes and an inherent resistance to change were significant (BECTA, 2004; Cox *et al*., 1999 b; Earle, 2002; Gomes, 2005; Schoepp, 2005; Watson, 1999). Integration of new technologies into an educational setting requires change, and different teachers will handle this change differently depending on their attitudes and beliefs (Watson, 1999). According to Korte and Hüsing (2006), educators who have not adopted new technologies, such as computers, in the classroom are still of the opinion that the use of ICT has unclear or no benefits. Resistance though, is a sign that something is wrong. A study by Schoepp (2005) found that although teachers felt that there was more than enough technology available, they did not believe that they were being technically supported, guided, or rewarded in the integration of technology into their teaching. Teachers who resist change are not rejecting the need for change, but lack the necessary education in accepting the changes and are given insufficient long-term opportunities to make sense of the new technologies for themselves.

The absence of an efficient policy and established planning strategy can also impede teachers' determinations to incorporate computers into the classroom (Cuban, 2000; Morton, 1996). In a critical evaluation of technology adoption in two "high-tech schools" Cuban *et al*., (2001: 830) warn that "... the prevailing assumptions guiding policy on new technologies in schools are deeply inconsistent and in need of re-assessment". The research community needs to provide guidance as to how schools can develop curricular plans and policies that are relevant and sensitive to the issues related to computer integration. The role of school administration extends beyond policy to include leadership within the school. Marcinkiewicz (1996) recommended the need for a perception change within the teachers' professional situation, that computer integration is an expected and necessary component of the job. This perception can be established through modelling the use of computers by administration, colleagues, students and the larger professional community (Coley, Cradler & Engel, 1997; Hannay & Ross, 1997). In addition, researchers have contended that access to reliable and functional computer resources is a key factor in the use of computers for instructional activities (Gilmore, 1995; Jaber & Moore, 1999). Increased access to computers might not be sufficient to promote classroom integration (Marcinkiewicz, 1996). In a survey of 4,083 teachers, Becker, Ravitz, and Wong, (1999) noted that only 5% of upper-elementary, 4% of middle grade and 13% of high-school teachers were currently using computers, despite their increased availability. Another study by Cuban, Kirkpatrick and Peck (2001) provides further evidence that increased access to computers and related resources does not necessarily lead to their more widespread classroom use.

2.5 Designing professional development programmes for teachers

The design of professional development programmes needs to be built on approaches based on teachers' practical knowledge that links both teachers' and learners' academic outcomes (Guskey, 2000). An inquiry-oriented approach to teaching and learning linked to pedagogical practices such as constructivism (von Glasersfeld, 1989) and project-based learning (Blumenfeld, Soloway, Max, Karajcik, Guzdial & Palincsar, 1991) are such professional development approaches that challenge the existing capabilities of teachers. The two approaches are widely recognised because they involve, for example, change in classroom management strategies and the organisation of knowledge and assessment. There is little doubt that an inquiry-oriented approach deepens and broadens teachers' subject knowledge more than traditional rote learning.

Kajander and Mason (2007) concluded that professional learning groups (PLGs) for teachers are effective in enhancing professional development for a number of reasons. According to them: (1) a PLG allows teachers to have common goals, hold systematic meetings and manage their own processes (Bissaker & Heath, 2005); and (2) a PLG relies considerably on teachers to form effective communities of discourse and engage in self-directed change processes (Darling-Hammond & Mclaughlin, 1995). The PLG model is based on group members setting their goals collaboratively and continuously, and negotiating how they will address these goals. As a consequence, PLGs are models of professional development and they are likely to be more sensitive to local conditions and teachers knowledge (Windschitl, 2002: 161) than traditional workshop-based models. However, the success of PLGs depends on the choices made by the participants. Some research suggests that the intentional self-questioning of practices can support professional growth (Manouchehri, 2002). Similar findings were reported by Miranda (2010) in a project conducted as part of an action research study carried out with 10 Namibian mathematics teachers in weekly in-service training sessions for a period of three months. This action research project emphasised the notion of developing teachers into researchers and reflective practitioners. These are closely related issues that might play a crucial role in collaboration. An advantage of PLGs is that the participants are able to practice analysing their own teaching through collaberation. In many studies, participating teachers' voices are commonly neglected (Angelides, Evangelou & Leigh, 2005: 85).

2.6 Role of curriculum materials in TPD and teachers' instructional practices

Curriculum materials may be defined as the resources that guide learners and teachers in direct activities for mathematics instruction. Curriculum materials include all of the books, guides and kits that influence the planned and enacted curriculum (Ball & Cohen, 1996; Brown & Edelson, 2003; Grossman & Thompson, 2004; Remillard, 2005). The planned curriculum refers to the teachers' lesson plans, whereas the enacted curriculum refers to the events that are enacted within the classroom (Remillard, 2005). Curriculum materials are associated with every day teachers' activities in the classroom and thus position teachers' learning in their own practice (Borko & Putman, 2000; Kauffman, 2005). The way teachers interpret and manipulate curriculum materials depends on the meaning they themselves construct through conveying ideas, meanings, and values. They can greatly influence teachers' actions, their planned curriculum, and the way students learn (Brown & Edelson, 2003; Remillard, 2005).

Teachers generally use available written resources to help them achieve what they have to do in the classroom and to make decisions about their own practices. For example, teachers frequently use curriculum materials to define what students need to know and are capable of as a result of instruction (Remillard, 2005). Since curriculum materials stipulate what and how to teach, teachers use them to guide their preparation and presentation of lessons (Ball & Cohen, 1996; Remillard, 2005; Shulman, 1986).

Thus, one possible way to influence in teachers' learning through curriculum materials has to do with the developers' intentions. In other words, developers have to think how they design and sequence the specific curriculum materials. Whatever they do will not be a guarantee that teachers will learn what is intended. Curriculum materials are not be naively interpreted as "something for students" or simply as teachers' guides that serve as instruction manuals for teachers (Ball & Cohen, 1996). Their role has a great deal to do with how they are used in context, e.g. in classrooms or workshops, with teachers.

Teachers are in a deep dynamic relationship with curriculum materials (Brown, 2009; Remillard, 2005). Some view teachers as ordinary conduits of curriculum materials (Welch, 1979). Others view teachers as active mediators who work together with curriculum materials, contributing to the development of the intended curriculum.

Curriculum materials play an active role in this relationship by enabling and constraining teachers' curricular decision making (Brown, 2009; Remillard, 2005). For example, curriculum materials describe innovative didactic approaches, which may promote changes in teachers' knowledge about how to teach this subject matter and lead to changes in their practice. As teachers interact and understand written materials such as textbooks, they draw upon their experiences, beliefs, knowledge and instructional goals (Brown, 2009; Remillard, 2005). These personal resources support teachers in conveying meaning to the curriculum materials and may shape how they use the materials, e.g. textbooks in practice (Cohen & Ball, 1999). Alternatively, teachers may adjust curriculum materials to be more useful and meaningful to their instructional goals and students' needs. Thus, not only do curriculum materials shape teachers' ideas and practices but teachers also simultaneously shape curriculum materials as they use and adapt the materials in ways that address their own unique characteristics, needs, and goals.

A growing body of research has investigated the ways in which teachers use curriculum materials to design and enact instructions (Collopy, 2003; Drake & Sherin, 2009; Grossman & Thompson, 2004; Schneider & Krajcik, 2002; Valencia, Martin, & Grossman, 2006). This body of research has shown that teachers engage in two important design practices. Firstly, teachers critique curriculum materials and they identify their strengths and weaknesses (Davis, 2006; Schwarz, Gunckel, Smith, Covitt, Bae & Enfield, 2008). Secondly, teachers make adaptations to compensate for their deficiencies (Drake & Sherin, 2006). Teachers' pedagogical design capacity plays a key role in shaping their ability to engage in these design practices. This capacity entails the "ability to perceive and mobilise existing resources in order to craft instructional contexts" (Brown, 2009: 24). Developing teachers' pedagogical design capacity is not just a function of developing particular types of knowledge and beliefs. It also includes developing their ability to act upon these personal resources while interacting with particular material resources to design powerful learning opportunities for students (Cohen & Ball, 1999; Remillard, 2005). Cultivating the capacity to critique and adapt curriculum materials in productive ways is a challenging task, especially for new teachers. For example, student and newly qualified teachers tend to consider a variety of ideas when they use curriculum materials to make plans (Davis, 2006; Schwarz *et al*., 2008), but their ideas are often limited in scope and depth (Lloyd & Behm, 2005; Mulholland & Wallace, 2005 ; Nicol & Crespo, 2006; Schwarz *et al*., 2008; Wallace, 2004). These teachers also tend to struggle with making adaptations, fail to make much needed modifications (Lloyd & Behm, 2005; Valencia *et al*., 2006), or make only superficial or counterproductive adaptations to materials (Ball & Feiman-Nemser, 1988; Grossman & Thompson, 2004; Nicol & Crespo, 2006). For these reasons, new teachers need support in developing their pedagogical design capacity for analysing curriculum materials.

Re-conceptualisation of resources, which could include curriculum materials, is an important theme in mathematics education. The term “resource”, may also be considered “as both a noun and a verb, as both object and action” (Adler, 2000: 207). Adler further classifies educational resources into three main categories, namely human resources, cultural resources and material resources. Firstly, human resources include teachers and the pedagogic content knowledge that they represent. Secondly, cultural resources which include language and time, and thirdly material resources which include spreadsheets and textbooks.

This study focused on the third type of resource, material resources, specifically spreadsheet-based algebra programs, which can be considered as curriculum material. Spreadsheet-based algebra programs are not textbooks but can serve the purpose of textbooks, i.e. they can be consulted and used in teaching as “didactical objects” (this will be discussed later on this chapter). Adler (2000: 205) argues that human resources serve as critical means to the successful implementation of curricular innovation and reform. Such an achievement is equally dependent on the “availability of supportive material resources”. At the same time Adler points out that whilst limited resources may have a negative impact on learners’ mathematical experiences and performance, it should not be assumed that an increase in material resources will lead to better pedagogic practices. Even if it does lead to significantly better practices, this may not happen in unproblematic and straightforward ways (Adler, Reed, Lelliot & Setati, 2002). Also one must bear in mind that "resources are not self-explanatory objects with mathematics shining clearly through them" (Adler, 2000: 207). Adler further argues that mathematics education needs to "shift from a broadening view of what such resources are to *how* they function as an extension of the mathematics teaching [and] learning process" (2000: 207). In addition to this and drawing on the work of Lave and Wenger (1991), Adler introduces the term "transparency" that is needed in the use of any material resources for mathematical teaching and learning. Defining transparency in terms of how the resources are contextualised and used, Adler contends that resources need to be visible and invisible at the same time. On one hand, they need to be seen (visible) "so that they can be used [touched, felt, manipulated] and so extend the practices" (2000:214). On the other hand, resources need to be seen through (invisible) "so that they allow smooth entry into the practice" (Adler, 2000: 214). In other words, both teachers and learners need to move beyond the material resources and see the mathematics through them, but not to be stuck with the materiality of the resource.

2.6.1 Spreadsheet algebra programs as curriculum materials

Computer-based technologies can be extensions of human aptitudes and contexts for social interactions to support learning (Bransford, Brown & Cocking, 2000: 218). The general accessibility of digital resources for mathematics teachers entails a complete transformation of curriculum materials (Remillard, 2005). Spreadsheet-based curriculum materials can provide teachers with a better understand of mathematical or algebraic concepts and their conceptualisation of relationships among numerical, graphical and algebraic representations (Drier, 2001; Stohl, 2001). Digital technologies are widely recognised for their ability to link and explore visual, symbolic, and numerical representations simultaneously in a dynamic way.

2.7 ICT-based didactic objects in teachers' professional development

Thompson (2002) pointed out that didactic objects can range from simple diagrams to more complicated computer simulations. Thompson further argues that the object is not didactic in itself, but it is how it is used to support teachers' or students' constructions of increasingly complex cognitive structures that are the issues.

Designing didactic objects includes conception of how teachers/students perceive specific mathematical topics and the imagination of the types of classroom discussions that could support these mental constructions (Bowers, Bezuk & Aguilar, 2011).

Adopting the perspective design on constructivist views of learning, Von Glasersfeld (1995) notes that learners construct knowledge through successive cycles of action, perturbation and reflection. In classrooms, the sources of these perturbations may come from any number of social catalysts including the teachers, students, textbooks, and SAPs. Thompson (2002) suggests that classroom teachers can support this equilibration process by creating thought-provoking questions that will form the basis of reflection and discussion. He calls these processes didactic objects.

Research conducted into technology in secondary schools indicates that the use of physical tools can assist students in building connections between mathematical ideas and forming a deeper understanding (Hawkins, 2007; Hiebert & Carpenter, 1992; Kober, 1991) through guided participation and interaction (Hennessy, Deaney & Ruthven, 2005). Mediation is a central aspect to be considered in the use of physical tools. This is the relationship between student and mathematical knowledge with the teacher's role as that of a mediator, using the spreadsheet to mediate mathematical content to the student (Bussi & Mariotti, 2008; inYesildere, 2010). The mediation of a tool is based on creating a communication channel between the teacher and the pupil (Noss & Hoyles, 1996) and this is largely dependent on teachers' pedagogical skills. The best tools are those that relate mathematical knowledge to mathematical concepts (Hoyles, 2003).

2.8 ICT tools in mathematics teaching

Some research has been conducted into using tools for mathematics teaching (Bennett, 2000; Clements & McMillen, 1996; Hawkins, 2007; Moyer, 2001; Olkun & Toluk, 2004; Thompson, 1992). Hoyles (2003) points out the importance of tools as part of both the individual and collective experience. In terms of technology in mathematics education, teachers' practices have been discussed in relation to the instrumental approach considered below.

The instrumental approach acknowledges the difficulty of using technology within mathematics education (Artigue, 2002; Trouche, 2004). According to this approach, the use of a technological tool, in this case the Spreadsheet programs, involves a process of instrumental genesis, during which the object or artefact is turned into an instrument.

The process of instrumental genesis, in which an artefact is appropriated by a learner, consists of two combined processes: instrumentation and instrumentalisation. The former refers to the way in which an artefact such as a spreadsheet influences the learner, allowing them to engage in mathematical activity using the artefact. The latter is directed towards the artefact, and refers to transforming the artefact to become a mathematical tool.

Many studies focus on students' instrumental genesis and its potential benefits for learning (Kieran & Drijvers, 2006). However, it was acknowledged that students' instrumental geneses need to be guided by the teacher through the orchestration (McKenzie, 2001) of mathematical situations (Mariotti, 2002). This instrumental orchestration describe the teachers' intentional and systematic organisation and use of various artefact available (SAPs in this case) in order to guide the learners' instrumental genesis (Trouche, 2004). The practice of what teacher actually does, however, have received relatively little attention in the literature.

2.9 Spreadsheet algebra programs as a tool in secondary school mathematics: pragmatic and epistemic values

Artigue, (2002) defined the pragmatic value of techniques as focusing on the productive potential, efficiency, cost, and field of validity; and the epistemic value of techniques as contributing to the understanding of the objects they involve.

