

The copyright of this thesis rests with the University of Cape Town. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

**A MIXED METHODS INVESTIGATION INTO THE IMPACT OF COMPUTERS AND
MATHS SOFTWARE ON MATHEMATICS TEACHING AND MATRIC RESULTS
OF HIGH SCHOOLS IN THE EMDC EAST, CAPE TOWN**

by

GARTH SPENCER-SMITH (SPNGAR001)

A dissertation submitted in fulfilment of the requirements for the award of
the degree of MASTER OF PHILOSOPHY

Faculty of the Humanities

Department of Education

UNIVERSITY OF CAPE TOWN

2010

Supervisor: Dr Joanne Hardman

PLAGIARISM DECLARATION

1. I know that plagiarism is wrong. Plagiarism is to use another's work and pretend that it is one's own.

2. I have used the **APA convention (5th edition)** for citation and referencing. Each significant contribution to, and quotation in, this dissertation from the work or works of other people has been attributed, and has been cited and referenced.

3. This dissertation is my own work, and has not been previously submitted in whole, or in part, for the award of any degree.

4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.

Signature _____

Date _____

ACKNOWLEDGMENTS

No work of this nature can be completed without significant support from others. My biggest thanks must go of course to my supervisor, Dr Joanne Hardman, whose encouragement and motivation for me to 'see the course', and her pertinent suggestions as to what I needed to complete at each stage of the process has enabled my Masters to be completed in good time. Her readiness to be called with questions even at evening times and deep into the ninth month of her pregnancy was most appreciated!

My lovely girlfriend, Ashley Leimkuehler, has been wonderfully supportive to me in this endeavour, and it is thanks to her that the transcripts of 10 hours of lessons and 2 interviews were produced in record time, along with a number of expertly reproduced diagrams. What a tedious set of tasks, and yet done with such a smile!

Further invaluable help during my classroom observation phase came from a number of people: thank you to Lance McLeod of the UCT School of Education for his reliability, excellent video-work and good company; and to the two Mathematics teachers at the Khayelitsha school (who unfortunately need to remain anonymous), who allowed me into their classrooms with a welcoming smile and answered my questions with great grace.

Anneli Hardy, the consultant at the Statistical Sciences Department at UCT, gave me invaluable, patient advice regarding my quantitative analysis (as did Anne Haig May), while Nuroo Ismail and Dianne Steele of the UCT Knowledge Commons uncomplainingly and very professionally showed me the ropes to ensure that the layout and formatting of my dissertation, and the citing and referencing, respectively, were up to scratch.

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

ABBREVIATIONS

ACOT	Apple Classroom of Tomorrow
BECTA	British Educational Communications and Technology Agency
CAI	Computer Assisted Instruction
CAL	Computer Assisted Learning
CAT	Computer Application Technology
CMI	Computer Managed Instruction
EMDC	Education Management and Development Centres
ERIC	Education Resources Information Centre
FD(P)	Fifth Dimension (Programme)
FET	Further Education and Training
GCSE	General Certificate of Secondary Education
HG	Higher Grade
ICT	Information and Communication Technology
IDRF	initiation, response, discussion, feedback
ILS	Integrated Learning Systems
IQ	Intelligence Quotient
IRF	initiation, response, feedback
IT	Information Technology
LD	Learning difficulty
MAT	Mathematics Achievement Test
MKO	More Knowledgeable Other
MSS	Mean Student Score

NAEP	National Assessment of Educational Progress
PPI	pen and paper instruction
SFL	Systematic Functional Linguistics
SG	Standard Grade
SPSS	(originally) Statistical Package for the Social Sciences
TIMSS	Trends in Mathematics and Science Study
TTA	Teacher Training Agency
UK	United Kingdom
USA	United States of America
WCED	Western Cape Education Department
ZPD	Zone of Proximal Development

University of Cape Town

ABSTRACT

This mixed methods dissertation investigates whether the Matric Mathematics results and enrolments at high schools in the EMDC East zone of Cape Town have been impacted by the availability of computers and mathematical software (as provided by the Khanya Project); how the teachers at one school in Khayelitsha, Cape Town are using the computer as a tool to teach Mathematics, and whether their pedagogy changes between the Mathematics lessons in the conventional classroom and the computer lab.

A series of statistical tests (Mann-Whitney U test; independent samples t-test; paired samples t-tests and the Wilcoxon Signed Rank test) were applied to various samples of the 2007 Matric Mathematics data of high schools in the EMDC East, obtained from WCED. What was concluded was that there was no significant difference between the Matric Mathematics results of the schools with the computers and those without; no significant change in the results after the Khanya labs were installed; no significant change in the percentage of pupils that passed Matric Mathematics; and no significant change in Higher Grade Mathematics enrolment rates.

The overall conclusion from the quantitative research was thus that no significant differences were brought about by the use of computers in Mathematics in the EMDC East schools. So, what does happen when the computers are being used? This led to qualitative research on whether and how computers impact pedagogy: observations of ten Mathematics lessons in a selective township school in Khayelitsha were undertaken, and transcriptions made. These transcriptions were analysed in order to determine how the teachers were using the computers as a pedagogical tool, and whether their pedagogy varies across different lesson contexts (face-to-face lessons and computer lab lessons). In the case of the former question, it was found that the computers were primarily being used as a drill-and-practise tool for revision purposes; in other words, as though they were electronic textbooks.

In order to answer the latter question, each sentence of each teacher was categorised according to an analytical framework in order to determine if there were any variation in semiotic mediation (in other words, teacher talk) between the classroom and the computer lab. Chi-squared tests for independence indicated that there was a significant, moderate to strong association between the location of the lesson and the type of talk; thus there is significant variation in semiotic variation between the two venues and the teachers' pedagogy does vary between the face-to-face classroom and the computer lab. Further chi-squared tests also indicated significant, moderate to strong associations between the location of the lesson and the scale of interaction (class or individual); and between the type of talk and scale of interaction.

TABLE OF CONTENTS

PLAGIARISM DECLARATION	I
ACKNOWLEDGMENTS	II
ABBREVIATIONS	III
ABSTRACT.....	V

CHAPTER ONE

INTRODUCTION.....	1
1.1. STATEMENT OF THE PROBLEM	1
1.2. THE RESEARCH QUESTIONS	3
1.3. BACKGROUND TO THE PROBLEM	4
1.4. THE KHANYA PROJECT – A SOLUTION?	7
1.5. MY CONCEPTUAL FRAMEWORK.....	9
1.6. MY RESEARCH DESIGN AND METHODOLOGY	9
1.7. OUTLINE OF THE DISSERTATION	10

CHAPTER TWO

CONCEPTUAL FRAMEWORK.....	12
2.1. INTRODUCTION.....	12
2.2. THE VYGOTSKIAN THEORY OF LEARNING.....	12
2.2.1. <i>The Zone of Proximal Development</i>	13
2.2.2. <i>Mediation and Semiotic Mediation</i>	16
2.3. SCAFFOLDING	21
2.4. CHAPTER SUMMARY	30

CHAPTER THREE

REVIEW OF LITERATURE AND EMPIRICAL STUDIES.....	31
3.1. INTRODUCTION.....	31
3.2. RESEARCH ON A LINK BETWEEN COMPUTER USAGE AND ACADEMIC ATTAINMENT	31
3.2.1. <i>Introduction</i>	31
3.2.2. <i>Research on Computers and Mathematics Performance in Developed Nations</i>	37
3.2.2.1. Research showing Positive Impact on Particular Strands of Mathematics.....	43
3.2.3. <i>Research on Computers and Mathematics Performance in Developing Nations</i>	46

3.3. RESEARCH ON THE IMPORTANCE OF <i>How</i> COMPUTERS ARE USED	51
3.4. RESEARCH ON VARIATIONS IN SEMIOTIC MEDIATION; AN INDICATOR OF PEDAGOGICAL VARIATION ...	58
3.5. CHAPTER SUMMARY	60

CHAPTER FOUR

RESEARCH DESIGN & METHODOLOGY	62
4.1. INTRODUCTION: QUANTITATIVE AND QUALITATIVE RESEARCH METHODS	62
4.2. RESEARCH TYPES WITHIN THE FIELD OF ICT AND EDUCATION	63
4.3. THE 'MIXED METHODS' RESEARCH DESIGN	64
4.4. MY RESEARCH DESIGN	65
4.4.1. <i>My Quantitative Research – an Outline</i>	65
4.4.2. <i>My Qualitative Research – an Outline</i>	67
4.4.2.1 Selecting the Case Study School	67
4.4.2.2. The Participants	69
4.4.2.3. Plato: The Computer Software Programme	70
4.4.2.4. The Observations and Method of Analysis	70
4.5. RELIABILITY, VALIDITY AND ETHICS	74
4.5.1. <i>Validity</i>	74
4.5.1.1. Validity in my Quantitative Research	74
4.5.1.2. Validity in my Qualitative Research	76
4.5.2. <i>Reliability</i>	77
4.5.2.1. Reliability in my Quantitative Research	77
4.5.2.2. Reliability in my Qualitative Research	78
4.5.3. <i>Ethical Considerations</i>	79
4.6. CHAPTER SUMMARY	80