From a pragmatic perspective, Computer Algebra Systems (CAS) is extremely effective (Artigue, 2002). However there is a challenge at the theoretical level as some users do not entirely master the mathematical knowledge and techniques involved in solving tasks (Chiappini & Pedemonte, 2009). As a consequence, the epistemic value of the CAS (instrumented technique) can remain hidden. This can constitute a problem for the educational context where technology should help, not only to yield results, but also to support and promote mathematical learning and understanding. In educational practice, techniques should have an epistemic value contributing to the understanding of objects involved. Therefore, whatever technologies are employed, there is need for a reasonable balance between the pragmatic and the epistemic values of instrumented techniques (Artigue, 2007: 73).

Spreadsheets have both pragmatic and epistemic value (Artigue, 2000). Pragmatically they allow a participant to make computations relatively easily. Epistemically they enhance understanding of the mathematical objects such as numbers, variables and parameters. A spreadsheet as an instrument is therefore a “mixed entity” carefully constituted on the one hand of artefacts and, on the other hand, of the schemes that make it an instrument for the specific student or user. Haspekian (2005) in her work on spreadsheets and instrumentation processes made two general observations about spreadsheets. Firstly they have pragmatic value, in that there are technical or instrumental processes that the user will have to learn and undertake which have “productive potential” i.e. they are considered efficient to do the task (Artigue, 2002: 248). Secondly they have epistemic value encompassing the understanding of the mathematical objects that live on the screen, in relation to their pen-and-paper counterparts that arise when the teacher attempts to do the task.These techniques require conceptual understanding of algebraic knowledge, in that the user must grasp the epistemic aspects, such as the process or object duality of the mathematical objects.

2.9.1 Spreadsheets use in the case of the secondary school algebra

There are several difficulties in learning algebra due to misconceptions and errors such as, the meaning of symbols (letters), the shift from numerical data or language representation to variables or parameters with functional rules or patterns, and the recognition and use of structure. Some of these difficulties are often caused by an approach that focuses on the calculation processes rather than on relational or structural aspects (Sajika, 2003, Sierpinska, 1992). Students often passively accept formal rules and techniques. One of the reasons for the problems in algebra teaching and learning is the evolution from procedural (procedures or processes) to structural conceptions (objects) (Sfard, 1991).

Haspekian (2003) states that the contribution of spreadsheets includes possibilities of calculation, representation, interactivity and interplay of various languages (natural, numeric, algebraic and graphic). Spreadsheets first found their use in mathematics teaching and learning in the field of algebra. Pioneer work was done in the 1980s by researchers such as Healy and Sutherland (1990), who found that spreadsheets helped students to develop powerful mathematical ideas such as generalisation, symbolisation and functional relationships. Other studies in the 1990s (Filloy, Rojano & Rubio, 2000; Kieran, 1992; Rojano, 1996; Sutherland & Balacheff, 1999) identified spreadsheets as an intermediate expression between natural or numeric language and algebra. It was claimed that spreadsheets would enable students to cope with the transition from a numeric or verbal representation to a symbolic representation: from the specific to the general; from the known to the unknown; and from intuition to abstraction. Studies of students working with spreadsheets as a problem solving tool on arithmetic or algebra problems found that students' communicative power was enhanced and interesting and powerful thinking strategies evolved (Ainley, 1996; Sutherland & Rojano, 1993). Spreadsheets were found to contribute positively to students' learning algebra, and they were also successfully used as a technological tool for other areas in mathematics as well as in science (Hershkowitz *et al*., 2002).

The benefits of spreadsheet use as compared to other methods are that they: facilitate a variety of learning styles (open-ended, problem-oriented, constructivist, investigative, discovery oriented); offer active learning and are student centred; are interactive; give immediate feedback to changing data or formulae; are visual; give students a large measure of control and ownership over their learning; and they can solve complex problems and handle large amounts of data without any need for programming (Baker & Sugden, 2003: 19).

The "purposeful" (Kieran, 2004) use of spreadsheets can synthesise the three principal activities of school algebra. Firstly, there are generational activities that involve the forming of expressions and equations arising from quantitative problem situations, geometric patterns and numerical sequences. Secondly, there are transformational activities such as changing the form of expressions and equations in order to maintain equivalence. Thirdly, we find global or metalevel activities such as problem solving, predicting and modelling (Ainley, Pratt, & Nardi, 2001). While the type and level of the activities may vary, research findings support the use of spreadsheets in education.

2.10 Summary

In this chapter we have seen the importance of teachers' perceptions with regard to spreadsheet algebra programmes as instances of curriculum materials to be used for the purpose of mathematics teachers' professional development. In her study, Haspekian (2003) discussed the contributions of the spreadsheet including possibilities of calculation, representation, interactivity, and interplay of various languages (natural language, numeric, algebraic, graphic). I have tried to show how SAPs has a transformative potential for mathematics classroom practice. It is these ideas of transformative action that can be supported through the use of educational technologies and together improve the professional development of teachers. How these SAPs will be used is indicated by the idea of making them didactic objects for teachers' attention to be drawn to the epistemic as well pragmatic aspects of spreadsheets.

Finally, probably one of the most profound, clear benefits of using spreadsheets that has emerged from this study is of saving time. The time saved could then be spent on investigating more mathematical concepts generated in the spreadsheet environment.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

The purpose of this study was to gain an in-depth understanding of the teachers' perceptions of spreadsheet algebra programs as curriculum materials in secondary school mathematics in Namibia. This chapter outlines the methodology used in this research study. The methodology is discussed in terms of orientation, design and process. It discusses the interpretive paradigm, the use of a qualitative case study, and the selection of the research site and participants. It further explains and clarifies the tools and techniques used in collecting data for the research. The data analysis procedures and research ethics are also discussed towards the end of this chapter

3.2 Research goal

This study set out to explore teachers' perceptions of spreadsheet algebra programs as curriculum materials in secondary school mathematics. In addition, it was hoped that it would contribute to teachers' curriculum decision making in order to consider ways of using spreadsheet algebra programs to support the teaching and learning of algebra.

3.3 The chosen paradigm

In this section a rationale will be provided for the paradigm and the design and methodology of the study. A paradigm, as defined by Guba and Lincoln (1989: 80) is "a basic set of beliefs, a set of assumptions researchers are willing to make, which serve as touchstones in guiding their activities". In addition to managing researchers' decisions, research paradigms determine the research design, as well as the methodological approach researchers choose to employ in conducting research. The research design involves the most effective strategy for finding the information most appropriate to answering the research question (Goodwin, 1996: 69). The strategy of this study can be described as a qualitative, descriptive and contextual design. Patton

(1987: 9) stated that a qualitative design is much more flexible in achieving the set goal. Babbie, Mouton, Voster and Prozesky (2001: 272) described qualitative design as a "lengthy description which captures the sense of events as they occur". In this study we used a set of spreadsheet algebra program activities as a means to interact with the participants (school teachers). Also, semi-structured interviews were used to collect in written form the teachers' perceptions of spreadsheet algebra programs as curriculum materials. There was also observation of one of the teachers who taught 15 Grade 11 learners the solution to linear equations using spreadsheets. The choice of the research design and the methodological approaches implemented in this study were to provide accurate and detailed information about the way the five participants perceived the potentiality of spreadsheet algebra programs as curriculum materials.

This research was oriented by an interpretivist paradigm because materials such as spreadsheet algebra programs are bound to influence teachers' perceptions. In this study I therefore sought to interpret teachers' perceptions of spreadsheets as curriculum material to improve algebra learning and teaching. An "interpretivist paradigm" is in the area of qualitative research and focuses on gaining meaning, understanding and building concepts and theories. It does so through the intuition of the researcher, who works to become an "insider" (Miles & Huberman, 1994).

Qualitative researchers gather information through multiple, usually interactive methods, identifying and systematically reflecting on their role in the inquiry and acknowledging and accommodating personal biases, values, and interests (Creswell, 2003). In qualitative research, the researcher has direct contact with and gets close to the participants, as she tries to make sense of or interpret the phenomenon being investigated. This is why, according to Cohen, Manion and Morrison (2008: 21), the "interpretive paradigm is characterised by concern for individuals." Furthermore, Creswell (1994) identifies five genres traditionally employed in qualitative research, namely: biography, phenomenology, grounded theory, ethnography and case study. To gain an in-depth understanding of the teachers' perceptions of spreadsheet algebra programs as curriculum materials in secondary school mathematics, this study adopted a case study approach.

3.4 Research methods

This study took the form of a case study. Bloor and Wood (2006: 27) define case study as "a strategy of research that aims to understand social phenomena within a single or small number of naturally occurring settings". Similarly, Creswell (1994: 1) defines case study as "an inquiry process of understanding a social or human problem...conducted in a natural setting." Merriam (2009: 203) identifies a "case study as providing a holistic, intensive description and analysis of a single, bounded unit". Consequently a case study allows the researcher to concentrate on specific instances or situations and attempt to identify the various interactive processes at work. A case study gives an opportunity for one aspect of a problem to be studied in some depth within a limited time scale (Bell, 1993: 8). According to Allison, O'Sullivan, Owen, Rothwell, Rice and Saunders (1996: 20 in Ilukena, 2008), a case study is an "in-depth study of particular events, circumstances or situations which offer the prospect of revealing understanding of a kind which might escape broader surveys".

This study focused on teachers' perceptions of the benefits of SAPs, and how the application thereof may enhance algebra teaching and learning in secondary school mathematics. The study was carried out in the natural settings of the participants. Gillham (2000: 11) asserts that "one of the major distinguishing characteristics of case studies is that the researcher tries to understand people in terms of their own definitions of the world."

3.5 Sampling

The sample population consisted of five teachers from Okamu (pseudonym) secondary school in the Ohangwena Region of Namibia. Four of them were teaching mathematics at different levels in the mentioned school and one was teaching Physical Science. Sampling of the participants in this study was guided by purposive sampling procedures. Johnson and Christensen (2004: 215) define purposive sampling as "a type of sampling where the researcher specifies the characteristics of a population of interest, and then tries to locate individuals who have those characteristics". The participants in this research were chosen to share their experiences on the potentiality of spreadsheet algebra programs as curriculum materials in secondary school mathematics. Cohen, Manion and Morrison (2000) refer to this sampling procedure as "convenience sampling". I chose individuals who worked closest to me and who were therefore easily accessible as respondents. The teaching profile of the five participants is reflected in table 3.1.

Participant names(pseudonyms)	Years of teaching	Level of teaching	qualifications	ICT familiarity	Name of school
Peter	4	9,10,11	BETD	Yes	Okamu SS
Maria	4	9,10,11	BETD,BED	Yes	Okamu SS
Harold	2	11,12	BETD	No	Okamu SS
Gift	4	9,11	BETD	Yes	Okamu SS
Gibson	7	11,12	BETD, PGD	Yes	Okamu SS

Table 3.1 Teaching profile of the five participants.

3.6 Data collection methods

Data is information that assists the researchers in drawing reliable conclusions. Researchers identify and accumulate data to formulate answers to their queries. The inclusion of various methods of data collection in the practitioners' inquires enhances the reliability of the findings (Babbie, Mouton, Voster & Prozesky, 2001: 278). In this study we used three methods to collect data: semi-structured interviews; focus group interviews, which gave us the possibility of gathering data from teachers' experiences with a set of spreadsheet-based algebra activities; observation of one of the participants demonstrating to a group of Grade 11 learners a solution to linear function (straight line equation) through the use of a spreadsheet algebra program.

3.6.1 Semi-structured interviews

In this study, the main research tools used were interviews (De Vos, Strydom, Fouché & Delport, 2005: 292) these were: unstructured interviews, semi-structured interviews and ethnographic interviews. In this study, we conducted semi-structured interviews with five teachers. Semi-structured interviews are defined as interviews organised around areas of particular interest, while still allowing a considerable flexibility in scope and depth (Morse, 1999: 189). De Vos *et al*., (2005: 296) emphasise that "semi-structured interviews allow the researcher to pursue particularly interesting revelations that might emerge from the interview, and allow participants to provide a comprehensive account of their feelings and opinions about a given subject". The semi-structured interview technique allows one to explore more deeply the perceptions and views of the participants (Cohen & Manion, 1994). As a skilful interviewer, Bell (1993: 91) suggests that one needs to follow up on ideas, probe responses and investigate the motives and feelings of participants.

A date, time and venue for the interviews were arranged with the participants. The school principal attended some of the interview sessions. All the four sessions were held in the computer laboratory in the school where the participants worked. Before the interviews were conducted, informed consent was obtained (Appendix D). During this time I introduced myself and explained the aim of my study. I assured the teachers that confidentiality would be maintained and that no information would be attached to them personally or used against them or their institution in any way. Pseudonyms were used to protect their identity. Semi-structured interviews were conducted over the course of the investigation. The duration of each interview was approximately 40 minutes. The five teachers were interviewed while they were interacting with a set of spreadsheet algebra programs. However, their written responses were only collected at the end of the last meeting. With the consent of the respondents, all interview sessions were audio-recorded and transcribed later on. The teachers' written responses were used as a main source of evidence of teachers' perceptions. Appendix E provides examples of some interview questions that were used to explore teachers' perceptions about the spreadsheet algebra programs.

3.6.2 Focus group interviews

Focus group discussions were used as a supplementary data collection tool. According to Lederman (cited in Thomas *et al*., 1995) a focus group is a technique that involves the use of in-depth group interviews with selected participants for a specific purpose. The focus group is not necessarily representative of the population.

Participants in focus group interviews are therefore selected on the criteria that they would have something to say on the topic are within the age-range, have similar socio-characteristics and would be comfortable talking to the interviewer and each other (Richardson & Rabiee, 2001). The researcher's intention during the interview process was to explore participants' perceptions of SAPs as curriculum materials. However, for some of them the integration of technology, especially the use of SAPs, in the teaching of algebra was practically new. An important aspect of focus-group interaction is the group dynamics, hence the type and choice of data generated through the social interaction of the group is often deeper and richer than that obtained from one-to-one interviews (Thomas *et al*., 1995). On the other hand De Vos *et al*., (2005: 299) saw focus group discussions as "a means of better understanding how people feel or think about an issue, product or service". The distinctiveness of a focus group interaction is its capacity to generate data based on the cooperation of the group (Green, Draper & Dowler, 2003). Thus, the participants of the group should feel comfortable with each other and enjoy the environment in which the discussions take place. It is for this reason that Krueger and Casey (2000) suggested spending time and effort in selecting group members. The participants in this study were therefore selected and nominated by the principal of the school because of their interests in ICT.

3.6.3 Observation of a teacher using his own spreadsheet algebra program

Observation was not originally meant to form part of the data collection techniques. However, it was included after it was realised that it would be helpful to use some key features that were observed during the process to support the findings. For example, the interaction of the teacher who demonstrated a solution of a linear function or straight line equation using a spreadsheet algebra program was audio-taped, video recorded and transcribed. This teacher made use of his schools computer laboratory, where he used a SAP to explore the possibility of enhancing his learners' understanding of the algebra activity that he was going to demonstrate to them. During his demonstration, photographs were taken to describe the setting and physical condition of the computer laboratory (see Figure 3).

3.7 Research design instruments

A research design is a plan that provides the researcher with a detailed approach that is suitable to address the research goals. De Vos, Strydom, Fouche and Delport (2005) define such a plan as "a logical strategy for gathering evidence about the knowledge desired". Yin (1994) argues that the research design deals with four problems: what questions to study, what data is relevant, what data to collect and how to analyse the results.

The instruments used to generate data were the following:

1. Background information on the teachers, their school and relationship with ICT in general
2. Spreadsheet algebra programs (SAPs)

2.1 "Equivalence" (Exploring equivalence)

2.2 Discriminant (Quadratic function)

3. Data collected from the teacher, and his interaction with a group of Grade 11 learners, during his teaching of linear function through spreadsheets

3.8 Ethical considerations

From the beginning of this study, ethical issues were taken into consideration. Johnson and Christensen (2007: 96) define research ethics as "a set of guidelines that assist researchers in conducting ethical research". To guarantee that ethical practices were followed in this study, the researcher took into account the following:

Authorisation to conduct the research was requested from the Ohangwena education directorate and the school principal where the research took place (Appendix F and G). In the letter, the reason for doing this study, the goal of the study, how investigating Information and Communications Technology (ICT) with specific reference to spreadsheets could enhance teachers' understanding of school algebra and the possibilities of SAPs as curriculum material in school mathematics was discussed. The teachers in particular were guaranteed anonymity during the investigation and also in the final writing up of this thesis.

- The practicality of the study was also specified, by showing that the study had the potential to make important contributions to the Education and Training Sector Improvement Program (ETSIP) in the Ohangwena region, Namibia. One of the purposes of the ETSIP project is to support the teachers' professional development, with specific attention to technological skills and content knowledge for mathematics teachers.

- In her approval letter, the Director requested that the research program should not interfere with the normal learning and teaching of the school. A copy of the agreement letter from the Ohangwena education directorate is shown in Appendix H.

- The participants in the study were mainly mathematics teachers, although other teachers in the school were allowed to participate. The mathematics teachers participated voluntarily without any consequences. See consent form in Appendix D.

3.9 Description of the spreadsheet algebra programs (SAPs) used in this study

3.9.1 Activity 1 (case 1)

Using SAP to explore equivalence

On the screen below there are multiple representations: numerical, algebraic and graphical displays of the linear functions of the form, y = 3(x + a):

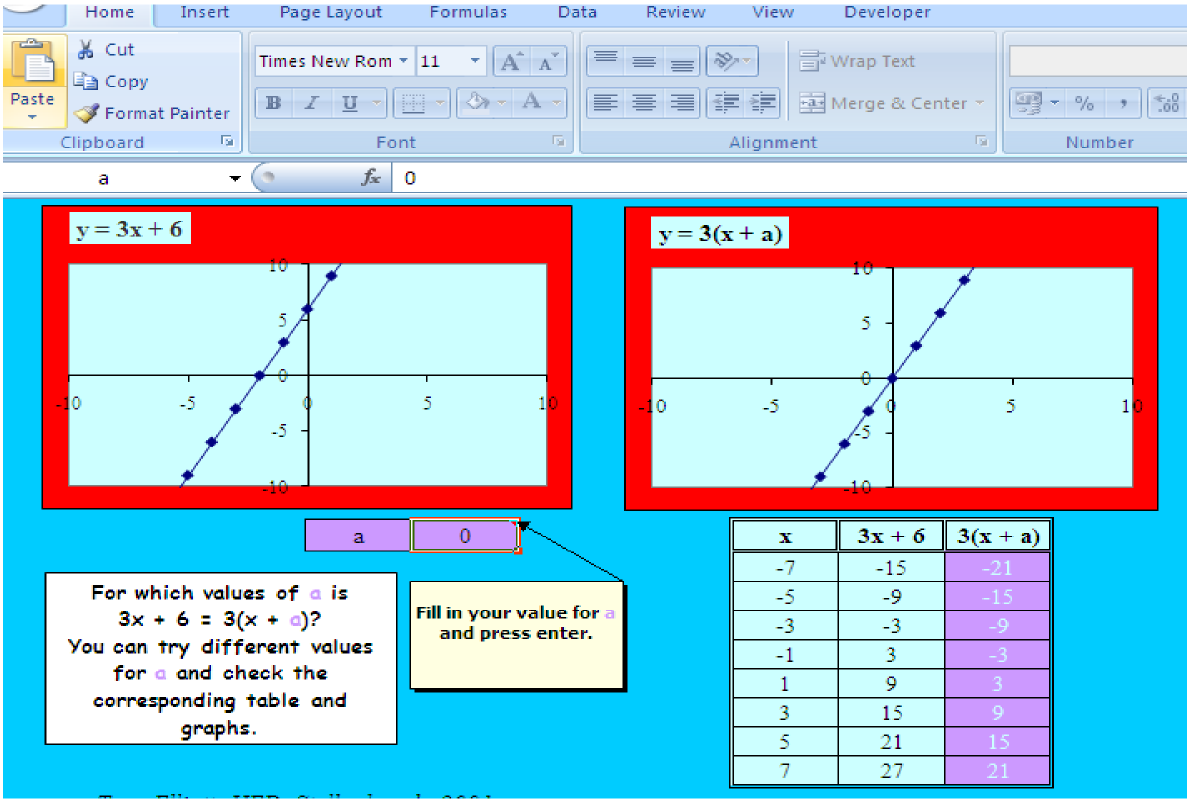


Figure 1: A "page" from SAP on exploring Equivalence

(*Source*: Research Unit Mathematics Education, University of Stellenbosch, 2000, [RUMEUS])

This program is used for exploring the "equation of the straight line" or linear function $y = 3x + 6$ and $y = 3(x + 6)$. the user has to fill in or choose values for *a* and explore "equivalence", i.e. when are the two functions equal? For example, for which particular "input" values are the "outputs" the same? In exploring this question, the user is making use of "spreadsheet algebra" (Leung, 2006) as a means of learning what particular numerical inputs are associated with which particular outputs. Spreadsheet algebra is conceptually different from pen-and-paper algebra, which is a point that will be addressed in the actual analysis.

In terms of mathematics teacher development, spreadsheet-based algebra activities can be used as "didactic objects" (Thompson, 2002) as a way to engage teachers' perceptions about their possible roles.

3.9.2 Activity 2 (case 2)

Using SAP on the discriminant of a quadratic function (DoQF).

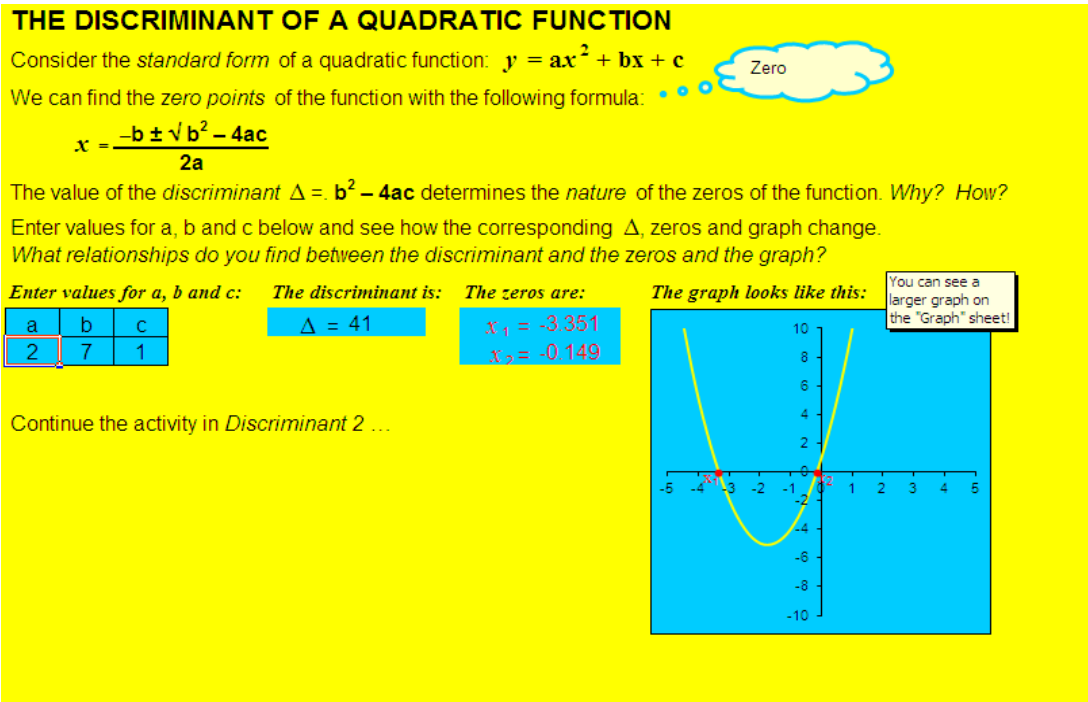


Figure 2: A "page" from the SAP DoQF

(*Source*: Research Unit Mathematics Education, University of Stellenbosch, 2000, [RUMEUS])

This SAP has been designed to explore the different values of the discriminant of a quadratic function $y = ax^2 + bx + c$. As a didactic object SAP was used to provide a conceptual understanding of the discriminant and a symbol sense (Tabach, Arcavi & Hershkowitz, 2008) for the values a, b and c in $b^2 - 4ac$. The discriminant in mathematical form is given as:

$$\Delta = b^2 - 4ac$$

The users (teachers) had to type in certain numerical values for a, b and c. Once this was done, the value of Δ (delta) was then computed and the zeros were computed. The "technical" or pragmatic values were changed once the user had typed in the values. "Epistemic" value lies in the fact that there are multiple representations, i.e. algebraic, graphical, numerical and verbal representations that are linked in the way the SAP was designed.

Knowledge of particular values of Δ could then be deduced through conversation in making the SAP a didactic object (DO).

In quadratic theory the discriminant is an index to indicate whether a quadratic function has no intersection ($\Delta<0$), intercepts as a single point ($\Delta=0$) or intercepts at multiple roots ($\Delta>0$) with the horizontal axis.

The following questions were posed to the participants in order to find the different possible values of the discriminant Δ.

1. When does the graph cut the X-axis and when not?
2. When does the graph touch the X-axis and when not?
3. When are the zeros real and when not?
4. When are the zeros equal and when not?
5. When are the axes of symmetry positive/negative/0?

3.9.3 Activity 3 (case 3)

A teacher demonstrating the plotting of a linear function using spreadsheets.

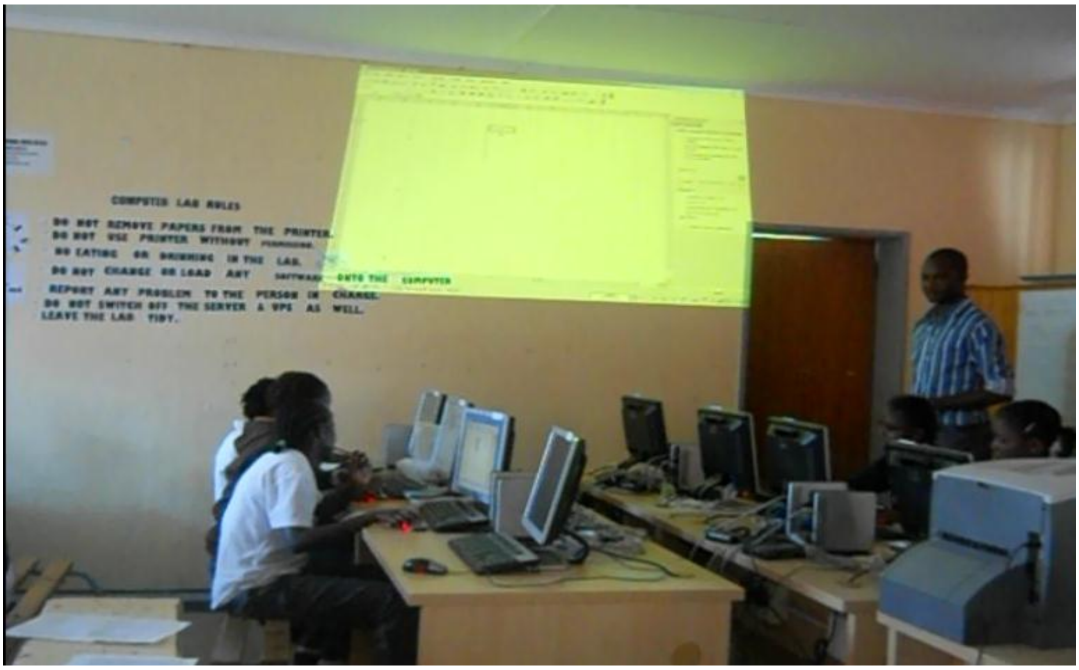


Figure 3: Inside the Okamu secondary school computer laboratory

Okamu secondary school has a total of twenty computers located in the computer laboratory. The picture above shows the computer laboratory and some of the learners seated at the computers. Included in the picture is Peter (pseudonym), the teacher, who had a computer and projector at his disposal. During the period of this study, Peter permitted the researcher to observe and video tape the 45 minute lesson on the solution of a linear equation through the use of spreadsheets to 15 Grade 11 learners. He gave the researcher permission to transcribe his video-taped teaching.

Peter however did not use one of the SAPs that the researcher had used with the teachers. Instead he used a blank spreadsheet to show the learners how to draw the linear function $y = 2x + 4$. Instructions were given to the learners to have a look at their homework given the previous day during the normal lesson, where they had answered a question about a pen-and-paper linear function $y = 2x + 4$. The teacher then showed to them how to use spreadsheets, noting that they had had some exposure to spreadsheets in their computer lessons. The drawing of a linear function through spreadsheets however, was a first for the learners as well as a first for Peter. He gave the class step by step instructions whilst the learners opened Microsoft Excel in their computers and produced a table with values of x (inputs) within the range of -3 to +3. Then they entered the spreadsheet formula in the next cell (=$B$5*(E5) +$B$8) to find the first value of y (outputs). After the users (learners) had obtained the first values of y they clicked and held the small square that appeared in the lower right hand corner of the selected cell. Drawing the square down to highlight the entire cell through to the bottom of the table, the computer gave all the other values of y. The task was to then produce a graph of the equation; the teacher showed them how to do this by highlighting the cells of the table that contained all the other values of y and clicking the chart wizard at the bottom on the toolbar. They selected "xy Scatter" as the type and "Scatter" with data points connected by lines to finally obtain the straight line graph. Discussion and detail around this activity is explained in the next chapter where the data is analysed.

3.10 Summary of data generation from the various appendices:

Appendix	Brief description & rationale for Appendix
A	Activity 1: Spreadsheet algebra programme (SAP) "Equivalence" Exploring "Equivalence" in order to engage teachers' perceptions on the possible roles of spreadsheet-based algebra activities.
B	Activity 2: Spreadsheet algebra programme (SAP) on the discriminant of a quadratic function (DoQF). Exploring conceptual understanding of the discriminant and symbol sense for the values a, b and c in $b^2 - 4ac$
C	Activity 3: Collection of data on teachers' backgrounds in teaching mathematics and their familiarity with ICT/spreadsheets; Being the first meeting, the rationale is to become familiar with the teachers as they are the subjects in the study.

3.11 Summary

In this chapter there is a description of the research design of the study. The chapter started with an outline of the orientation in which the study was located. The study was oriented in an interpretivist research paradigm which used a qualitative approach. The study was a case study and its meanings and importance were discussed. The chapter talked about the research sites and participants. The sites as well as the participants and the way they were sampled were described. This study used three research instruments: a semi-structured interview; a focus group interview where the researcher and the participants interacted with a set of SAPs; and a demonstration lesson from one of the teachers who participated in the study teaching linear function through spreadsheets. These instruments were described in detail. The process of data collection was also described in detail. In the next chapter, the data that was collected is presented, analysed and discussed.