CHAPTER FIVE

ANALYSIS, INTERPRETATION AND DISCUSSION	81
5.1 INTRODUCTION	81
5.2. DATA ANALYSIS AND INTERPRETATION: MATRIC MATHEMATICS RESULTS	81
5.2.1. <i>The Tests</i>	82
5.2.2. <i>The Mean Student Score</i>	82
5.2.3. <i>Test 1: Comparing the 2007 Matric Mathematics Results of an Experimental and Control Group</i>	84
5.2.4. <i>Test 2: Comparing Matric Mathematics Results Before and After the Khanya Intervention</i>	93
5.2.5. <i>Further Tests</i>	96
5.2.6. <i>Interpretation of the Test Results</i>	102

5.2.6.1. Other factors influencing Mathematics results	103
5.3. DATA ANALYSIS AND INTERPRETATION: CLASSROOM OBSERVATIONS	106
5.3.1. <i>Analysis of the Variation in Semiotic Mediation in the Mathematics Classroom</i>	107
5.3.2. <i>Statistical Analysis: Chi Squared Tests</i>	115
5.3.2.1. Categorising the Data	115
5.3.2.2. The Relationship between the Location of the Lesson and Type of Talk	116
5.3.2.3. The Relationship between the Location of the Lesson and the Scale of Interaction	120
5.3.2.4. The Relationship between the Type of Talk and the Scale of Interaction	123
5.3.2.5. Conclusions	126
5.3.3. <i>Extracts from Lessons illustrating Variation in Semiotic Mediation across Different Teaching Contexts</i>	126
5.3.4. <i>How the Teachers used the Computer as a Teaching Tool</i>	139
5.3.5. <i>Extracts from Lessons illustrating the Manner of Use of the Computer</i>	144
5.4. DISCUSSION.....	151
5.4.1. <i>Quantitative Findings: the Impact of Computers on Mathematics Performance</i>	151
5.4.2. <i>Qualitative Findings: the Impact of Computers on Semiotic Mediation</i>	152
5.4.3. <i>Qualitative Findings: the Importance of How Computers are Used</i>	152
5.5. CHAPTER SUMMARY	153
CHAPTER SIX	
CONCLUSION	155
6.1. SUMMARY OF FINDINGS	155
6.2. SHORTCOMINGS OF MY STUDY AND SUGGESTIONS FOR FUTURE RESEARCH.....	161
REFERENCES.....	164
APPENDICES.....	180
APPENDIX 1: QUESTIONS FOR TEACHER INTERVIEWS.....	180
APPENDIX 2: KHANYA PERMISSION E MAIL	182
APPENDIX 3: PARTICIPANT CONSENT FORM	183
APPENDIX 4: RAW DATA ON TEACHER TALK	185

LIST OF TABLES

TABLE 1: CHARACTERISTICS OF QUANTITATIVE AND QUALITATIVE RESEARCH ON A CONTINUUM IN THE PROCESS OF RESEARCH.....	63
TABLE 2: 'TYPE OF TALK' CATEGORIES.....	72
TABLE 3: UCT'S ADMISSION RATING SYSTEM FOR THE SOUTH AFRICAN SCHOOL LEAVING QUALIFICATION... 83	83
TABLE 4: 2007 MATRIC MATHEMATICS RESULTS FROM THE KHANYA 'PILOT' SCHOOLS	83
TABLE 5: KOLMOGOROV-SMIRNOV TEST FOR NORMALITY (TEST 1)	85
TABLE 6: MEAN STUDENT SCORE RANKS (TEST 1)	87
TABLE 7: MANN-WHITNEY U TEST RESULTS: MEAN STUDENT SCORE (TEST 1)	87
TABLE 8: KOLMOGOROV-SMIRNOV TEST FOR NORMALITY (TEST 1 – REDEFINED GROUPS).....	89
TABLE 9: GROUP STATISTICS (TEST 1 – REDEFINED GROUPS)	91
TABLE 10: INDEPENDENT SAMPLES T-TEST RESULTS (TEST 1 – REDEFINED GROUPS)).....	92
TABLE 11: KOLMOGOROV-SMIRNOV TEST FOR NORMALITY (TEST 2)	94
TABLE 12: PAIRED SAMPLE STATISTICS (TEST 2).....	95
TABLE 13: PAIRED SAMPLES T-TEST RESULTS (TEST 2).....	96
TABLE 14: KOLMOGOROV-SMIRNOFF TEST FOR NORMALITY (TEST 3).....	98
TABLE 15: PAIRED SAMPLES STATISTICS (TEST 3).....	98
TABLE 16: PAIRED SAMPLES T-TEST RESULTS (TEST 3).....	99
TABLE 17: KOLMOGOROV-SMIRNOFF TEST FOR NORMALITY (TEST 4).....	99
TABLE 18: WILCOXON SIGNED RANK TEST - RANKS (TEST 4)	101
TABLE 19: WILCOXON SIGNED RANK TEST RESULTS (TEST 4).....	101
TABLE 20: WILCOXON SIGNED RANK TEST – DESCRIPTIVE STATISTICS (TEST 4).....	101
TABLE 21: SUMMARY OF TALLIES: COMPUTER LAB LESSONS (NUMBERS OVERALL; PERCENTAGES BY TEACHER AND OVERALL)	108
TABLE 22: SUMMARY OF TALLIES: TRADITIONAL CLASSROOM LESSONS (NUMBERS OVERALL; PERCENTAGES BY TEACHER AND OVERALL).....	109
TABLE 23: SUMMARY OF INDIVIDUAL TEACHERS' INTERACTIONS (PERCENTAGES, FACE-TO-FACE VERSUS COMPUTER LAB LESSONS)	112
TABLE 24: CROSS TABULATION TABLE – LOCATION OF LESSON AND TYPE OF TALK.....	117
TABLE 25: CHI SQUARED TEST RESULTS - LOCATION OF LESSON AND TYPE OF TALK.....	118
TABLE 26: CRAMER'S V COEFFICIENT – LOCATION OF LESSON AND TYPE OF TALK	119
TABLE 27: CROSS TABULATION TABLE – LOCATION OF LESSON AND SCALE OF INTERACTION.....	120
TABLE 28: CHI SQUARED TEST RESULTS - LOCATION OF LESSON AND SCALE OF INTERACTION.....	121
TABLE 29: PHI COEFFICIENT – LOCATION OF LESSON AND SCALE OF INTERACTION.....	122

TABLE 30: CROSS TABULATION TABLE –TYPE OF TALK AND SCALE OF INTERACTION	123
TABLE 31: CHI SQUARED TEST RESULTS - TYPE OF TALK AND SCALE OF INTERACTION	124
TABLE 32: CRAMER’S V COEFFICIENT – TYPE OF TALK AND SCALE OF INTERACTION.....	125
TABLE 33: SUMMARY OF TALLIES: COMPUTER LAB LESSONS (NUMBER OF INTERACTIONS, CLASS BY CLASS)	185
TABLE 34: SUMMARY OF TALLIES: TRADITIONAL CLASSROOM LESSONS (NUMBER OF INTERACTIONS, CLASS BY CLASS)	186

LIST OF FIGURES

FIGURE 1: ILLUSTRATION OF ZONE OF PROXIMAL DEVELOPMENT	15
FIGURE 2: TEACHER STRATEGIES FOR SCAFFOLDED LEARNING	26

LIST OF GRAPHS

GRAPH 1: HISTOGRAM OF MEAN STUDENT SCORE (TEST 1).....	86
GRAPH 2: NORMAL Q-Q PLOT OF MEAN STUDENT SCORE (TEST 1)	86
GRAPH 3: HISTOGRAM OF MEAN STUDENT SCORE (TEST 1 – REDEFINED GROUPS).....	89
GRAPH 4: NORMAL Q-Q PLOT OF MEAN STUDENT SCORE (TEST 1 – REDEFINED GROUPS).....	90
GRAPH 5: HISTOGRAM OF MEAN STUDENT SCORE (TEST 2).....	94
GRAPH 6: NORMAL Q-Q PLOT OF MEAN STUDENT SCORE (TEST 2)	94
GRAPH 7: HISTOGRAM OF HG PERCENTAGE (BEFORE KHANYA)	100

CHAPTER ONE

INTRODUCTION

1.1. Statement of the Problem

Computers and other forms of information technology are being used more and more in classrooms around the world and, rather belatedly, in South Africa. In the Western Cape since 2001, for example, the Western Cape Education Department (WCED), through the Khanya Project, has been rolling out technology and support, such as computers, computer laboratories, educational software, and Information and Communication Technology (ICT) teacher training, to all the public schools in the province, starting with some of the most disadvantaged schools (see <http://www.khanya.co.za/projectinfo/?catid=32>). These computers have been used in a variety of subjects, including Mathematics, due to the concurrent rollout of instructional software - like MasterMaths and CAMI Maths - aimed at improving Mathematics results.

In the South African education system, poor Mathematics results are a great cause for concern, as indicated by South Africa's last place in the Trends in International Mathematics and Science Study (TIMSS) of 2003 (Reddy, 2006) and the ongoing poor Matric Mathematics results (Department of Education, 2009). The multi-million rand Khanya Project was initiated to assist with improving these, but the question that needs to be asked is whether a difference has been made by providing the computers and associated infrastructure and technology to schools.