CHAPTER 4

DATA ANALYSIS AND FINDINGS

4.1 Introduction

In this chapter there will be a presentation of findings and an analysis of teachers' perceptions. This study addressed the research question: How do Namibian high school teachers' percieve spreadsheet algebra programs as curriculum materials?
To answer this question, various types of data collection were used, as shown in chapter 3. A semi-structured interview schedule was used. The questions in the interviews gave teachers the opportunity to share their perceptions of the potential benefits of spreadsheets and SAPs as curriculum materials in the algebra curriculum. All teachers interviewed were teaching mathematics at a secondary shool in Namibia.

Several definitions of data analysis can be found in the literature. One of them, related to qualitative analysis states that:

> Qualitative analysis is the segmenting of data into relevant categories/cases and the naming of these categories with codes while simultaneously generating the categories from the data. In the reconstructing phase the categories are related to one another to generate theoretical understanding of the social phenomenon under study in terms of the research question. (Boeije, 2010: 76).

In this chapter there will be a presentation of findings and an analysis of teachers' perceptions. To answer the research question, various types of data collection were used, as shown in chapter 3. A semi-structured interview schedule was used. The questions in the interviews gave teachers the opportunity to share their perceptions of the potential benefits of spreadsheets and SAPs as curriculum materials in the algebra curriculum. All teachers interviewed were teaching mathematics at a secondary shool in Namibia.

The research question was answered as follows:

Case 1*:* The teachers' perceptions with regards to SAPs were influenced by *time concerns and constraints*

Case 2*:* Teachers' showed a willingness to use SAPs on linear and quadratic functions in the classroom; this willingness had pragmatic and epistemic dimensions.

Case 3: In a particular instance, a teacher perceived spreadsheets as useful as a curriculum material and used it to teach linear functions to his grade 11 leaners.

To analyse the teachers' written responses some background to their responses was needed. During the first few meetings the teachers were shown demonstrations of SAPs on equivalence in the case of linear functions. The research was divided into four main sessions. In the first session the researcher introduced SAPs to the teachers and showed them an example of how to solve a simple linear equation using a SAP. In the same meeting teachers discussed the potential use of SAPs through "equivalence" in the case of linear equation. In the second meeting teachers continued with another example of SAP to solve "discriminant" functions and issues relating to quadratic function were discussed. During the third meeting, teachers continued with the same discriminant activity and they completed the semi-structured interview given to them by the end of meeting four. In the fourth meeting, one of the participants offered his time voluntarily to demonstrate what he had learnt whilst teaching 15 Grade 11 learners using his own SAP as part of the current research. After every contact meeting, the teachers were asked for specific feedback regarding that session, to provide more information about their experiences of interacting with the SAPs. Later on, data categories emerged from the analysis of the teachers' written feedback on the various sessions and interviews.

The teachers' written responses and interactions with SAPs were guided by the following questions:

1. Do you believe that there is a role for ICT/spreadsheets in deepening algebra learning? Please elaborate.

2. What did you like about today's session? What was today's session about? (In your own words).

3. How did today's session make you think about the related linear functions that you teach in your classroom? Please elaborate.

4. What about today's session was new for you and why? Please say more.

5. What did you make of the differences between spreadsheet use and the Pen-and-paper version of the same linear function in the classroom?

In the second meeting teachers continued with another example of SAP to explore the discriminant, and issues relating to quadratic functions were discussed (Please see Appendices A and B for SAP activities/tasks).

The teachers' written responses were collected towards the end of the third meeting. *Time concerns and constraints* emerged as a common response, intermingled with epistemic and pragmatic issues. Below is a graphical way to illustrate what is meant:

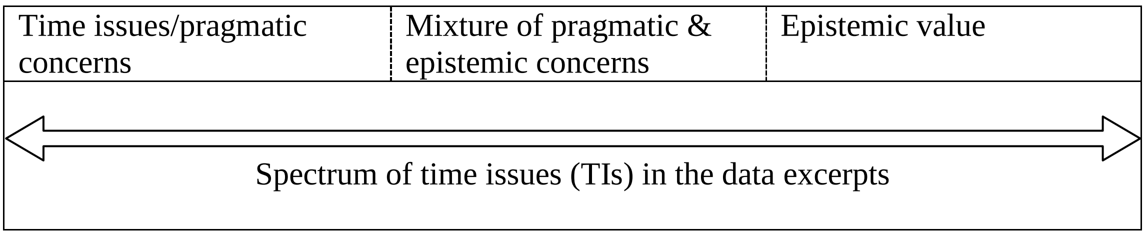


Figure 1: Relationships between time constraints, epistemic and pragmatic issues

4.2 Case analysis

4.2.1 Case 1

The teachers' perceptions with regards to the SAPs were influenced by *time concerns and constraints.*

An important finding with regard to teachers' perceptions (TPs) of SAPs as curriculum materials and resources for teaching secondary mathematics in Namibian schools was issues concerning time (time issues abbreviated as TIs), such as *time concerns and constraints*. In other words, in the TPs, various categories of TIs came to the fore. Evidence for these categories from the first meeting with the teachers will now be given.

We should note that TIs are related to the context of teachers' place of work, such as secondary schools and institutions and organisations where teaching and learning are intended to happen (Watson, 2008). Also, time is a crucial resource (Adler, 2000) in schools and thus has to be used in optimal ways so that mathematics teaching and learning can happen. In other words, teachers are quite aware how much time they have at their disposal and the degree to which SAPs can help or hinder them in their teaching

The TPs with regards to TIs come from their observations of demonstrations on the potential uses of SAPs in relation to the teaching of mathematics, specifically algebra, in Namibian secondary schools.

The following are examples of teachers responses during first meeting related to question 11 (see Appendix C or question 1 above)

> GIFT**:** Yes, very big role because SAPs expose learners to symbolic and visual representation of algebra that can perform in a short period of time in comparison to the traditional representation.

This excerpt shows that Gift raised a time concern in addition to a discourse related to SAP use. Gift appropriated the researcher's discourse *(*symbolic as well as visual representation of algebra) and commented on how the demonstration of the program happened “in a short period of time.” No claim could be made about Gift’s understanding of relationships between the different representations. The only claim that could be made was that he realised that “in a short period of time” it was possible to plot points and draw a graph of a particular algebraic (symbolic) equation. This teacher knew that in the “traditional classroom” it took time to plot points, draw axes and then to connect the points or coordinates to produce a graph on paper. The time issue here was therefore a pragmatic and not epistemic one, that is, not about understanding the objects or symbols in the specific SAP he observed during the demonstration.

> HAROLD**:** The spreadsheets use less time to design the table of values and produce a straight line graph.

This teacher realised that time could be saved when using the SAP to demonstrate algebra. Evidence was shown of his/her use of “less time” to draw up or “design the table” and to draw the graph. It was therefore pragmatic.

> MARIA**:** It makes me think about the essential uses of ICT as a teaching aid in the class. The activities performed during the interview gave me confidence in the use of SAPs and I trust learners can understand the content much better, in the same time we save time ploting the graph.

Maria was also concerned about “saving time” (save time), but appeared to see the value of “more information” as being represented in the SAP.

> GIFT: I’m of the idea that learners could understand better with spreadsheets when they do linear functions and it’s done in short time.

Gift similarly valued the time saved when teaching with a SAP ("in a short"), He was concerned with the pragmatic value of teaching with the SAP happening "in a short time," and he might have been thinking about the multiple representations that "could help learners understand better the linear functions."

> GIBSON: I feel teachers have to change their methods of teaching mathematics and also try to avoid the use of chalkboard because it is time-consuming it also reduces the learner's interest levels in the subject.

Gibson was concerned about the need for mathematics teachers to find other approaches or alternatives to teaching mathematics. This was probably founded on him/her noticing that SAPs can serve as a resource materials, that they can be used to involve more learners in the process of teaching and learning, or keep them more motivated in what they learn. In other words, increasing the time available for the learners during the possible interaction and use of SAPs, could give more opportunity for them to engage more deeply and find other alternatives of thinking about different solutions. The assumption here was that if the learners took more time to analyse their own hypothesis, they might be more motivated to learn.

It is evident that TPs were influenced by the time that could be gained and saved when using SAPs in the classroom.When teaching with SAPs, less time is used compared to when using pen-and-paper methods. The excerpts about TPs revealed that the teachers were aware that more time could then be spent on other representations such as tabular and graphical ones, in addition to the traditional symbolic manipulations. Specific data relating to the exploration of the underlying objects (symbols) in the SAPs or the visual, numerical or graphical effects of changing them was not available. We also could not discount "researcher effects", i.e. instances where the teachers picked up or appropriated the researcher's discourse with regard to spreadsheet algebra and SAPs, such as numerical and graphical representations.

4.2.2 Case 2

Teachers' perceptions showed a willingness to use SAPs on linear and quadratic functions in their teaching, this willingness had pragmatic and epistemic dimensions.

Willingness to use SAPs was something that emerged during the semi-structured interviews in the second meeting and during the teachers' interactions with the SAPs. In figure 2 below, we can see an example of a SAP on equivalence. This specific SAP was used for the generation of data related to TPs.

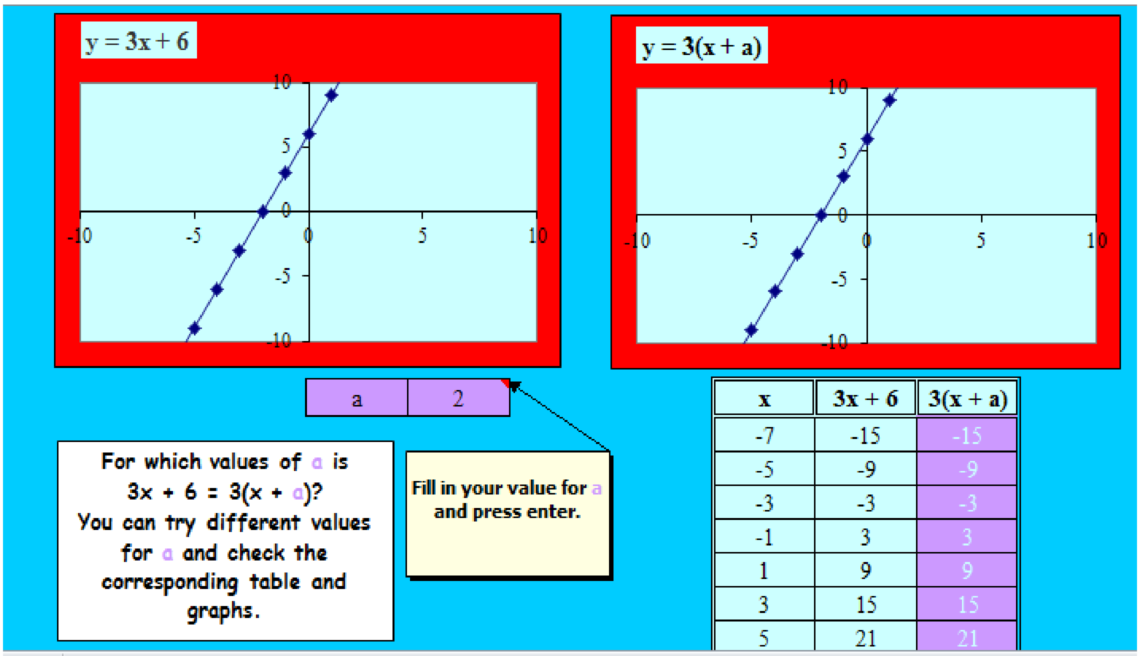


Figure 2: A "page" from SAP on exploring equivalence

(*Source*: Research Unit Mathematics Education, University of Stellenbosch, 2000, [RUMEUS])

Written in the form of a task, the SAP required the teachers to figure out what value(s) of a would make the two graphs $y = 3x + 6$ and $y = 3(x + a)$ equivalent. As the teachers varied the value of a they would have noticed that the graph $y = 3(x + a)$ changed as well as the numerical values in the table. As soon as they had found the right value, the two graphs would have looked the same and also the numerical values for the two graphs in the table would have become identical.

At a pragmatic level when using SAPs, one can change the numerical vlaues of *a* and quickly see the results. Changing this value of *a* in the classroom context could support and promote algebra learning and understanding (Chiappini & Pedemonte, 2009). Artigue (2007: 73) argues for a balance between pragmatic and epistemic values of instrumented techniques when using SAPs to teach and learn algebra. Thus in this case, the hypothesis is that teachers and learners will have a better understanding of the topic of equivalence, which is important in algebra teaching and learning. Evidence of the pragmatic and epistemic issues interacting, is given next.

REASEARCHER: Why do we call this task “equivalence?”

> PETER: We can only call it equivalence if we change the value of a. For example entering the value of 2 we get the same values in both equations, and then the two equations will be the same.

From the above statement it is evident that Peter recognised the concept of equivalence in this specific activity. He was aware of *a* as a parameter that could be varied by using the SAP, but he did not mention that the numbers in the corresponding table would also be the same. However, generally speaking, the teachers were excited to explore the different possibilities that SAPs would bring in their algebra teaching. The following excerpts illustrate this willingness:

> MARIA: The use of spreadsheet as a medium shows the learners how to get the value of ‘a’ (referring to figure 2). Learners can change the value of ‘a’ until they find its real value. The learners then realised that the two graphs are the same. Before they just changed the number without knowing the specific value but surprisingly they could see that the two graphs are the same.

Maria had the perception that using this specific SAP could help her learners to find the solution of the task, even if the learners were only trying to change the different values of the parameter *a*.

In an actual classroom situation, it is possible for learners to explore the possibilities and not necessarily be wrong. It is possible that the use of SAPs can enable learners to plot functions in a short time, manipulate graphs and improve generalisations about the functions (Swanepoel & Melake, 2010), thereby contributing to a possible conceptual understanding of linear and quadratic functions. In other words, there are interrelationships between the multiple representations.

In the above quote Maria's comment was pragmatic, not epistemic, because the technique used only produced a result without a deep understanding as to why the two algebraic expressions were equivalent. The possible effectiveness of this SAP involved converting the spreadsheets from being an artefact to becoming an instrument that could be used to solve linear equations. As a result learners could spend more time investigating the mathematical concepts embedded in this specific task. Varying the values of *a* has an epistemic role (Kieran, 2004) because it can enable the user to acquire a conceptual understanding of related numerical, tabular and graphical changes.

> MARIA**:** I would expect them to learn more about parabola using spreadsheets as a medium. This will help learners to interpret information quick and easier from the graph. They could find values of x and y without solving the equation.

In the above quotation Maria noted how the learners' possible experiences using SAPs might open up possibilities to explore more information (multiple representations) easily and quickly with less calculation. Indeed, the spreadsheet program used gave almost instantaneous responses when data was inputted into a formula. This enabled the rest of the participants to be more interactive and responsive to the output. They were able to test their evolving ideas and theories quickly and model situations relatively easily. She expected that the learners could also learn important issues relating to the parabola using SAPs.

During the second and third meetings the teachers were shown and allowed to explore a SAP called "The discriminant of a quadratic function" (See figures 3 and 4, below).

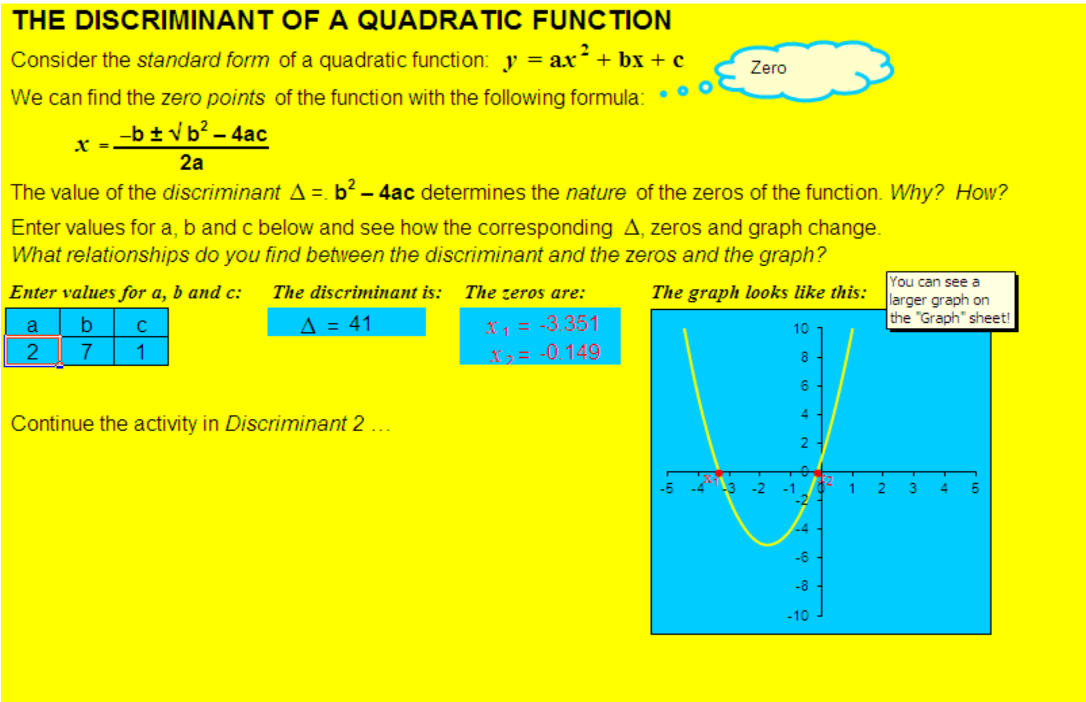


Figure 3: A “page” from SAP “The discriminant of a quadratic function”

(*Source*: Research Unit Mathematics Education, University of Stellenbosch, 2000, [RUMEUS])

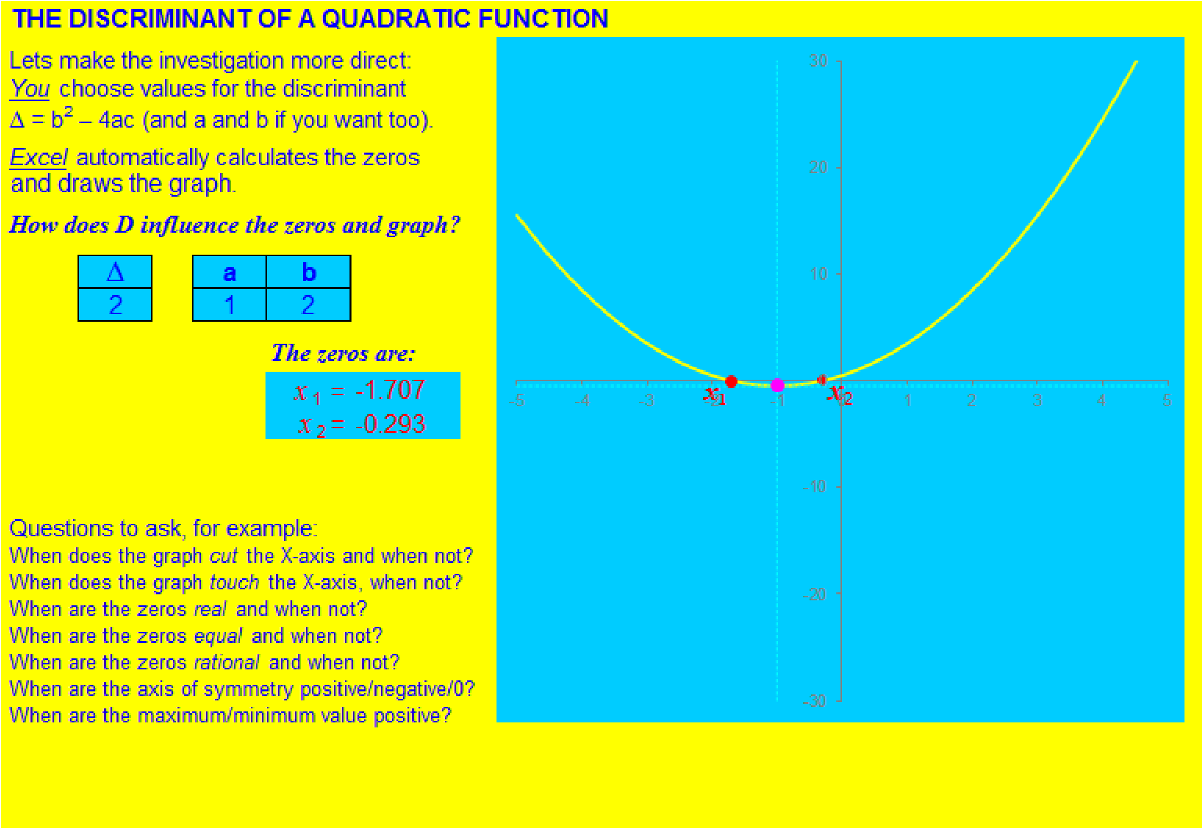


Figure 4: Another "page" from a SAP titled "The discriminant of a quadratic function"

(*Source*: Research Unit Mathematics Education, University of Stellenbosch, 2000, [RUMEUS])

This SAP was designed to explore the different values of the discriminant of a quadratic function $y = ax^2 + bx + c$. This SAP can be used to provide a conceptual understanding of the discriminant (Artigue, 2000; Drijvers, 2005) and a symbol sense for the values a, b and c in $b^2 - 4ac$. The discriminant in mathematical form is given as

$$\Delta = b^2 - 4ac.$$

The following excerpt from teachers' writing and from interview transcripts during meeting two related to discriminant of the quadratics function gives a typical picture of their experiences interacting with this SAP as an activity.

RESEARCHER: What did you learn from this activity?

> GIFT: I have learned that if you change the value of *a* and *b* in the quadratic function there is a possibility that the curve remains the same or the curve is cutting at one point of the x-axis.

RESEARCHER: When the value of the discriminant of the quadratic function is equal to zero, what happens?

> MARIA: There is one solution. When the value of the discriminant is greater than zero there will be two solutions.

> PETER: If the discriminant is less than zero then there is not real solution.

RESEARCHER: When does the graph cut the *x*-axis and when not?

> MARIA: The graph cuts the x-axis when the discriminant is more than zero or equal to zero.

> GIBSON: I think you are wrong; the graph cuts the x-axis when the value of Δ is greater than zero.

> MARIA: Yes, if delta is greater than zero, the graph will cut the x-axis. Now I see when the graph cuts the x-axis.

In the beginning the teachers were not sure how the different values of the discriminant were related to the graph behaviour. When the value of the discriminant is less than zero ($\Delta < 0$) the graph does not cut the *x*-axis. When the value is ($\Delta = 0$) the graph touches the x- axis, and when the value is ($\Delta > 0$) the graph cuts the *x*-axis twice. There is no clear evidence about how well the teachers understood the relationship between the different parameters and behaviour of the graph. At this point, pragmatic comments dominated the teacher's conversations and the epistemic understanding of the possible causes of the graph behaviour still remained hidden.

However, this specific interaction with the teachers created an opportunity for them to be more curious as to how the SAP is used and how other representations (multiple representations) could or might enable them to find relationships between the values of the discriminant and the possible graph behaviour.

RESEARCHER: What can you tell me about the axis of symmetry?

> PETER: Oh. If the value of b is negative, then the axis of symmetry is positive, so when the value of b is positive then the axis of symmetry will be negative; the way I see these things (axis of symmetry), I think my learners will learn as well.

Peter recognised the pragmatic aspects when entering different values of *a*, *b* and *c* when using the SAP. He identified the actual behaviour of the axis of symmetry when the values of *b* were positive or negative. According to our observation Peter was excited in how this SAP could give more than one representation at the same time. Nothing like that happens in the traditional methods of teaching algebra. Peter hoped that in the future, when using SAPs in teaching that his students would also learn like this.

These comments have allowed us to see how different teachers' perceive the discriminant of the quadratic function when using SAPs. Some of them discovered for the first time ever the relationship between graph behaviour and the value of the discriminant without any frustration or boredom. My personal observation was that the teachers' willingness and enthusiasm became more evident as they continued to interact with each other and the SAPs. While teachers were learning how to use the SAPs they also commented on the possible future impact of using spreadsheets in their algebra teaching and of the benefits in deepening their learners' understanding of linear and quadratic functions.

> HAROLD: The spreadsheet algebra programs enable the learners to understand concepts better, especially when one is teaching straight line and quadratic functions. They can discover themselves how the graphs behave as the parameter change.

MARIA: what I have learned here make me think about of using SAPs, because learners can see clearly what is happening and can understand the content much better.

According to our understanding, linear and quadratic functions are some of the most difficult topics in the mathematics curriculum in Namibia. In an overall sense, the teachers showed excitement and a willingness to use SAP as a new tool.

The following excerpts are examples of the teachers' participation during meeting three.

RESEARCHER: Think about a real situation in the classroom, where you will present a solution of a linear equation using one of these SAPs. Do you think your learners will have better understanding of the task?

PETER*:* Yes, such an exercise will enable them to have better understanding of the discriminant.

RESEARCHER: Can you tell me why?

PETER: Some of these things are new to me. I'm learning by playing with this for the first time, I think learners can discover their own answers as I did.

MARIA: It is the visual representation and numerical answers as well.

GIFT: Yes, I can see.

RESEARCHER: Can you see the real potential of spreadsheets as a medium that can deepen algebra understanding?

PETER: Sure, very much interesting. Everyone can be curious to see what is happening to the graph.

Now I know how to enter the formulas in spreadsheet. I will invite a few of the grade 11 learners to come to the computer laboratory. The learners will perform linear equations using paper-pencil method. Thereafter they will be shown how to use spreadsheet to compare the result obtained. This will help learners to come to some good conclusions.

> GIFT: I have learned much here, I'm quite confident to use spreadsheet in my everyday mathematics teaching, specially the linear and quadratic functions.
>
> This program makes work easier for the learners. They could see what happened, for example, when the values of 'a' and 'b' of the discriminant change, the graph also change.

RESEARCHER: Did you learn anything new from this activity, which you did not know before?

> GIFT*:* I was aware of everything in this activity, but then, using spreadsheets makes my work easier. I feel like if I was going to use this program in the future, my learners will have a better understanding of what is happening in mathematics.
>
> PETER: Some of the things are new to me.
>
> MARIA: Yes, it was my first time to learn about the discriminant of the quadratic equations.
>
> GIBSON: Yes, when I attended the research project sessions I realised that spreadsheets can enhance learners' interest and understand, and improves learners' participation in class because they can work on the screen which is very interesting.

The category related to willingness (as a perception) with its pragmatic and to a lesser extent epistemic dimensions, identified a range of perceived practical, motivational and educational benefits which underpin the teachers' evident enthusiasm for using ICT (spreadsheets). Thus teaching linear and quadratic graphs using SAPs might enable learners to gain insight that enables them to construct richer and more coherent graphing concepts and to develop important techniques needed to reason with mathematical algebraic ideas (Asp, Dowsey & Stacey, 1992).

4.2.3 Case 3

A teacher's perceptions were evident in his teaching of linear functions through spreadsheets: His teaching revealed specific epistemic and pragmatic dimensions.

Case 3: In a particular instance, a teacher perceived spreadsheets as useful as curriculum material and used it to teach linear functions to his grade 11 leaners.

Background and context:

Towards the end of collecting data one of the teachers (Peter), decided to use spreadsheets to teach linear functions to his learners. He agreed to have the researcher observe his teaching. Peter's decision was a result of his willingness and enthusiasm to use SAPs in his mathematics teaching. Peter held a certificate in International Computer Driving License (ICDL). This is one of the courses available for teachers in Namibia to upgrade their computer knowledge. For his teaching session Peter organised a class of 15 Grade 11 learners to meet one afternoon after school. This one-hour meeting took place in a computer laboratory. Learners each had her own computers. Peter did not use a ready-to-use SAP but instead used his own program (a blank spreadsheet) to show and compare the results with the pen-and-paper linear equations (LE) that had been discussed in a previous lesson in the classroom the day before. It is important to mention that it was Peter's first time using spreadsheets in his teaching.

Peter's teaching was videotaped and audio-recorded. The purpose was to explore more about his perceptions of spreadsheet potentialities and affordances as a curriculum material. In his teaching session he demonstrated how to move from a pen-and-paper linear function (LF) $[y = 2x + 4]$ towards using a spreadsheet-based version of this LF. To do this there was a need to orchestrate between the two different mediums, Pen-and-paper and the spreadsheet. He had to guide learners on how to make the spreadsheet a mathematical instrument through particular actions.
We now focus on how Peter guided his learners' construction of meaning for the linear function $y = 2x + 4$. This construction of meaning is related to the meaning of algebra through the use of formulae and graphing and specifically to the meaning of the variable through the notion of a "variable cell" and a "variable column" (Haspekian, 2003).

Peter's lesson involved demonstrations of how to construct a spreadsheet formula (=$B$5*(E5) +$B$8), how to drag down this formula and how to construct a scatter graph. (See figure 5). Firltly he started entering the formula in *Excel* with equal sign (=). The equal sign informs excel that what is follows is part of a formula and also is an instruction for a computation to happen.

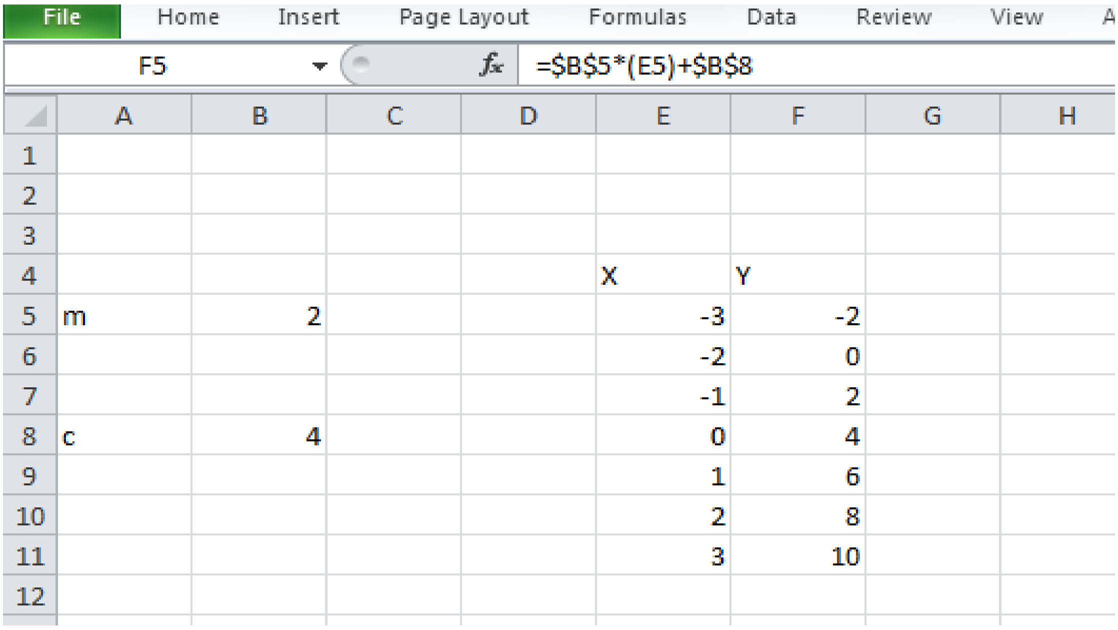
Secondly he entered the absolute reference of $B$5 which correspond with the gradient (m=2), then multiply (*) the value of the gradient by the initial value of x= -3 and finally add (+) the absolute reference $B$8, which is the value of y-intercept.