Much research has been completed around the world in order to answer just this question, with thousands of books and journal articles on this topic (see, for example, Watson (1993); Askew, Brown, Rhodes, William & Johnson (1997); Harrison et al. (2002); Hinostroza, Guzman & Isaacs (2002); BECTA (2003); Cox et al. (2003); Higgins (2004); Blanton, Mayer, McNamee & Shustack (2006); Condie & Munro (2007) and Louw, Muller & Tredoux (2008)). A couple of startling findings or observations from these and other sources are:

- i. whilst the research has generally shown a positive relationship between the use of computers and mathematical performance, this is by no means an unequivocal and unanimous finding, with some writers finding no significant link;
- ii. almost all the research – with only a few notable exceptions, like the studies of Banerjee, Cole, Deflo & Linden (2005) and Louw et al. (2008) - has been completed in developed nations of the world.

Point 2 above indicates a significant gap in knowledge that my dissertation attempts to, in some small way, fill through my research in disadvantaged schools in Cape Town, South Africa. It will also add to the general body of knowledge around the impact of computers on mathematical attainment.

Furthermore, the results of my quantitative research on the impact of the computers on Matric Mathematics results will assist in determining whether the significant investment on the Khanya Project by the WCED has been money well spent. As the following quote puts it: “The considerable investment that has gone into introducing ICT into schools – hardware, software, networking and staff development – will be deemed worthwhile (only) if there is evidence that it has made a commensurate impact on the performance levels and progress of pupils” (Condie and Munro, 2007, p. 4).

The findings of my research will be of use to a number of different audiences. Researchers and lecturers will be interested in my findings as they shed some light on a well-known topic that has been under-researched in less developed nations; while policy makers within WCED and Khanya will (or should) be most interested in my findings in terms of helping them ascertain whether or not the many millions of rands spent on the Khanya Project has brought about the desired improvements in mathematics results.

The purposes of this study are three-fold:

- i. to test whether the Matric Mathematics results and enrolment at high schools in the EMDC (Education Management and Development Centre) East zone of

Cape Town have been impacted by the availability of computers and mathematical software (as provided by the Khanya Project).

- ii. to determine whether pedagogy alters between the conventional classroom Mathematics lessons and those in the computer labs, with a focus on variations in semiotic mediation (teacher talk) between the two venues, in one school in the township of Khayelitsha, Cape Town.
- iii. to explore how teachers are using the computer as a tool to teach mathematics, at one school in Khayelitsha.

1.2. The Research Questions

The following questions have been investigated in this study:

- i. Are Matric Mathematics results in EMDC East high schools that have Khanya computers better than those at EMDC East high schools without Khanya computers?
- ii. Have Matric Mathematics results in EMDC East high schools improved since the beginning of the Khanya intervention?
- iii. Did the Khanya intervention result in a higher pass rate in Mathematics in EMDC East high schools?
- iv. Did the Khanya intervention result in a higher percentage enrolment in Higher Grade mathematics in EMDC East high schools?
- v. Is there a variation in pedagogy between Mathematics classes in the computer laboratory and those in the conventional classroom, as evidenced by variation in semiotic mediation between the two locations in one school in Khayelitsha?
- vi. How do the Mathematics teachers at a school in Khayelitsha use the computers in the lab as tools to mediate mathematical concepts?
- vii. How does the qualitative follow up data help us to understand the quantitative first phase results a little better?

1.3. Background to the Problem

Mathematics is one of the core subjects in any school curriculum, including that of South Africa. The amount of formal teaching time allocated to numeracy in Grades 1-3 (35% of the overall teaching time) and mathematics in Grades 4-9 (18% of the overall teaching time), indicate the importance given to this core subject. A further indication is the fact that the National Curriculum for Grades 10 – 12 (Mathematics) (Department of Education, 2003) requires some form of Mathematics to be taken not only until the end of Grade 9 (as under the previous curriculum) but until the end of Grade 12, as either Mathematics or Mathematical Literacy. In addition, the National Senior Certificate, a school leaving certificate for Grade 12s, will only be issued to pupils who have successfully obtained at least 30% for either Mathematics or Mathematical Literacy in the final Grade 12 exams (Department of Education, 2008).

The expectation that pupils at schools develop a high level of competency in Mathematics at school level is becoming the norm in South Africa and most nations around the world. This is not all surprising as Mathematics is the basis of most of physical science and technology, and as development and technological innovations sweep the globe there needs to be a growing body of mathematically literate adults.

In the National Curriculum Statement: Grades 10-12 Mathematics, produced by the South African Department of Education (2003), the purpose of the Mathematics taught is outlined below: “In an ever-changing society, it is essential that all learners¹ passing through the Further Education and Training band acquire a functional knowledge of the Mathematics that empowers them to make sense of society. A suitable range of mathematical process, skills and knowledge enables an appreciation of the discipline itself. It also ensures access to an extended study of the mathematical sciences and a variety of career paths” (Department of Education, 2003, p.9).

¹ The word that I have chosen to use for a child at school is ‘pupil’. However, where I have quoted other authors and they have used the term ‘learner’ I have quoted them verbatim.

It is all very well to make grand statements like the above; what is critical is determining whether or not the teachers on the ground are actually able to deliver the curriculum in such a way as to ensure pupils achieve competence in mathematical procedures. International benchmarking, in the form of the Trends in International Mathematics and Science Study (TIMSS), show that South African pupils are way below their peers internationally when it comes to Mathematics (and Science, for that matter). As Howie (2001) succinctly puts it: “these international studies ... serve to highlight the plight of education ... in a country like South Africa” (p. xix). The importance of the TIMSS studies is highlighted by Reddy (2006): “In a country where there are many small-scale, qualitative studies providing information on aspects of science and mathematics education, TIMSS 1995 offered the first national analysis of learner achievement, and the subsequent cross-national studies have provided systemic information and external benchmarking of the South African educational system” (p. 5).

The TIMSS studies have been carried out by a study centre based in Boston, USA, which conducts large-scale studies in comparative educational achievement in mathematics, science and reading (see <http://timss.bc.edu/>). In particular, there have thus far been 4 sets of TIMSS data collected; the years of collection being 1995, 1999, 2003 and 2007. In each of these, the same mathematical tests were given to pupils in dozens of countries around the globe, at Grade 4 and Grade 8 level. South Africa participated in the first three studies at Grade 8 level but declined to take part in the 2007 study.

In the most recent TIMSS study that South Africa participated in (the 2003 study), 255 public schools and 8952 Grade 8 pupils took part. To select the schools and pupils, the TIMSS sampling design used a three-stage stratified cluster design, which involved:

- i. selecting a sample of schools from all eligible (public) schools, stratified by province and language of teaching and learning (English and Afrikaans); and
- ii. randomly selecting mathematics class from each sampled school; and
- iii. randomly selecting pupils within a sampled class in cases where the class size was over 40 (Reddy, 2006)

The results showed our Grade 8 pupils to be far below the world average in Mathematics, a repeat of the performance in the 1999 TIMSS tests. The 2003 national achievement scores for mathematics were not statistically significantly different from the 1999 scores (Reddy, 2006).

In the case of the Grade 8 pupils involved in the Mathematics testing, South Africa was placed last (45th out of the 45 countries sampled in the analysis), with a score of 264 (the international average was 466 and the top scoring country, Singapore, had a score of 605) (Reddy, 2006). What is important to note is that the list of 45 participant nations not only included many of the world's wealthy countries (for example, the United Kingdom (UK), the United States of America (USA), and Japan) but also a number that have a far lower average GDP than South Africa, and thus might be expected to have performed worse than South Africa. Nations such as Botswana, Morocco, Egypt, Ghana and Chile in fact all performed better than South Africa; in some cases significantly better. A further interesting observation is that South Africa had the largest variation in overall scores of all the participating nations, ranging from a preponderance of very low scores to a few high scores. This resulted in the distribution of scores being heavily skewed to the left (the 'floor effect') (Reddy, 2006).

A further indicator that all is not well in the sphere of Mathematical education in South Africa is the ongoing poor Matric Mathematics enrolment and results. The first issue is the very low number of pupils that chose Mathematics as a subject in the Grade 10-12 band under the previous curriculum (as mentioned above, all pupils in Grades 10-12 now have to take either Mathematics or Maths Literacy, whereas previously Mathematics was optional). In 2007, 564 775 pupils sat the Matric exam across the nation, as against 1 012 947 people of appropriate school age for that grade in the country (Department of Education, 2009). Of this number, only 347 570 (or 61.5% of enrolled Matrics) wrote Mathematics at either Higher or Standard Grade Level.

The second issue is the number of pupils that *passed* Mathematics at Matric Level: in 2007 only 25 415 passed Higher Grade (HG) Mathematics; while a further 123 813 passed Standard Grade (SG) Mathematics. A further 34 433 pupils failed their

Standard Grade Mathematics exams but passed on the Lower Grade level (Department of Education, 2009). Thus, only less than a third (32.5%) of all Matric pupils gained a pass at Mathematics at some level, with only 4.5% passing at Higher Grade level (the level accepted by universities as sufficient for study in the science or technology fields).

1.4. The Khanya Project – a Solution?

Various attempts have been made by governmental and non-governmental departments and organisations to ameliorate this alarming situation. In particular, with reference to my research, the Western Cape Education Department (WCED) has, through the Khanya Project, begun a roll out of technology (computers, numeracy and literacy software, ICT teacher training and the like) to some of the most disadvantaged schools around the Western Cape.