Peter showed the learners instrumented as well as pen-paper procedures, often using the chalkboard to demonstrate how they produced the table for this specific exercise in previous paper-and-pen lessons. In many cases the technical aspects of how to enter the formula in spreadsheets were interwoven with his commentary, which aimed to draw learners' attention to particular aspects, such as the need to use certain spreadsheet notation.

> PETER: Now move to the next column near 8 and type equal sign there. What is the value of c? Ok, let put 4, now go to column E, cell 4, where column E and cell 4 meet, notice that when you click in that cell, the computer will respond, highlighting E as well as 4, just there put x, now go to the next one right side and put y. Now, I want you to go again to your table (pen and paper version). Tell me what was the smallest value used from this table?
>
> LEARNER 1: negative 3 (-3).

Peter used personal pedagogic strategies, probably with the aim of guiding the learners' progress in understanding spreadsheets and making links to the paper-and-pen activities in the curriculum.

Some others evidence from the audio/video recordings of how Peter guided or orchestrated learners through this specific spreadsheet activity of drawing a linear function will be presented next.



File | Home | Insert | Page Layout | Formulas | Data | Review | View

F5 =$B$5*(E5)+$B$8

	A	B	C	D	E	F	G	H
1								
2								
3								
4					X	Y		
5	m	2			-3	-2		
6					-2	0		
7					-1	2		
8	c	4			0	4		
9					1	6		
10					2	8		
11					3	10		
12								

Figure 5: A'page' from the spreadsheet construction of the linear function Y=2X+4

PETER: Now go again to your spreadsheet and press -3 for the first value of x, go down pressing -2, -1, 0, 1, 2, 3, 4 and so on, these are the range of values of x, from -3 to 4. Our equation is y = mx +c (writing in the chalkboard), now we are going to enter this formula in the spreadsheet. There is a way that you can enter this equation and automatically the computer will give us the straight line or will respond spontaneously. Go to the next column near y, click there and press the equal sign, shift then dollar sign ($), now we want to enter the value of 2, but we are not going to put 2 as a number. Where is number 2 in the spreadsheet?

LEARNER 1: in B5.

PETER: Ok, then add multiplication sign after $B$5 . It seems as if you are having problems to do that, probably because you did not cover spreadsheet in your computer lesson yet.

In leading the leaners through this specific linear function using spreadsheet activity as an instrument, considerable time was spent on explaining step by step how to enter the formula (y = 2x + 4) in the spreadsheet. Peter encountered difficulties in entering the formula correctly. For example, when a formula is filled down through dragging the cursor down, learners see a range of values as a list in the variable column. The formulae then include different variable cells such as A5, B5. However in his demonstration he drew learners' attention to the meaning of the variable columns B, E and F (Figure 5) and developed certain rules of "dragging down" (an instrumented action) the formula, but little attention was given to the meaning of this process. It seemed that in his intention to guide the learners, he needed to keep track of how and where the different algebraic objects, whether numbers or letters in cells, such as y = 2x+4 were written in their corresponding spreadsheet syntax. In *Excel* a function's syntax refers to the layout of the function and includes the function name, bracket and argument. Examples are the absolute references for the parameter needed to fill down and drag, thus producing a relationship between numbers across columns. However, he realised that there were mistakes in terms of spreadsheet syntax somewhere during his explanation. He localised the problem and successfully used the absolute reference "$" (typing a dollar symbol before the numbers and letters of each cell reference). Peter's difficulties, such as the use of spreadsheet syntax, are examples of the technical work related to using the spreadsheet and its epistemic aspects. Such technical work has pragmatic as well as epistemic aspects that are connected to instrumented techniques.

PETER: I think it is wrong.

LEARNER 1: Yes, it is.

LEARNER 1: my values are not the same. The values are -2, 0, 2, and 4

PETER: I see the values are not exactly the same. We can try again, maybe there is something wrong somewhere, let's deletes everything and try again. Let's find the values of y again. Ok, go to the equal sign, enter the dollar sign $B$5, then multiply by E5, enter the $ sign here, than add $B$8, then press enter. I think it is right now. Now we highlight the entire x and y values and drag down like we did before. From there go to insert, select charts, then xy scatter and finish. That is the straight line graph for these specific values. (See Figure 2 below)

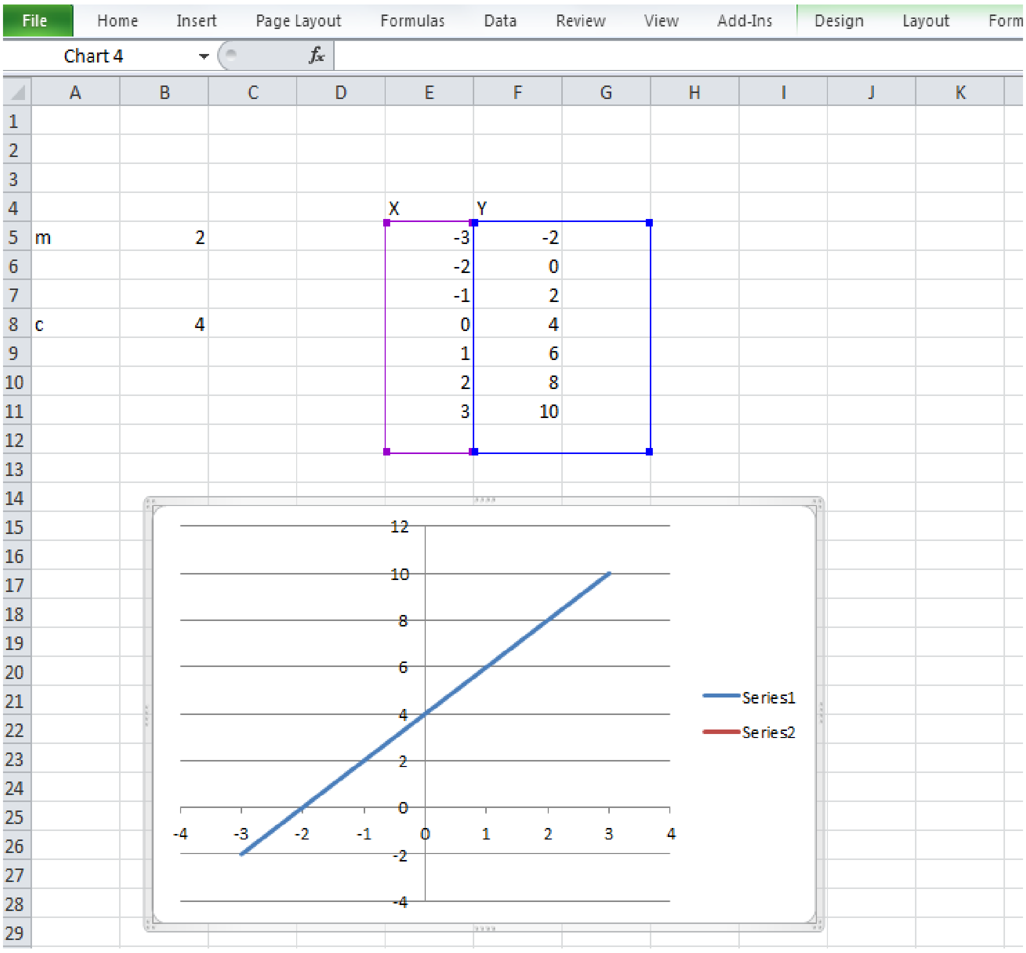


Figure 6: A spreadsheet graph of the function y=2x+4

The above shows evidence of how Peter ran into difficulty orchestrating between pen-and-paper and the spreadsheet syntax. One possible way around these difficulties, would have been to work collaboratively with the computer teacher in the school. The learners had to learn the spreadsheet syntax almost simultaneously while developing deeper knowledge of the symbols such as m and c (as in $y = mx + c$). More importantly, Peter must have realised that he was working with a different "medium", i.e. spreadsheet algebra, which pre-supposes a particular set of skills related to learning the spreadsheet syntax compared to pen-and-paper algebra skills.

This is an indication of the need for Peter to work on learners' knowledge of spreadsheet syntax and how to orchestrate this knowledge with pen-and-paper equivalent knowledge forms. What Peter did in the aforementioned, showed his perception as his “early vision” or object perception of spreadsheets as a curriculum material or as a resource. Early vision does not include the entire cognitive system (memory, concepts etc), which in this case are the graphical, numerical and tabular representations. In other words, these are the instructional affordances of spreadsheets that Peter needed to use to draw learners cognition onwards. It is the epistemic aspects of the representation that should be tapped into for the learners to understand the meaning of the gradient *m* and *y* intercept. These are fact perceptions, i.e. they link the representations and meanings.The pragmatic aspect such as saving time (the computer is faster) is a particular instructional affordance that is necessary in actual school teaching.

The fact that Peter had to end his teaching session when the learner spoke about the computer being faster, means that he and the teachers who intend on using SAPs, must realise that there are also epistemic aspects, such as the multiple representations, graphics, numeric and syntactic (symbolic) that need to be attended to for deeper understanding (Ainsworth, 1999).

> PETER: Let’s say for example, you master the spreadsheet and you have an activity to solve. Are you going to use the traditional way or the computer?
>
> LEARNER 1: I will go for the computer.
>
> PETER: Why?
>
> LEARNER 1: Because the computer is faster.

However, there are glimpses of early vision in Peter’s perceptions of SAPs in terms of learners’ possible understanding of LFs. (See figure 5).

> LEARNER 4*:* We have learned how to plot values in the computer using spreadsheets and how to get the values of X and Y, and also how to add different values of the gradient m and y- intercept.
>
> PETER: Ok, in the position of 2 let’s put this time -2, and press enter, what happens? Any change?

LEARNER 4: Yes, now the line is cutting the positive side of the graph. The positive gradient will change from the right to the left.

PETER: And the negative gradient?

LEARNER 4: The line will move from the left side to the right.

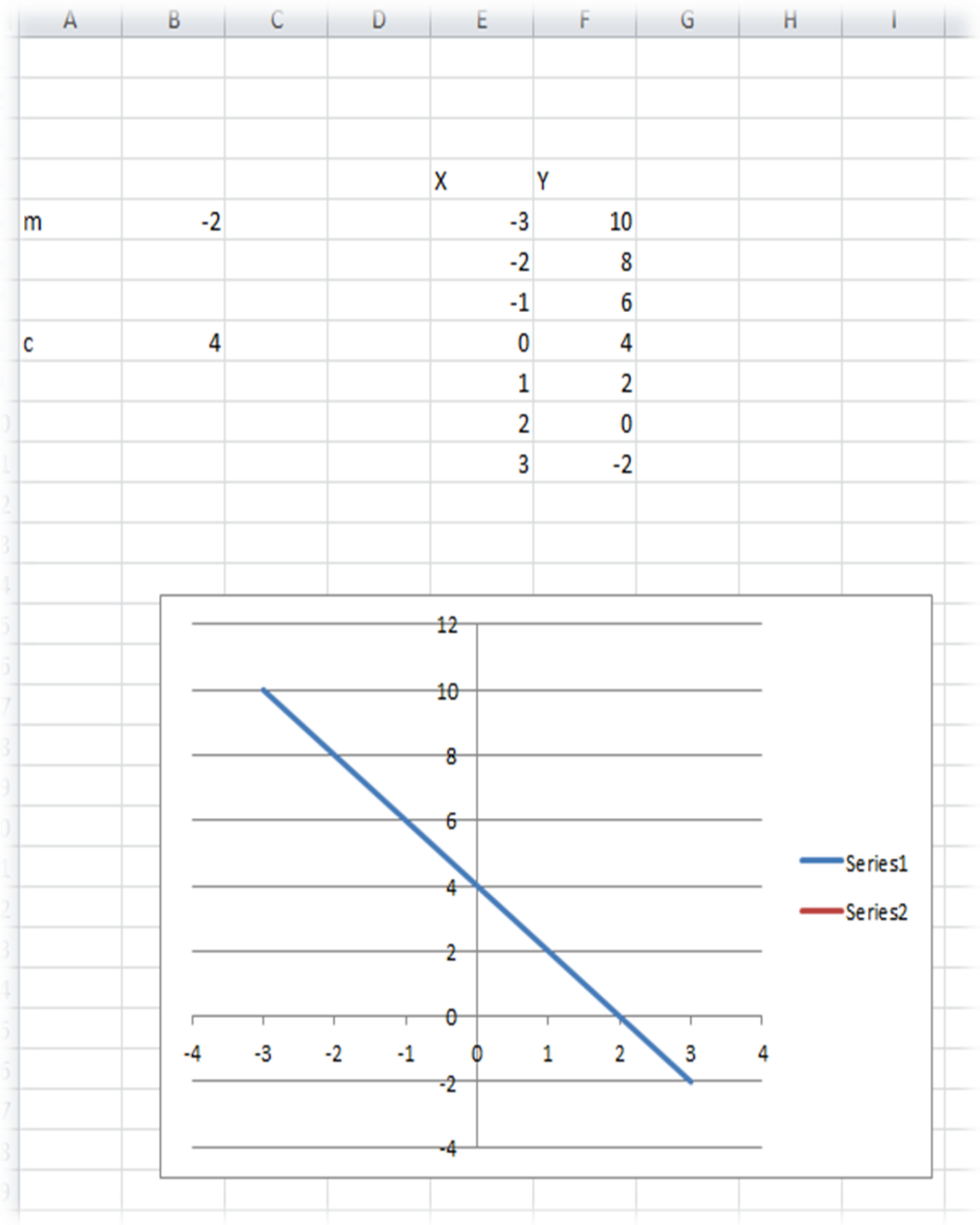


Figure 7: A graph with a negative gradient (Y= -2x+4)

4.3 Summary

In this chapter I reported the findings, i.e. how the teachers perceived SAPs as curriculum materials and a discussion on these findings. The following three cases were found:

1. Time concerns and constraints influence teachers' perceptions of spreadsheets use and SAPs as curriculum materials.
2. Teachers' enthusiasm was growth while they continued to interact with each other and the SAP. While teachers were learning how to use the SAPs they also acknowledged the possible future impact of spreadsheets in their algebra teaching, focus their perception on the possible benefit in deepen the learners understanding of the linear and quadratic function which in term is one of the difficult topic in their mathematics curriculum, also they showed excitement to use this new didactic tool.
3. In a particular instance, a teacher perceived spreadsheets as useful as a curriculum material and used it to teach linear functions to his grade 11 leaners.

For example, in case 3 we saw how Peter perceived spreadsheets to the point where he used it for the first time to teach linear functions to his class of grade 11 learners. He is a teacher who has some knowledge of spreadsheets and was willing to use that knowledge. In an implicit sense he sees spreadsheets as a curriculum material that might be useful to his teaching. He needs more opportunities where he learns to experience relations between the pragmatic and epistemic dimensions of spreadsheets use when it comes to linear functions. In particular, there are relationships between numerical, graphical and symbolic representations, i.e. the affordances of spreadsheets.

The teacher-learners interaction with multiple representations of the algebraic objects in the spreadsheet can promote enhanced learning, thus enabling broader perceptions than might have been gained from the single representation of the same algebraic object (Calder, 2010). Hence the use of SAPs could help mathematics teachers to play an important role in influencing learners' mathematical thinking, particularly in the context of algebra learning, through multiple representations. If SAPs can be used to enhance teachers and learners algebra understanding, then it is reasonable to think that there is a need to balance the development of the spreadsheet environment with the mathematical thinking (Calder, 2010). On the other hand, mathematics teachers should not be expected to create and develop their own spreadsheet activities, but as they gain familiarity and their repertoire of abilities develops, this could become possible. The teachers experience is also linked with their ability to systematically orchestrate the learners through the technological environment and for them to eventually work independently with spreadsheets as a tool (Burn-Wilson & Thomas, 1997 in Calder, 2010).

Finally, the cases in the above identify a range of perceived practical, motivational, and educational benefits which underpin how the teachers perceive SAPs as curriculum materials. Thus teaching linear and quadratic functions using SAPs might bring teachers and learners to insights that enable them to construct richer and more coherent graphing concepts and develop important techniques needed to reason with mathematical ideas (Asp, Dowsey & Stacey, 1992).

CHAPTER 5

CONCLUSIONS AND RECOMENDATIONS

5.1 Introduction

This study examined teachers' perceptions of spreadsheet use in algebra teaching and learning, specifically spreadsheet algebra programs (SAPs) as curriculum materials in Namibian high schools. The decision to focus this research on SAPs in the Namibian high school mathematics curriculum was motivated by the fact that almost all schools in Namibia were equipped with computers with spreadsheets in the form of *Microsoft Excel.*

An important reason for conducting a study of this nature was to contribute towards the limited literature surrounding this topic, specifically in the case of Namibia. Namibia, like other developing countries, is challenged by a lack of qualified personnel to lead the promotion of ICT, especially in mathematics education.

Moreover, it is believed that this study has the potential to contribute to teachers' involvement in curriculum decision making in order to consider ways in which SAPs might support algebra teaching and learning.

The research objective was to find out teachers' perceptions of the potential use for ICTs such as SAPs in the teaching and learning of high school algebra.

5.2 Summary of findings and conclusions

This section will revisit the research objective as stated above, summarise the findings of this research work and offer conclusions based on the findings.In the previous chapter the case study results was a large section and needs to be summarised, hence the summary in this chapter. Recommendations, limitations and reflection for future research will also be discussed, in terms of how to progress further with this research study.

Teachers' perceptions of SAPs as curriculum materials and as resources to teach algebra at secondary level in Namibian high schools were presented in the following cases.

> **Case 1:** Firstly, the study revealed teachers' perceptions about *time concerns and constraints* with regards to spreadsheet use in algebra teaching and the SAPs.
>
> **Case 2:** Secondly, the study revealed teachers' willingness and enthusiasm to use SAPs on linear and quadratic functions in their teaching; this willingness has pragmatic and epistemic dimensions.
>
> **Case 3:** Thirdly, the study revealed how a teacher's early vision about the use of spreadsheets as an instrument to teach linear functions can produce pragmatic value. In his excitement, the teacher overlooked the fact that learners require computer skills in order to perform activities on the SAPs.

From these research findings the following conclusions were reached and these recommendations were made.

Conclusion 1 – based on the findings of **case 1**, teachers perceived that using spreadsheets and SAPs could assist them in teaching linear and quadratic functions more effectively. They felt that using ICTs, such as SAPs, made it easier for students to look at more examples in a shorter time. Therefore, it can be concluded that teaching mathematics using SAPs, uses less time in comparison to using the traditional symbolic manipulations associated with algebra.

T**he recommendation** that can be made from this conclusion is about what needs to be taken into account if an ICT such as spreadsheets is to be used as part of in-service professional development. Part of teachers' development is to offer in-service professional development about the technology that is used in mathematics. This helps teachers to learn how their knowledge and skills in algebra could be used in the classroom more effectively in order to save time. It is recommended that teachers should not only learn about the technology hardware and software, but also learn the practical skills that they can use in teaching. By using ICTs such as SAPs correctly, might help them to carry out their particular algebra teaching in a shorter time.

Conclusion 2 – based on the findings of **case 2**, there was an undisputed expression of interest and willingness to use ICTs to support the teaching and learning of mathematics education, especially algebra. Yet a primary barrier to teachers' readiness and confidence in using ICTs, despite general enthusiasm and belief in the benefits for learners, was their lack of relevant preparation. The teachers in this study were willing to use ICT in their teaching practice. They felt that by using ITC they could provide authentic learning experiences, teach new applications and provide opportunities for the learners to work more confidently in the new technological environment. An example of this enthusiasm was Peter, who proposed to teach linear function through SAPs to 15 selected Grade 11 learners during this research. Correspondingly at meetings held during the data collection process, the teachers commented on how much they enjoyed the experience of using the spreadsheets on rich, open-ended problems.

> PETER: Now I know how to enter the formulas in spreadsheet. I will invite a few of the grade 11 learners to come to the computer laboratory. The learners will perform linear equations using paper-pencil method. Thereafter they will be shown how to use spreadsheet to compare the result obtained. This will help learners to come to some good conclusions

The recommendation that can be made from this conclusion would be in the design of future professional development programmes. They need to be designed to stimulate and promote teachers willingness and to construct an understanding of the characteristics of ICT applications and ways in which they can promote mathematical understanding.

Conclusion 3 – based on the findings of **case 3,** for students to work independently with spreadsheets as a tool they initially require computer skills development embedded in mathematical contexts (Burns-Wilson & Thomas, 1997 in Calder, 2010). Evidence from the study showed that teachers' early visions of teaching algebra using SAP could be of both pragmatic and epistemic value, in the sense that it could produce positive results as well as deepen learners understanding of algebra. What Peter definitely overlooked or was not aware of the epistemic value of the spreadsheet as a mathematical tool. Instead he becomes excited about the pragmatic values of the spreadsheet, i.e. a tool or a medium to draw the linear function. The epistemic value of the spreadsheet lies in using it to explore the influences of the symbols 'm' and 'c' and related changes in the graphical and tabular representation of a linear function (y=mx+c).

The recommendation from this conclusion is that new software be designed to improve algebra learning. The design of such software may deepen the understanding of school algebra at secondary level. Working group 6 from the Congress of the European Society for Research in Mathematics Education (CERME) describes two pieces of educational software (Lagrange & Chiappini, 2007). One of these was designed for the teaching of functions and variation, and combines features of computer algebra and dynamic geometry. The other was developed to provide versatile means of representing algebraic expressions and the solution sets of their associated equations and inequations. It is believed that these are relevant to the Namibian situation as well.

Furthermore it is recommended that the mathematics teachers, in collaboration with the computer teachers, help learners to acquire the necessary skills needed to use spreadsheets more effectively. In this way the mathematics teachers may not spend a lot of unnecessary time explaining the techniques of spreadsheets because the learners would have acquired the ICT skills beforehand.

5.3 Limitations

The most important limitations of this study related to teachers' perceptions of SAPs as curriculum materials in Namibian high schools can be highlighted as follows:

- A small sample size, which was not representative of mathematics teachers in the Ohangwena region.
- Poor or almost no sustained Teacher Professional Development (TPD) with regard to the use of ICTs in mathematics education, as emphasised by Government through ETSIP.
- Time constraints as a major challenge in the implementation of SAP in Namibian schools.
- More time needed to be spent interviewing and observing the teachers teaching the same algebra in the classroom as the SAPs in the computer room. This may have enabled the study to reach broader findings and more could have been learned about the similarities and differences.

5.4 Reflection and future research

5.4.1 Self- reflection

Why the use of spreadsheets or SAPs in school mathematics teaching?

I was always concerned about the challenges teachers and learners faced in mathematics, especially algebra. This research has shed light on how to approach these difficulties in teaching and learning algebra. Through my research, I have discovered that SAPs are important didactic tools, which can significantly reduce the challenges faced in secondary (high) schools with mathematics as a subject. These challenges contributed to the increasing difficulty in motivating learners and maintaining their interest in mathematics. The findings shared some commonality across the teachers' interactions, in that the majority of them, according to their comments, revealed willingness to possibly use SAPs in their future algebra teaching.

According to this finding, using spreadsheets a as tool may lead to a deeper understanding for learning and teaching algebra.

In Namibia the teaching and learning of mathematics, especially algebra, in the secondary schools has been dominated by the pen-and-paper technique, which has created difficulties in the teaching of algebra (as discussed in chapter 2).

The literature reviewed for this study has shown strong evidence that spreadsheets might help learners to develop powerful mathematical ideas such as generalisation, symbolisation and functional relationships (Healy & Sutherland, 1990). Studies conducted by Filloy, Rojano and Rubio (2000) and Kieran (1992) to mention a few have claimed that spreadsheets would enable learners to cope with the transition from a verbal representation to a symbolic representation, from the specific to the general, from the known to the unknown and from the perception to conception. Also the use of spreadsheets could contribute positively to learners' mathematisation in the domain of beginning to learn algebra, and they have been successfully used as a technology tool for other areas of mathematics (Hershkowitz et al., 2002). In addition, spreadsheets are interactive, they can give immediate feedback to changing data or formulae and they enable data, formulae and graphical output to be available instantly. These are some of the reasons why I wanted to undertake this study.

The teachers in this research showed some familiarity with the use of computers. However, internationally there is research evidence that shows that by simply improving teachers' access to technology has not generally lead to increased use or to movement towards more learner-centred teaching practice (Cuban, Kirkpatrick & Peck, 2001; Wallace, 2004).

This suggests that teachers should learn to use a computers as cognitive tools to improve learners learning of content materials (e.g. mathematics) rather than acquiring isolated skills in basic computing application (e.g. word processing, and spreadsheets). Thus to promote the use of technology for the learners' conceptual development, mathematics teachers should learn how to use widely available software, such as spreadsheets, as a conceptual teaching and learning didactic tool (Abramovich & Drier, 1999).

Teachers' interaction with SAPs has allowed me to identify a range of percieved practical, motivational and educational benefits that underpin the use of such programs. On the other hand there is a need to take into consideration that the pedagogical and technical ability of the teachers is absolutely critical. Thus to use SAPs in their future algebra teaching, the teachers should know how to use these didactic instruments properly. The critical issue is not in the instruments themselves. In other words, instruments are not didactic in themselves; it is the way in which they are used to support learners' constructions of increasingly complex cognitive structures that are (Thompson, 2002). A particular case in this research (Peter teaching his learners using his own SAP) showed that the use of spreadsheets as didactic objects might be good practice for mathematics teachers in addressing some of the difficulties that occur when teaching algebra. This teacher encountered some difficulties in his teaching because it was his first time using SAP in his mathematics teaching.

5.4.2 Future research

This study was restricted to a specific geographical location and teacher population. It was also limited to a short time period of investigation with only five participants, providing baseline data on teacher perceptions of SAPs as curriculum materials. Hence, it would be advisable to conduct other future studies with a larger scope and a more in-depth focus to explore what might happen in other regions that were excluded from this study. This would include more participants who are eager and who show commitment to use SAPs in their teaching. This may be a way to motivate mathematics teachers to discover the potential benefits (and limitations) of SAPs as tools to provide rich and deep understandings of important algebraic concepts such as variables, expressions, equations and solutions in secondary school mathematics.

This study recommends that in-service professional development must be included on the use of ICTs, such as spreadsheets and SAPs, in mathematics teaching and learning. This may help teachers to learn how their knowledge and skills could be used in the classroom more effectively in order to save time. The latter is a pragmatic concern. This can be achieved with the help of teachers that have acquired the necessary technical and pedagogical skill related to ICT (spreadsheet) helping others.

If the purpose of in-service professional development is to produce real solutions, it needs to be delivered over a longer period of time in order to effectively change the confidence levels of teachers in the use of spreadsheets. Therefore, one to three day workshops are not sufficient to address this problem effectively.

A final observation that emerged from this study was that time and access to ICT needs be provided to mathematics teachers. This access to ICT would mean that teachers were better-informed, skilled, ready, and possessed the correct tools to contribute more effectively in the teaching of mathematics in high schools. Research shows that ICT may significantly enhance learners' development of important competencies, foster better attitudes towards mathematics, and stimulate a wider vision of the nature of this subject (NCTM, 2000). Thus teachers are important players in making this development happen.

It is recommended that further research into this field regarding teachers' perceptions of SAPs should be undertaken. It would be of great help in finding out more about teachers concerns of how to minimize the actual algebra learning difficulties in the Namibian secondary/high schools.

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APPENDICES

Appendix A

A spreadsheet algebra program (SAP) exploring "equivalence"

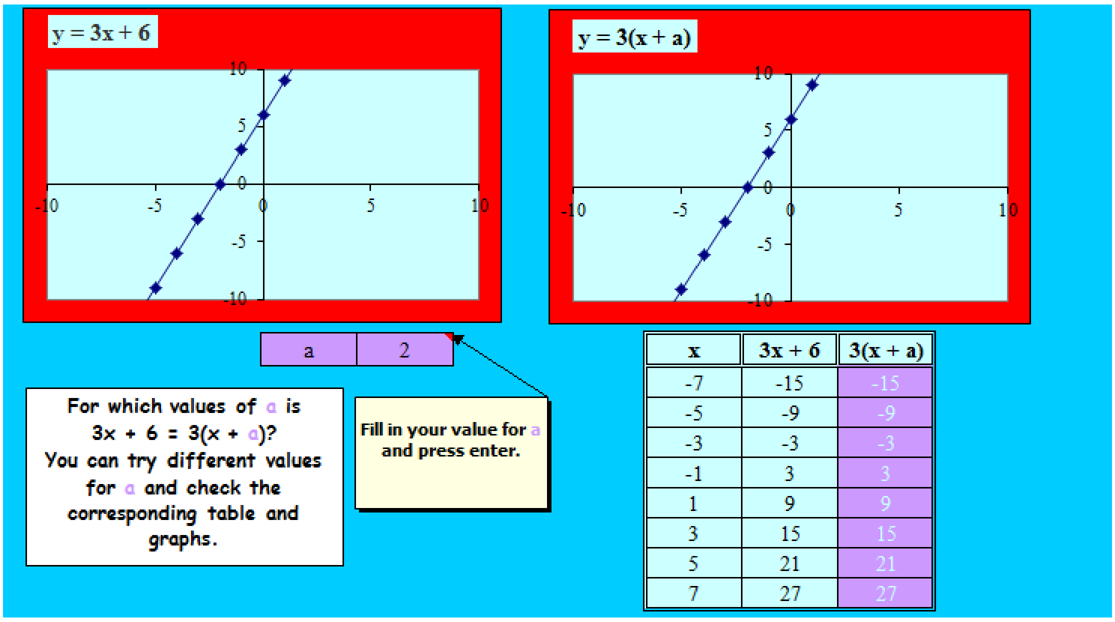

Figure 1: A "page" from SAP exploring "equivalence"