The Khanya Project is an initiative of the Western Cape Education Department, and was established in April 2001 “to determine the contribution that technology could make towards addressing the increasing shortage of educator capacity in schools. With many skilled educators leaving the profession, fewer ones entering it, and AIDS already starting to take a significant toll amongst educators, it was necessary to explore alternatives. One of these alternatives is to use technology, already being used extensively in other disciplines, as an aid to augment teaching capacity” (van Wyk, 2002).

The dire need for computers in South African schools is illustrated by the fact in a study undertaken in the year 2000, only 24.4% of schools had access to any computers, and only 12.3% of schools reported the existence of computers for teaching and learning (Howie, Muller & Paterson, 2005). The Western Cape was, however, much better off than this average, as 45.2% had computers – albeit typically in very small numbers – available for teaching and learning (Howie et al., 2005).

The Khanya Business Plan, version 4.1 and dated 26 March 2002, described the “very ambitious goal” of the project to be: “By the start of the 2012 academic year, every educator in every school of the Western Cape will be empowered to use appropriate and available technology to deliver curriculum to each and every learner in the Western Cape.” (van Wyk, 2002). The emphasis of the Khanya Project is “not on providing computer technology for the sake of making learners computer literate, but rather to use technology as a teaching aid, hence to improve curriculum delivery.” (van Wyk, 2002).

Some of the secondary objectives for the project, that are relevant for my research, are to:

- Increase educator capacity and effectiveness by means of technology
- Harness the power of technology to deliver curriculum
- Improve Senior Certificate and FET (Further Education and Training) results, as well as pupil outcomes in all grades, in terms of number of passes and quality of results
- Increase the number of pupils taking Mathematics and Science on the Higher Grade and coping successfully
- Increase the number of pupils qualified and competent to enter tertiary education institutions after obtaining their Senior Certificates and FETS
- Improve numeracy and literacy in lower grades in order to build a stronger foundation for future matriculants

As of early January 2010, the achievements announced by Khanya on their website are as follows:

- 1102 schools (out of the total in the Western Cape Province of 1570 public schools) have been helped to use technology effectively
- Another 119 schools are in various stages of preparation for the next wave of implementation
- A total of 43293 computers are used in Khanya schools (of these 26705 have been funded by Khanya or its donor partners, and the balance of 16588 have been procured by the schools themselves)

- 24417 Educators are being empowered to use technology optimally for curriculum delivery
- 805818 pupils are already reaping the benefits of the project

(see the 'Khanya Achievements' section on the webpage

<http://www.khanya.co.za/projectinfo/?catid=23> for the latest values)

1.5. My Conceptual Framework

My research is concerned with the use of computers as cognitive tools. The relevant theories that I will be drawing on in my research are essentially Vygotskian and neo-Vygotskian socio-cultural theories, with emphasis on the ideas of mediation; semiotic mediation as an indicator of pedagogy; and scaffolding. These theories were chosen as my theoretical framework because they recognise how important cultural tools, such as computers, are in impacting cognitive development. In effect, these theories speak to tool mediation by means of computers and ICT – they will, therefore, assist in the development of a framework of understanding of the impact of computers on the mathematical performance of students and on the pedagogy of teachers.

1.6. My Research Design and Methodology

I have chosen to utilise a mixed methods approach as my research design, as I have undertaken both quantitative and qualitative research. My quantitative research involved analysing the 2007 Matric Mathematics results of schools in the EMDC East district of Cape Town in order to ascertain whether the Khanya Project's IT interventions have impacted in any way on the pupils' mathematical performance. My qualitative research involved observing ten mathematical lessons at one case study school in Khayelitsha (six in the computer lab and four in the traditional classroom), in order to determine how the Mathematics teachers are using the computers as a teaching tool and whether or not there are any variations in the 'teacher talk' across the two lesson contexts.

1.7. Outline of the Dissertation

This dissertation consists of six main chapters. This introductory chapter introduced the dissertation by stating the problems and questions to be researched and the background to the current crisis in Mathematics education in South Africa. It also introduced the Khanya Project which, through its massive investment in computers and related infrastructure, is one of the ways WCED is attempting to ameliorate the situation.

In Chapter 2 I outline my conceptual framework; the theoretical underpinnings of my research. My analysis of my research is essentially based on the Vygotskian (socio-cultural) Theory of Learning, and so the chapter introduces many of the key elements of his theory, such as mediation, semiotic mediation, and the Zone of Proximal Development (ZPD). My focus in the qualitative portion of my study is particularly on the way in which teachers teach with the computers, and thus a lot of attention is given to how they use mediation and scaffolding to ensure that the pupil moves through the Zone of Proximal Development. Scaffolding is unpacked in detail; in particular, Anghileri's (2006) tri-level hierarchy of Mathematical scaffolding practices.

In Chapter 3 I review the large body of literature and the numerous empirical studies surrounding the question of whether or not there is a link between computer usage in schools and academic attainment, focussing on Mathematics. This section is broken down into two parts: research in developed- and research in developing nations, and I indicate that research in the latter in this field is rare. In two further shorter sections, I also review the prior research that has been undertaken into the importance of how computers are used in the classroom, and on variations in semiotic mediation in the Mathematics classroom.

In Chapter 4 I give some background on the two main research types that dominate educational research: quantitative and qualitative methods; as well as the 'mixed methods' research design that combines the two and which I have chosen as the research design for my dissertation. I then outline the methods and procedures that I used in collecting both my quantitative and qualitative data.

Chapter 5 is my results chapter, in which I present in great detail the analysis and interpretation of the data I collected. The first half of the chapter outlines the different statistical tests I performed on the Matric Mathematics results and enrolment I obtained from WCED, and describes the findings and the interpretations thereof. The second half of the chapter outlines my analysis of the data I collected through my observations of Mathematics lessons in a school in Khayelitsha. In particular, I report the findings of the chi-squared tests I performed on the 'verbal utterances' of the teachers in different contexts, and give a descriptive analysis of how the teachers used the computer as a tool to mediate understanding.

In Chapter 6 I summarise the findings of my research and indicate some shortcomings of my study. This leads to recommendations and suggestions for future research.

University Of Cape Town

CHAPTER TWO

CONCEPTUAL FRAMEWORK

2.1. Introduction

In this chapter I outline the conceptual basis for this thesis, starting with a review of the basic Vygotskian theory on learning, with particular focus on the topics of mediation, semiotic mediation and the Zone of Proximal Development. The second half of this chapter covers the critical concept of scaffolding, a key neo-Vygotskian concept, with a focus on the work of Anghileri (2006).

2.2. The Vygotskian Theory of Learning

According to Vygotsky (1978), consciousness is constructed through a subject's interactions with the world, and development cannot be separated from its social and cultural context. Put another way, individual mental functioning is inherently situated in social, cultural, institutional and historical contexts. Thus, in order to understand human thinking and learning, one must consider the context and setting in which that thinking and learning occurs.

Vygotsky (1981) makes a distinction between what he termed 'lower, natural mental behaviour' and 'higher, cultural mental behaviour'. The former are mental behaviours we share with animals, like elementary perception, memory and attention; the higher forms include logical memory, selective attention, decision-making and comprehension of language. According to Vygotsky (1978, 1981), all the higher order mental processes are mediated by tools and signs. He distinguishes between the two by "the different ways in which they orient human behaviour" (1978, p. 55). The tool is externally oriented; is "the means by which human external activity is aimed at mastering, and triumphing over, nature" (1978, p. 55), and leads to changes in objects. The sign, however, is internally oriented and "is a means of internal activity aimed at mastering oneself" (1978, p. 55).

A key idea of Vygotskian socio-cultural theory is that cognitive development occurs twice, once socially with others and later (secondly) as independent problem-solving behaviour – in other words, it moves from an external to an internal plane. Vygotsky states it thus: “ every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first between people (inter-psychological), and then inside the child (intra-psychological)...All the higher functions originate as actual relations between human individuals” (Vygotsky, 1978, p. 57). This process converting the social to psychological is called internalisation and is defined by Vygotsky as “the internal reconstruction of an external operation” (Vygotsky, 1978, p. 56). Bonk and Cunningham (1998) expand on internalisation to define it as involving “taking new information that was experienced or learned within a social context and developing the necessary skills or intellectual functions to independently apply the new knowledge and strategies” (p. 36).

In the course of their joint activity, adults teach tools like language and symbols to children, the children internalise them through appropriation, and these tools then function as mediators in order to transform the natural forms of behaviour into the higher cultural forms unique to humans, in a process Vygotsky (1981) calls ‘semiotic mediation’, which will be discussed later in the chapter. During joint activity, predominantly through semiotic mediation, the pupil/child is guided by the more competent other to solve problems that he/she is unable to solve alone. This gives rise to a unique pedagogical space: what Vygotsky (1978) terms the Zone of Proximal Development (ZPD). This ‘space’ is important in the current thesis because it provides a teacher with access to what the student knows and what they need to know: that is, it provides a window into the student’s experience and enables the teacher to design pedagogical practices to meet the pupil’s unique needs. The ability to recognise this pedagogical space and act within it provides the basis for learning.

2.2.1. The Zone of Proximal Development

The notion of the Zone of Proximal Development was developed in part as a critique of and an alternative to static, individual testing of intelligence, viz intelligence quotient (IQ) testing. Vygotsky’s claim was that static testing assessed only mental functions that had already matured, and that it was only through collaborative

activities that maturing or developing mental functions should be fostered and assessed (Moll, 1990). According to Kozulin (2003), the notion of the ZPD “focuses our attention on those psychological functions of the child that are emerging at a given moment but have not yet been fully developed” (p. 17).

According to Vygotsky, instruction both precedes and leads development: “what a child can do in cooperation today he can do alone tomorrow. Therefore the only kind of instruction is that which marches ahead of development and leads it; it must be aimed not so much at the ripe as the ripening functions” (Vygotsky, 1986, p. 104). He believed that good instruction is aimed at the pupil’s ZPD, and that mediation is particularly effective when it is offered within this ZPD (see Salomon, 1988; Wertsch, 1991).

The ZPD is defined by Vygotsky (1978) as “the distance between a child’s independent problem-solving level and that obtained under adult guidance or in collaboration with more capable peers” (p. 78). In other words, it is the gap or difference between what a given child can achieve alone and that which they can achieve through assistance and guidance from a ‘more knowledgeable other’ (MKO). The MKO refers to someone who has a better understanding than the pupil with respect to a particular task, process, or concept. Although most often the MKO is a teacher or an older adult, this is not necessarily the case – in some instances a child’s peers may be the individuals with more knowledge or experience. In fact, the MKO need not be a person at all but could, for example, be a piece of computer software.

The ZPD can be illustrated as follows:

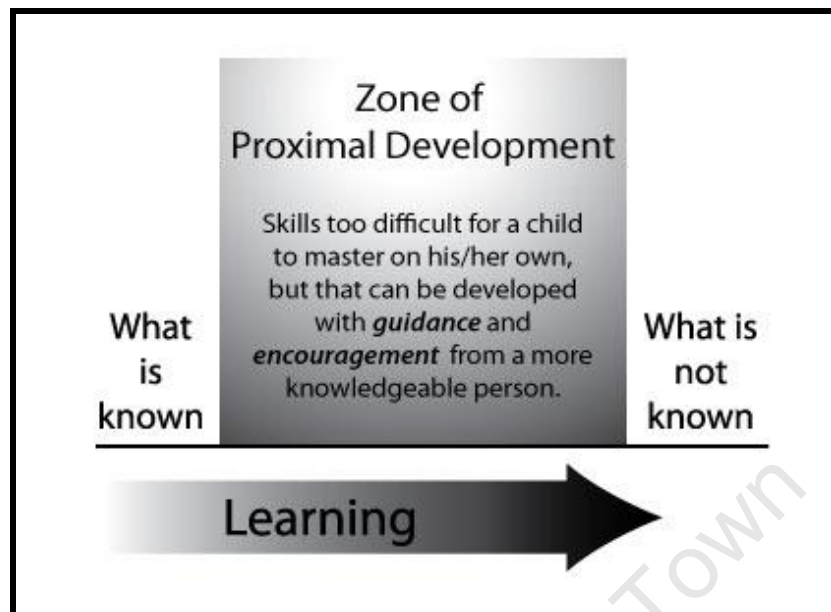


Figure 1: Illustration of zone of proximal development
(adapted from <http://www.simplypsychology.pwp.blueyonder.co.uk/vygotsky.html>)

Moll (1990) summarises the ZPD as typically being presented with the following three characteristics:

- i. establishing a level of difficulty (challenging for the pupil but not too difficult).
- ii. providing assisted performance (the adult or MKO provides guided practice to the child).
- iii. evaluating independent performance (ensuring that the child can perform the task without assistance).

Moll (1990) cautions, however, that "it is misleading to assume that [all] classroom activities containing these three characteristics represent zones of proximal development" (p. 7) because otherwise even rote-and-practice instruction would be an acceptable example of a Vygotskian teaching type. "Clearly, standard instructional practices do not represent what Vygotsky meant by a zone of proximal development" (p. 8).

A key part of my quantitative research will be to determine just how effective Mathematics software is in mediating understanding of that subject, through

determining whether the use of such software brings about an improvement in Mathematics grades. In addition, I use the concept of the ZPD in my qualitative component, by indicating *how* the teachers are using the computers to ensure their pupils move through the ZPD. That is, the analysis in the current thesis attempts to track the extent to which teachers use the computers to open up pupils' ZPDs, given that the ability to do this is considered by Vygotsky to lead to learning.

2.2.2. Mediation and Semiotic Mediation

Vygotsky (1978) placed much emphasis on mediation, stating that our social interactions are mediated through auxiliary means, most prominently by speech. Wertsch (1985) believed that it was with this concept of mediation that Vygotsky made his most important contribution to our understanding of children's development. Humans use artifacts (cultural signs and tools, such as speech, writing and mathematics) to mediate their interactions with each other and their surroundings. A fundamental property of these artifacts is that they are social in origin: they are first used to communicate with others (to mediate our contact with our social worlds); but later, through practice mainly in schools, these artifacts come to mediate our interactions with self. "Therefore, from a Vygotskian perspective, a major role of schooling is to create social contexts (zones of proximal development) for mastery of and conscious awareness in the use of these cultural tools. It is by mastering these technologies of representation and communication that individuals acquire the capacity, the means, for 'higher order' intellectual activity" (Moll, 1990, p. 12).

Vygotskian theory specifies that "the development of the child's higher mental processes depends on the presence of mediating agents in the child's interaction with the environment" (Kozulin, 2003). Vygotsky himself primarily emphasized symbolic tools; mediators appropriated by children in the context of particular socio-cultural activities, including formal education; but Russian students of Vygotsky added two further types of mediation: mediation through another human being and mediation in the form of organised learning activity (Kozulin, 2003).

Kozulin (2003) talks of “two faces” of mediation: one human and the other symbolic (p. 18). Human mediation is discussed in much more detail later, when different mediational and scaffolding techniques that may be used in the classroom are discussed. In terms of symbolic mediators, Vygotsky (1978) mentions some of the most ancient: “casting lots, tying knots and counting fingers” (p. 127). Beyond these primitive tools one may find a number of higher-order symbolic mediators which include signs, symbols, writing, formulae and graphic organizers. Cognitive development and learning, according to Vygotsky, depends a great deal on whether a child can master these symbolic mediators; appropriating and internalising them in the form of inner psychological tools. Research into the use of symbols by young children shows that an understanding of the meaning of symbols as cognitive tools does not come naturally, but must be properly mediated to the child (Kozulin, 2003): “By their very nature symbolic mediators have the capacity to become cognitive tools. However, in order to realize this capacity the mediators should be appropriated under very special conditions that emphasize their meanings as cognitive tools” (Kozulin, 2003, p. 25).

According to Saljo (1999), “a fundamental assumption in a sociocultural understanding of human learning is...[that] learning is always learning to do something with cultural tools.....This has the important implication that when understanding learning we have to consider that the unit that we are studying is people in action using tools of some kind” (Saljo, 1999, p. 147). He argues thereafter that computers are a physical tool for learning, as they allow for the “appropriation and understanding of conceptual knowledge” (Saljo, 1999, p. 152). This is because they allow:

- by means of computer modeling, the construction of ‘microworlds’, which simulate events and processes.
- the visualization of many different kinds of phenomena, even relatively abstract mathematical concepts like functions and vectors.
- the production of multiple representations (for example, a function can be described algebraically in mathematical notation and presented as a graph).
- for interaction between the pupil and the material to be learnt. This interactivity can “provoke active reflection on the part of the learner who has

to consider alternatives, manage concepts and representations and so on in order to work through a task” (Saljo, 1999, p. 154).

Saljo (1999) does, however, caution against assuming that simply using the computer will ensure that the pupils’ understanding improves: “what technologies provide are experiences, but they do not guarantee a specific interpretation of these experiences that would amount to learning what was intended” (Saljo, 1999, p. 158). He supports the Vygotskian view that “to facilitate learning, the expertise of a teacher or a knowledgeable conversation partner would still be required” (Saljo, 1999, p. 158). Similarly, he argues “what the technology does is increase the range and nature of experiences that can be provided for the learning of subject matters that are complex and abstract...but the full realization of the potentials of such experiences will still rely on students’ access to conversation partners who carry on discussions” (Saljo, 1999, p. 159).

This emphasis on tools as a mediational means, which permeates much of the socio-cultural theory of learning, is the primary reason I use this theory as a conceptual framework for my study. In my quantitative research I am investigating learning with computers (in terms of how they impact academic performance), and in my qualitative research I focus on the impact computers have on teaching. Both sections of the current thesis, therefore, rely on a notion of mediation and socio-cultural theory, which with its focus on mind as mediated in joint activity, enables me to understand the utilization of computers as tools of learning. Putting it another way, socio-cultural theory provides the lens through which I look at learning and teaching with computers.

In the context of tool mediation, Wegerif’s (2004) argument on the role of educational software as a support for teaching and learning conversations is very useful. He argues that computers as partners in learning conversations have “an ambivalent ontological status” (p. 180) as they sometimes act as machines (objects) and sometimes as people (subjects), and this dual nature allows them “to play a potentially distinctive and valuable role within educational conversations” (p. 179).

The issue is that software which is more directive or closed can if used incorrectly limit the possibilities of thought and discussion. This is particularly the case when the computer software generates only IRF type exchanges (as described originally by Sinclair & Coulthard (1975)), where I stands for initiation (a question by the teacher or computer), R a response by the pupil, and F feedback by the teacher or computer.