Appendix B

A spreadsheet algebra program (SAP) exploring “The discriminant of a quadratic function”

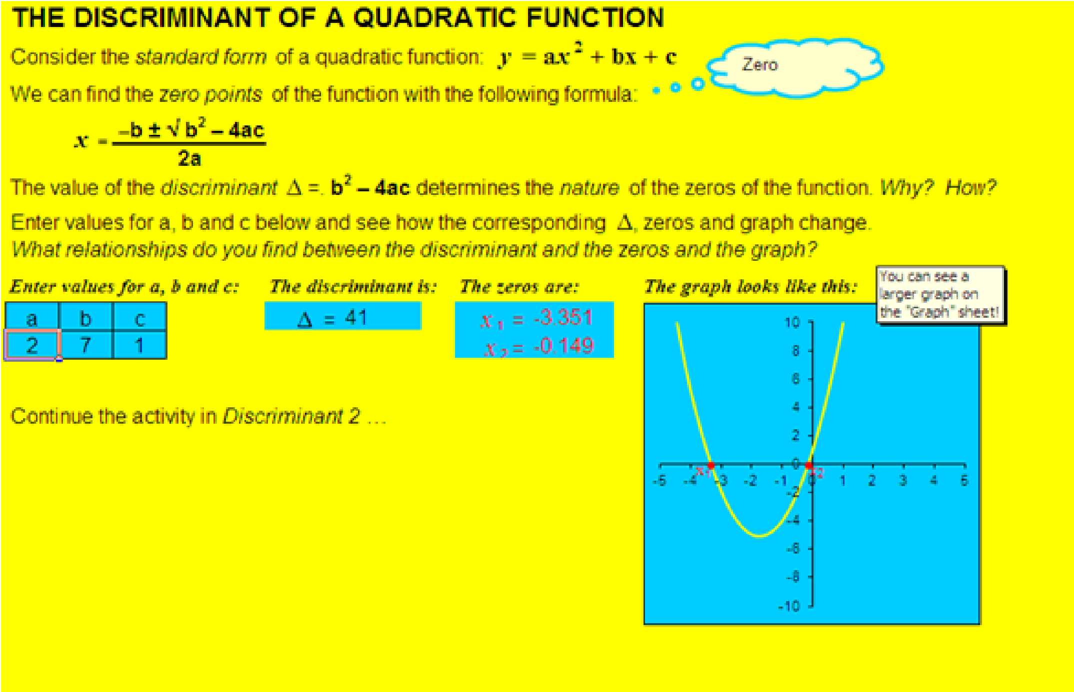

Figure 2: A “page” from thea ASP on the discriminant of a quadratic function

Appendix C

The interview schedule for the participants in the study

Research project:

Teachers' perceptions of spreadsheet algebra programs as curriculum materials in secondary school mathematics

Ricardo Rodrigues Losada

Meeting one

Background information

At the beginning of the research project the following details will be collected from the participating teachers:

1. Respondent's name and contact details:--
2. Sex: male or female:---
3. Number of years teaching:-- -
4. Grade level you are teaching: --
5. Name of school/ location of school:---

6. Familiarity/ non-familiarity with information communication and technology (ICT)? Give examples:

   ----

7. Are you involved in any ICT learning/networks? If yes, give details.

   ----

8. How long have you been using ICT? Why?

   ----

9. Familiarity with spreadsheets? If yes, provide details.

   ----

10. Have you ever used spreadsheets in relation to the secondary school mathematics curriculum? If yes provide details.

    ----

11. Do you believe that there is a role for ICT/spreadsheets to deepening algebra learning? Please elaborate.

Reason:

1. To develop a database of the participating teachers and communicate with them electronically about further details of the research.

2. To find out familiarity with spreadsheets.

3. To see whether they are connected to any ICT networks.

4. To provide background details on the teachers in order to help with explaining findings.

In this session the researcher will demonstrate one activity of spreadsheets-based functions/equations.

Demonstration one: straight line graph (linear functions)

After every contact session, the teachers will be asked specific feedback regarding the session. The following are examples of questions that will be posed to the teachers:

a) What did you like about today's session. What was today's session about. (In your own words).

b) How does today's session make you think about the related linear function ideas that you teach in your classroom? Please elaborate.

c) What about today's session was new for you and why? Please say more.

d) What do you make of the differences between spreadsheet use and the pen-and-paper version of the same linear function in the classroom?

Teachers' responses to these questions will be in written form. At times teachers responses to the same questions will be collected through semi-structured interviews.

Meeting two

Questions on algebra learning

Please answer the following questions to the best of your knowledge. Responses will be confidential; your privacy will be protected to the maximum. Responses will be used only with the purpose of understanding how teachers know and apply spreadsheets as a medium of school algebra teaching. In some cases, actual written work may be used in the discussion of results in my project. If this is done, your name will not be used.

1. How do you introduce parabola? Provide details. At what levels?

   ----

2. How do you expect your learners/students to learn the parabola? Provide details.

   ----

3. What are the problems your students have when you teach them parabola? Provide details. Explain.

   ----

4. What, if any, readings have you consulted to help you understand your students' difficulties with algebra?

Demonstration two:

a. Parabola parameters (quadratic functions).
b. The discriminant of the quadratic functions

The following are examples of questions that will be posed to the teachers:

a) What did you like about today's session. What was today's session about. (in your own words).

   How does today's session make you think about the related to quadratic functionsideas that you teach in your classroom? Please elaborate.

b) What about today's session was new for you and why? Please say more.

c) What do you make of the different between spreadsheets use and the pen-and-paper version of the same quadratic function in the classroom?

Meeting three

Interview procedures

	Yes	No
1. Can I audio record the interview		
2. If I reveal information that you would not like to be associated with, please indicate no.		

Interview questions.

1. How would you incorporate this spreadsheets-based program into your classroom practice? Please elaborate. What considerations would be necessary?

2. How has the demonstration on the linear functions/forms and quadratic functions/forms made you think about the underlying algebra? Please elaborate.

3. What have you found out from the demonstrations that you did not know before? Please elaborate.

Appendix D

STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

Title of research project:

Teachers' perceptions of spreadsheet algebra programs as curriculum material in secondary school mathematics

You are asked to participate in a research study conducted by Ricardo Rodrigues Losada (Qualifications: Litentiate in Education, B.Ed.Hons) under the supervision of Doctor M.F. Gierdien from the Education Faculty at Stellenbosch University. You were selected as a possible participant in this study because your contribution will help me to obtain the information required for the completion of my thesis.

1. PURPOSE OF THE STUDY

The purpose of this research is to explore teachers' perceptions on spreadsheets as an alternative to enhanced school algebra understanding at the secondary school level.

PROCEDURES

The investigation initially will involve the gathering data from teachers' experiences with a set of spreadsheets-based algebra activities. Teachers will volunteer. The aim of teachers' interaction with spreadsheet activities is not to demonstrate that spreadsheets can be used as a better tool in solving algebra problems, but rather to gauge the teachers' perceptions in developing the use of ICT to support subject teaching and learning. The envisaged research will utilise a case study method as a means of understanding teachers' perceptions on the use of spreadsheets as an alternative to foster their knowledge of school algebra. The study also includes transcripts of the observations and teachers interviews. No information identifying any participants will be released to anyone outside of the investigative activities, note that all interactions with the researcher may be recorded by audiotape so that everything will be analysed correctly

2. POTENTIAL RISKS AND DISCOMFORTS

In the investigative sections participants will be asked to explore the algebraic concepts that are embedded in spreadsheets. One possible discomfort for the participants is that spreadsheets are not a common tool to teach algebra in their mathematics curriculum, therefore they may find difficulty in using such a program, but I hope that the participants will find it interesting and useful using spreadsheets as an alternative to foster their knowledge of school algebra.

3. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

It is hoped that the participants in this particular study will assist the researcher in finding out how teachers understand algebraic concepts that are embedded in spreadsheets programs. Specifically at the high school level and reveal the teachers experience with educational technology, also Participants in the study will possibly benefit to understand the potential spreadsheet environment has to allow learners to develop mathematical concepts and relationships through multiple representations simultaneously (visual, symbolic and numerical) and recognize spreadsheets as a powerful tool to teach algebra.

4. PAYMENT FOR PARTICIPATION

No financial remuneration is involved for participating in this investigative study

5. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained at all times. Transcriptions of the participants' interviews or interaction with the researcher as well as the recorded conversations will be coded. All data will be safely kept in a personal computer to which only the researcher has access. After the research all audio-taped and recorded data will be destroyed.. The data collected will be given to each participant for review.

6. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise that warrant doing so.

7. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Mr. Ricardo Rodrigues Losada at r.losadaricardo@yahoo.com or Tel no: +27785481172. Supervisor: Dr. M.F. Gierdien at faaiz@sun.ac.za or Tel no: 27846199639.

8. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Malene Fouche [mfouche@sun.ac.za or 27 21 8084622] at the Unit for Research Development, Stellenbosch University.

Appendix E

Attention: The Principal

Ongha Secondary School

P.O. Box 2023

Ondangwa 17 May 2011

RE: AUTHORISATION LETTER TO THE PRINCIPAL

Dear Sir

I am a candidate for a Master's degree programme in Mathematics Education in the Department of Education at Stellenbosch University, South Africa. As part of the department requirement, Master degree students have to carry out a research in areas of their interest.

The aim of my research is to investigate how Information Communications Technology (LCT), using spreadsheets as an alternative, can enhance teacher's understanding of school algebra. The data collection process will last for approximately three to four weeks; however this will not interfere with the normal school activities because the research will be undertaken after normal working hours. I would be grateful if you would allow me to use Ongha Secondary School as the research site for the research which I am required to complete. This is because I am familiar with many teachers in the school and I hope that they will not be hesitant to share their experiences with me. The circuit, region and teachers in particular will be assured of anonymity in the final research report and will be invited to proofread drafts of the report to ensure that details are accurately recorded and reported. Should you have any concern or questions about this request, please don't hesitate to contact me on my email address r.losadaricardo.yahoo.com or my phone number +27785481172

I thank you in advance for your assistance in this regard

R.J Rodrigues Losada

Faculty of education (Stellenbosch University)

Appendix F

15 March 2011

The Regional Director: Ohangwena
Private Bag 2028
Ondangwa

RE: AUTHORISATION LETTER TO THE DIRECTOR OF EDUCATION

Dear Sir/madam

I am a registered full-time student for Master's degree in Mathematics Education programme with the Department of Education in Stellenbosch University, South Africa. This is now my second and final year, and as a department requirement, Master students have to carry out research studies in areas of their interest in their final year.

As a student and teacher responsible for Mathematics Grades 11-12 and also HOD (maths & science) at Ongha Secondary School, I'm interested in investigating how Information Communications Technology (ICT) with specific reference to spreadsheets, can enhance teacher's understanding in school algebra. On the basis of that, I have chosen Ongha Secondary School at Ohangwena region as the research site of my study. This is because I am familiar with many teachers in the circuit and I hope that they will not be hesitant to share their experiences with me.

I am confident that the findings of my study will make valuable contributions to the current ongoing project of Education and Training Sector Improvement Programme (ETSIP), aimed to embed ICT at all levels of the education system and to integrate the use of ICT as a tool in the delivery of curriculum and learning, thereby leading to the marketd improvement in the quality of learning and teaching process across all levels.

I will be grateful to receive authorisation from your office to conduct my research in your region. The aim of this research is not to test for teachers' knowledge level of mathematics but to discover how teachers' can improve students understanding of school algebra through ICT with specific reference to spreadsheets.

The circuit, region and teachers in particular will be assured of anonymity in the final research report and will be invited to proofread drafts of the report to ensure that details are accurately recorded and reported.

Should you have any concerns or questions about this request, please don't hesitate to contact me on my email address: r.losadaricardo@yahoo.com

I thank you in advance for your assistance in this regard.

R J. Rodrigues Losada
Faculty of education (Stellenbosch University)

Appendix G

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

19 July 2011

Tel.: 021 - 808-9183
Enquiries: Sidney Engelbrecht
Email: sidney@sun.ac.za

Reference No. 579/2011

Mr RR Losada
Department of Curriculum Studies
University of Stellenbosch
STELLENBOSCH
7602

Mr RR Losada

LETTER OF ETHICS CLEARANCE

With regards to your application, I would like to inform you that the project, *Teacher perceptions of spreadsheets use as a medium to understand algebra in a secondary school mathematics curriculum in Namibia,* has been approved on condition that:

1. The researcher/s remain within the procedures and protocols indicated in the proposal;
2. The researcher/s stay within the boundaries of applicable national legislation, institutional guidelines, and applicable standards of scientific rigor that are followed within this field of study and that
3. Any substantive changes to this research project should be brought to the attention of the Ethics Committee with a view to obtain ethical clearance for it.

We wish you success with your research activities.

Best regards

DIE UNIVERSITEIT VAN STELLENBOSCH
19 JUL 2011
THE UNIVERSITY OF STELLENBOSCH

MR SF ENGELBRECHT
Secretary: Research Ethics Committee: Human Research (Humanora)

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Appendix H

OHANGWENA REGIONAL COUNCIL

OHANGWENA EDUCATION DIRECTORATE

Private Bag 2028, Ondangwa, Tel. 264 65 281 900, Fax. 264 65 240190

Enquiries: EN Namundjanga
E-mail: enmbongo@yahoo.com

Ref: 15/2/4

18 March 2011

TO: Mr. R J Rodrigues Losada
Faculty of Education
Stellenbosch University
RSA

Dear Mr. R J Rodrigues Losada

RE: PERMISSION TO CONDUCT A RESEARCH AT ONGHA SECONDARY SCHOOL IN OHANGWENA REGION

We refer to your letter dated 15 March 2011 in which you requested for permission to conduct a research Ongha Secondary School in Ohangwena Education Directorate.

Our region hereby grants you permission to go to the above mentioned school and carry out your research. Kindly take note that the research program should not interfere with the normal learning and teaching processes.

We look forward to seeing the contributions this study will make towards the teaching of mathematics in the region.

Yours sincerely,

18/03/2011
Sanet L. Steenkamp
Director: Ohangwena Education Directorate

OHANGWENA REGIONAL COUNCIL
DIRECTORATE OF EDUCATION
2011 -03- 1 8
PRIVATE BAG 2028, ONDANGWA
REPUBLIC OF NAMIBIA

Appendix I

Ministry of Education
Ongha Secondary School
Ongha Circuit
Private Bag 2023, Ondangwa
Tel: 065- 245400 Fax 065- 245401

Enq: A. Amoomo
E-mail: andreasamoomo@gmail.com

To: Mr R J Rodrigues Losada
Stellenbosch University
+27785481172

March 18, 2011

RE: AUTHORIZATION TO CONDUCT RESEACH IN ONGHA SECONDARY SCHOOL OHANGWENA REGION

I write to refer to your letter dated March 17, 2011 with regard to the above subject matter.

Permission is hereby granted for you (Mr. R J Rodrigues Losada, student number 16068483-2010) to do research in our school and conduct interviews as contemplated in your letter. The following conditions should however, apply:

- Participation by individual teachers is voluntary
- School academic programmes are no way to be disrupted
- Proofread in the final research report to be assured anonymity.

I wish you success in your studies,

Yours sincerely

Andreas Amoomo
School Principal

MINISTRY OF EDUCATION
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ONGHA SENIOR SECONDARY SCHOOL
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18 MAR 2011
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REPUBLIC OF NAMIBIA