However, the ambivalent nature of the computer, as seeming like a subject but actually being an object, allows them to support a different type of exchange (if the teacher encourages it), particularly when two or more users work together on a computer tutorial. The rather limited IRF exchange can be replaced by an IDRF exchange (Wegerif, 1996) in which an additional component is added: the D representing the discussion amongst the pupils of the question posed by the computer and what their response will be. This option is available precisely because the computer is a machine and can be made to wait until a response is agreed upon. In the discussion process, the pupils are able to construct their own meanings, which add to the knowledge that the computer has already provided them. Thus, “the IDRF structure can be seen as embodying a neo-Vygotskian model of teaching and learning: neither as transmission alone nor as construction alone but as both and more” (Wegerif, 2004, p. 183).

The key, however, is that such IDRF interactions need to be encouraged by the teacher when their pupils are using computer software. If this is so, if there is both “the right pedagogy and educational software, computers can not only serve as a shared focus for group work but can also interactively direct that work towards the goals of the curriculum while also, simultaneously, serving as a learning environment in which the students explore and test out their ideas. It seems likely that only computers can do all of this at once in an integrated way” (Wegerif, 2004, p. 189). The question that we are now faced with is what is mediated during joint activity?

Vygotsky (1987) differentiated between ‘scientific’ concepts and ‘everyday’ concepts. The everyday concepts “are the results of generalization and internalization of everyday personal experience in the absence of systematic instruction” (Karpov & Haywood, 1998); are typical of pre-schoolers; and tend to be unsystematic, empirically derived, and often wrong. In contrast, scientific concepts “represent the

generalization of the experience of humankind that is fixed in science, and that children are taught in the course of systematic instruction” (Karpov & Haywood, 1998). Once these concepts have been acquired and internalized, they are able to mediate the problem solving of the child. While the current thesis does not track the development of scientific concepts, it is important to understand that it is these uniquely mediated concepts that are taught during mathematics lessons.

Different as they are, Vygotsky (1987) also emphasized that the two concepts are interconnected and interdependent. “It is through the use of everyday concepts that children make sense of the definitions and explanations of scientific concepts...that is, everyday concepts mediate the acquisition of scientific concepts. However, Vygotsky proposed that everyday concepts also become dependent on, are mediated and transformed by the scientific concepts; they become the gate through which conscious awareness and control enter the domain of the everyday concepts” (Moll, 1990). It is clear from the definition that pupils will be dealing with scientific concepts in the mathematics classroom, but equally the latter quote indicates how important it is for these concepts to be brought to life by linking the concepts to the ‘real world’ as much as possible.

In school classrooms, the primary means by which mediation is carried out is by teacher talk. Part of my qualitative research is thus focussed on semiotic mediation, a short form for ‘semiotic mediation by means of the modality of language’; defined by Hasan (2005) as ‘the mediation of something by someone to someone else by means of the modality of language’ (p. 3). The focus on language was chosen because my conceptual framework is Vygotskian and, as Gallimore and Tharp (1993) put it, “Vygotsky insisted on the primacy of linguistic means in the development of higher order mental processes” (p. 178). This viewpoint regarding the supremacy of language over other modalities of meaning is supported by many other researchers, like Hasan (1992, 2004) and Wertsch (1985). Language is acting here as a psychological, abstract tool by which mediation is able to occur and which “alters the entire flow and structure of mental functions (Vygotsky, 1981, p. 137). The current thesis focuses on semiotic mediation as the primary pedagogic tool used in classrooms, and part of my qualitative research will explore how semiotic mediation

differs across the two teaching contexts of the traditional classroom and the computer lab.

2.3. Scaffolding

Moll (1990, p. 11) states that “Vygotsky never specified the forms of social assistance to learners that constitute a zone of proximal development”. He wrote about collaboration and direction, and about assisting children “through demonstration, leading questions, and by introducing the initial elements of the task’s solution” (Vygotsky, 1987, p. 209), but did not specify beyond these general prescriptions. It has been left up to neo-Vygotskian academics to develop his ideas further.

A metaphor used by many socio-cultural theorists, which has a similar meaning to mediation, is that of ‘scaffolding’ or ‘scaffolded instruction’, first introduced by Wood, Bruner and Ross (Wood et al., 1976) in the context of tutorial interactions between an adult and individual children. Scaffolding may be described as “the process by which a child (or novice) could be assisted to achieve a task that they may not be able to achieve if unassisted, until they are able to perform the task on their own” (Lajoie, 2005a, p. 542) or as “the process whereby pupils build up knowledge and understanding by linking new concepts to those previously understood, through a mental framework of linked concepts” (Cox et al., 2003). The overall emphasis is on “the creation of a pedagogic context in which combined effort results in a successful outcome” (Daniels, 2001, p. 107). It should be added that the scaffolding process “can potentially achieve much more for the learner than an assisted completion of the task. It may result, eventually, in development of task competence by the learner at a pace that would far outstrip his unassisted efforts” (Wood et al., 1976).

The notion of scaffolding is of particular importance in the current thesis in relation to how teachers use computers in mathematics lessons. The assumption underpinning scaffolding is that it provides a pedagogical bridge across a student’s ZPD, leading ultimately to learning. Lack of scaffolds in a classroom setting could, then, point to the absence of structured learning. The current thesis, drawing on socio-cultural

work, assumes that a computer can be used as a tool to scaffold the development of scientific concepts. The extent to which this is in fact so will be determined during the analysis of the qualitative data. While Vygotsky did not provide an elaboration of teaching in the ZPD, neo-Vygotskians have gone some way towards developing the concept of 'scaffolding' as a pedagogical technique.

Wood et al. (1976), in their breakthrough journal article, identified six key elements of scaffolding:

- *Recruitment* (enlisting the pupil's interest and adherence to the requirements of the task).
- *Reduction in degrees of freedom* (simplifying the task so that feedback is regulated to a level that could be used for correction).
- *Direction maintenance* (a verbal corrector or prodder which helps to keep the pupil in pursuit of the objective).
- *Marking critical features* (confirming correct understanding and checking or interpreting discrepancies).
- *Frustration control* (responding to the learner's emotional state).
- *Demonstration* (modelling a solution to the task).

Bonk and Kim (1998) have taken the six teaching methods that Collins, Brown and Newman (1989) provide for cognitive apprenticeships, and the seven basic strategies for teachers to assist in the learning process (basically scaffolds) as developed by Tharp and Gallimore (1988) and Tharp (1993), and 'merged' them to create the following list of socio-culturally based teacher mediation techniques:

- *Modelling* – offering behaviour for imitation - to illustrate performance standards and verbalise invisible processes.
- *Coaching* to guide pupils toward expert performance.
- *Scaffolding and fading* to support what pupils cannot yet do and gradually removing that support as competence is displayed.
- *Questioning* so as to obtain a verbal response from pupils.
- Encouraging pupil *articulation* of their reasoning and thought processes.
- Encouraging pupil *exploration* and application of their problem solving skills.
- Fostering pupil *reflection* and self awareness.

- Providing *cognitive task structuring* by explaining and organising the task within the pupil's ZPD.
- *Managing instruction* with performance *feedback* and positive reinforcement.
- Using *direct instruction* to provide clarity and fill in gaps of knowledge.

When these means of assistance are woven together, the teaching-learning situation evolves into what Tharp and Gallimore (1988) refer to as a rich “instructional conversation” (p. 111).

Over the past few decades, a number of educators and researchers have written about how the concept of scaffolding fits into the Vygotskian concept of the ZPD (see, for example, Bruner, 1997; Daniels, 2001; Wells, 1999). For example, Wood and Wood (1996a, b) and Wood (1998) have developed an approach to tutoring which is based on an interpretation of the ZPD. They speak about how pupil *uncertainty* makes learning more difficult because it reduces motivation and memory of the task itself, and how important it is for the expert (tutor) to assist in reducing the uncertainty in a task situation. Another key principle of the Woods' approach is that the support offered within the ZPD of a pupil should be *contingent* on the responses of the child. They suggest five levels of increasing control in a learning/tutorial situation, as indicated by questions that the tutor might ask in order to enable to pupil to complete the task:

- Level 0: no assistance
- Level 1: a general verbal prompt (“What might you do here?”)
- Level 2: specific verbal (“You might use your computer tools here”)
- Level 3: indicates materials (“Why not use the graph plotter?”)
- Level 4: prepares materials (selects and sets up tool)
- Level 5: demonstrates use

Each time the pupil does something correctly, Wood's principle of contingency would have the tutor reduce the level of control (and vice versa). The task of the tutor is to ensure that the pupil progresses, whilst concurrently reducing their (the tutor's) level of control.

Specifically within the field of Mathematics, Wood (1994) observed numerous Mathematics lessons and identified two distinct patterns of interactions based on the types of questions teachers asked:

- The *funnel pattern* of interactions: this was where pupils were provided with leading questions in order to guide them to a pre-determined solution preferred by the teacher. Interacting in this manner does not allow the pupil opportunities to explore ways of solving the problem for him- or herself; indeed, in this type of interaction the teacher “is seen as curtailing the possibility that the student will engage in any meaningful thinking of his own” (Wood, 1994, p. 155).
- The *focusing pattern* of interactions: here the teacher asked questions to draw pupils’ attention to the critical or discriminating aspects of a problem, ultimately leaving responsibility for resolving the situation with the pupils.

It is in the latter pattern of interactions that the teacher is truly supporting mathematics learning.

Bliss, Askew and Macrae (1996) observed classroom teaching in mathematics, science and Design and Technology classes in the UK (Key Stage 2; ages 9-11), looking for examples of scaffolding. A “major finding” was a “relative absence” (of scaffolding) in most lessons, even after a ‘reflective phase’ during which the teachers involved identified scaffolding strategies and how to implement them in the classroom. Some of the scaffolds they did notice and identify were the following:

- Actual scaffolds – approval, encouragement, structuring work, organising people.
- Prop scaffolds – where the teacher provides a suggestion to help the pupils.
- Localized scaffolds – providing specific help with one part of an idea or concept so as to enable the pupil to begin moving towards understanding.
- Foothold scaffolds – usually a step-by-step series of questions.
- Hints and slots scaffolds – narrowing questions until only one answer fits.

The last two scaffolds mentioned above correspond quite closely to the funnel pattern of interactions identified by Wood (1994).

Tharp and Gallimore (1988) believe that the paucity of scaffolding in the classroom is due to two main factors:

- Large class sizes: this makes it very difficult for teachers to know each pupil well enough so as to provide the sensitive and accurate assistance each requires in order to progress through the ZPD.
- Lack of training: most teachers do not possess the pedagogical skills needed to scaffold their pupils. “Teachers themselves must have their performance assisted if they are to acquire the ability to assist the performance of their students” (Tharp & Gallimore, p. 43). Kozulin (2003) talks about the need for systematic training [for teachers] in both the general types of mediation and specific techniques appropriate for a given age and subject matter” (p. 21).

The subject domain of my research is Mathematics; hence the most useful work in the area of scaffolding for my dissertation is that of Anghileri (2006), as she developed a hierarchy of three levels to incorporate the particular scaffolding practices that teachers could use as pedagogical strategies in the Mathematics classroom to enhance the learning of that subject (see Figure 2 below). Her work is important in the current thesis in that it provides a detailed account of how scaffolding potentially plays out in a mathematics lesson. This will hopefully shed light on the question of how teachers use computers in the mathematics lesson.

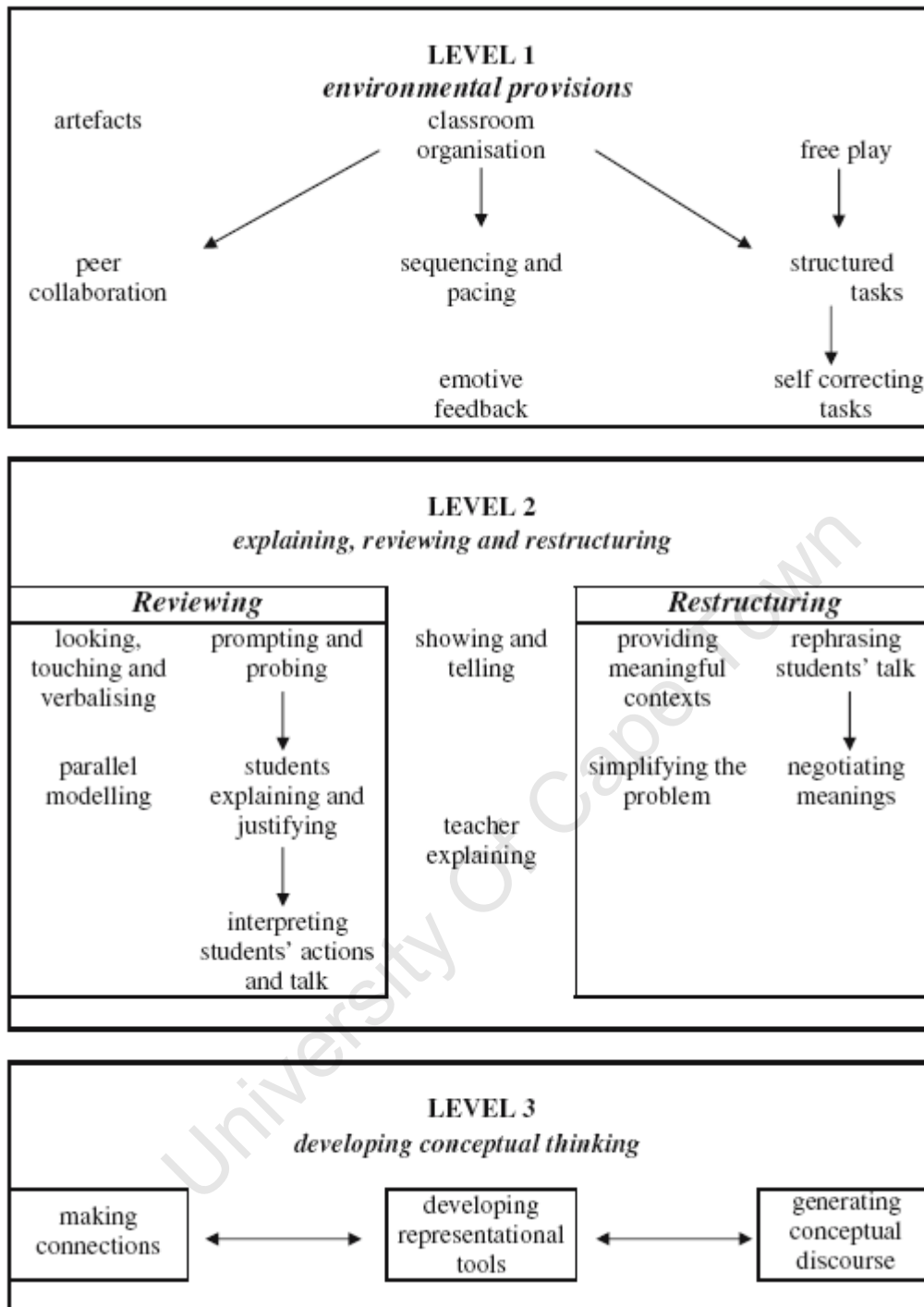


Figure 2: Teacher strategies for Scaffolded Learning
(source: Anghileri, 2006, p. 39)

A fairly detailed outline of the scaffolding practices of Anghileri (2006) is made below:

Level 1 scaffolds covers the environmental provisions that teachers provide to scaffold learning before interacting with their students. These include *artefacts* (like

wall displays, puzzles and manipulatives) and *classroom organization* (which includes seating arrangements; *structured tasks*, like worksheets; and grouping so that pupils are able to work together to solve particular problems by means of *peer collaboration*). One Level 1 scaffolding practice that does involve a direct interaction between teacher and pupils is that of *emotive feedback*. It includes remarks and actions used to gain attention, encourage or approve of pupil activities. Bliss et al. (1996) found that such ‘approval and encouragement’ constitutes the majority of the interactions classified as actual scaffolds, along with ‘structuring work’ and ‘organising people’.

Level 2 scaffolds include explaining, reviewing and restructuring. Explaining, allied to ‘showing and telling’, is a very traditional classroom teaching practice that relates to Wood’s (1994) funnel pattern of interactions. Little use is made of pupil contributions as the teacher controls exactly what is happening. In fact Anghileri (2006) believes that explaining can be detrimental in another way in that it “inadvertently constrains students’ thinking...Where the explanation is not ‘in tune’ with a student’s thinking this can compound the difficulty, giving the student a problem in reconciling different ideas” (p. 41).

Scaffolding strategies that are more likely to develop the pupil’s own understanding of mathematics and which fit more into Wood’s (1994) ‘focusing pattern of interactions’, including reviewing and restructuring.

Reviewing includes interactions between teacher and pupils involved in a task, that will help the pupils identify what aspects are most pertinent to the mathematical problem being solved; refocus their attention and allow them to develop their own understanding.

The five types of reviewing interactions are:

- Getting pupils to *look, touch and verbalise* what they see and think: handling manipulatives, for example.
- *Interpreting pupils’ actions* and talk.
- Using *prompting and probing* questions: prompting questions successively lead a pupil toward a predetermined solution, and are an example of a funnel

pattern of interactions (Wood, 1994). Probing questions – that focus on the most critical points in an explanation - are better in that they try to ensure the pupils expand on their own thinking.

- *Parallel modeling*: if the pupils are having difficulty solving a mathematical problem, parallel modeling would have “the teacher create and solve a task that shares some of the characteristics of the student’s problem” (Anghileri, 2006, p. 43).
- Getting pupils to *explain and justify* their solutions: this requires pupils to make explicit their thinking to the group or class.

Restructuring involves the teacher introducing modifications to arguments, ideas and problems to enable them to be more accessible but also to take meanings forward.

The four types of restructuring interactions are:

- Providing *meaningful contexts* to abstract situations. A classic example of this would be to take the abstract calculation ‘ $6 \div 12 = _$ ’ and shift it to a contextual setting “6 pizzas to be shared amongst 12 people”.
- *Simplifying the problem* by constraining and limiting the degrees of freedom: this involves initially reducing the complexity of the task so that the pupil can cope, and then building in progressive steps so as to enable the pupil ultimately to come to an understanding of the original problem.
- *Rephrasing pupils’ talk*: this goes further than interpreting pupils’ actions and talk mentioned earlier; to rephrasing what the pupil has said using correct formal mathematical terminology.
- *Negotiating meanings*: this involves the teacher and pupils sharing their mathematical understandings and ultimately negotiating interpretations and solutions.

Level 3 scaffolds – the highest level – consists of “teaching interactions that explicitly addresses developing conceptual thinking by creating opportunities to reveal understandings to pupils and teachers together” (Anghileri, 2006, p. 47). There are three types of interactions that fit this level:

- Developing *representational tools*: these tools include language, both formal and informal; symbols; and visual imagery.
- Making *connections*: this involves indicating the links between different ideas in mathematics; for example, the connections between fractions, decimals and percentages. Such approaches have been termed ‘connectionist’ by Askew et al. (1997) in their study of the teaching of numeracy in the UK.
- Generating *conceptual discourse*: this goes beyond the explanations and justifications of Level 2 scaffolds by “initiating reflective shifts such that what is said and done in action subsequently becomes an explicit topic of discussion” (Anghileri, 2006, p. 49).

The concepts of mediation and scaffolding are important in this thesis because there is an assumption made in schools that computer software can mediate pupils’ engagement with mathematics. Much has indeed been written about the different types of scaffolding that can be provided by computers acting as cognitive tools (see, for example, Pea, 1985; Salomon, 1988; Jonassen & Reeves, 1996; Lajoie, 2005b).

It should be noted that the view of ICT as mediator is not entirely accepted by all. For example, Pachler (2005) says that although “ICT can be seen to have mediatory potential in the Vygotskian sense...this view is...not unproblematic” (p. 198). His concern centres on the fact that unless used wisely “ICT will undermine the social quality of education” (p. 198), which is a critical component of a socio-cultural view of learning.

A few researchers have cautioned that we need to also be aware of the limitations of the scaffolding metaphor. For example, Verenikina (2003) warns that “it is essential to keep in mind that a literal interpretation of the scaffolding metaphor might lead to a narrow view of child-teacher interaction and an image of the child as a passive recipient of a teacher’s direct instruction” (p. 3). Instead, a teacher that adopts a socio-cultural approach will focus on assisting learning, not directing it (Tharp and Gallimore, 1988). According to Tharp (1993), quality socio-cultural teaching is responsive in nature: rather than simply assigning tasks and fostering standard

practices, socio-cultural teachers value assisting or supporting the performance of their pupils.

Another critique of the scaffolding metaphor comes from Griffin and Cole (1984) who, drawing on the work of Bernstein and Leontiev, suggest that this approach will cause the child's creativity to be underplayed: "Adult wisdom does not provide a teleology for child development. Social organisation and leading activities provide a gap within which the child can develop novel creative analyses" (p. 62).

2.4. Chapter Summary

This chapter has outlined the Vygotskian Theory of Learning; the theory that underpins my research. Various key ideas in the Vygotskian analysis are defined and elaborated upon, such as the importance of mediation by artefacts or tools in the cognitive development of pupils, and the concept of the Zone of Proximal Development. The chapter then narrows its focus to a discussion of one aspect of neo-Vygotskian theory: the scaffolding process, by which pupils' skills, knowledge and understanding are developed by various techniques. Key scaffolding techniques, such as those of Wood et al. (1976) and Bonk and Kim (1998) are described.

The work of Anghileri (2006) into scaffolding practices that may be used within the Mathematics classroom is described in some detail. She developed a hierarchy of three levels of instructional tools, from basic environmental provisions within the classroom (Level 1) through to scaffolds at Level 3 that can be used to develop conceptual thinking.

Having now set out the theoretical background of this dissertation, this dissertation moves on in the next chapter to the review of the published literature in the fields of:

- the link between the use of computers in schools and academic attainment (with particular reference to the subject of Mathematics); and
- the importance of how computers are used in the classroom; and
- variation in semiotic mediation

CHAPTER THREE

REVIEW OF LITERATURE AND EMPIRICAL STUDIES

3.1. Introduction

As mentioned in the previous chapter, my research uses Vygotsky's socio-cultural theories regarding cognitive development as a theoretical framework by which to examine how effective computers (and in particular Mathematics software packages and programmes) are on

- improving the performance in Mathematics of disadvantaged high school pupils in Cape Town, and
- impacting pedagogy

This literature review therefore considers the key existing studies investigating

- i. the link between computer usage and academic attainment (with a special focus on Mathematics as that is the subject domain of this dissertation), and
- ii. the way in which computers should best be used to bring about improved mathematical understanding, and
- iii. whether the use of computers alters classroom pedagogy.

I will now consider each of these separately.

3.2. Research on a Link between Computer Usage and Academic Attainment

3.2.1. Introduction

Due to the paucity of research on this topic in less developed nations I have been forced to focus mainly on research in the UK and USA where this is an extremely hot, and contentious, issue. The contention is over just how effective computers are in mediating understanding, as results from different studies vary from showing great improvements in attainment to none at all, or occasionally even a backwards

movement. Reynolds, Treharne and Tripp (2003) describe three groups of researchers into this topic: the optimist-rhetoric group, the pessimistic-rhetoric group and the academic research group. They claim that most of the research of the first group (that claims that ICT does raise standards of pupil achievement) is faulty because of methodological problems and unsubstantiated claims; while the second group is opposed in principle to the use of computer technology in schools. The third group, that have been researching this topic “for over 20 years using a range of research methodologies that have a proven track record in terms of reliability,.... [have] consistently thrown up evidence that refutes the optimistic rhetoricians claims” (Reynolds et al., 2003, p. 153). However, these strong statements of Reynolds et al. (2003) are, in themselves, also unsubstantiated and thus the same fault that is laid at the door of the optimistic-rhetorics is, I feel, committed by Reynolds et al themselves.

One of the pessimistic group who is widely cited for his negative views of computers in education is Stoll (1995), who compared computers to the children’s programme Sesame Street, arguing that “both give you the sensation that merely by watching a screen, you can acquire information without work and discipline “ (p. 147). Another is Healy (1998), who believes that much educational software is crowded with extraneous effects that distract children and distance them from real learning. Dangers of the use of computers, according to her, include impulsive clicking, trial-and-error use or guessing; while she believes computer time can reduce the opportunities for children to socialise, play and imagine; all critical parts of the learning process.

On the other side of the fence, researchers like Barrow, Markman & Rouse (2007), Olusi (2008) and Wang & Chan (1995) have provided a set of reasons why the use of computers might provide an advantage over the traditional chalk-and-talk method of instruction:

- i. computers can offer individualised instruction. In other words, pupils can study exactly what it is that they need to study, which gives them greater control over their learning.
- ii. pupils using computers can learn at their own pace. This is particularly advantageous for struggling pupils who might not be able to keep up with the

pace of their peers in a traditional classroom, and also for more advanced pupils who would no longer become bored by being held back by the teacher needing to provide more in-depth instruction to the weaker pupils.

- iii. a pupil that is absent from a traditional lesson would miss all the work covered by the class in that day, but in contrast, the computer would simply pick up where the pupil left off last time.
- iv. if each pupil has access to a computer, then the individual instruction time is much more productive in the lab due to the fact that the computer can tutor the pupil at any point, whereas in a traditional classroom there is usually only one teacher trying to help the whole class, and inevitably this means that there are times when pupils are stuck and can make no progress until the teacher gets to their desk and helps them.
- v. computers, with their exciting graphics and greater variety of presentations (including simulations), motivate pupils more than most teachers can, and ensure that pupils stay more on task.
- vi. computers are infinitely patient, never getting frustrated or angry, thus ensuring there are fewer emotional constraints to learning.
- vii. computers give immediate feedback, allowing pupils to learn from their errors and move on without delay.

The above arguments sound plausible, but the litmus test is to ascertain whether there is any proof that the above (suggested) advantages translate into improvements in pupils' test scores.

BECTA, the 'British Educational Communications and Technology Agency', is a UK government agency aiming to ensure the effective and innovative use of technology throughout learning. As such, they have undertaken numerous studies into the efficacy of computers in improving learning that are relevant to my dissertation. A very recent BECTA study (Smith, Rudd & Coghlan, 2008) involved the analysis of

thousands of questionnaires completed by UK mathematics teachers across the spectrum from primary to secondary schools. One of the questions asked was: “do you agree or disagree that using ICT can have a positive impact on attainment outcomes?” The response was very much in favour of ICT in that, across the board, around three-quarters of respondents either agreed or agreed strongly with this statement. Virtually no respondents disagreed with this statement. This study clearly shows that, in the UK at least, the perception of educators is very much that ICT *does* make a positive impact on pupil attainment. However, perceptions can be mistaken and so I focus in this literature review on research undertaken around the world, published in peer-reviewed journals, that attempts to find a statistical link between computer use and academic performance.

In this review I will focus on studies that have ascertained a positive link between computer use in Mathematics classrooms and pupil performance, and other major studies in which positive or mixed results have been shown. However, I will also point out various cautions about the validity of some of these findings and present the findings of some of those few researchers who found that computers could, at times, have a negative influence on mathematics attainment.

Of all the extensive research that has been done worldwide into the use of computers as tools to mediate the understanding of pupils, perhaps the best example, due to its longevity, is the ‘Fifth Dimension’ programme.

The Fifth Dimension programme is an after-school educational programme that was set up in 1986 by Michael Cole of the University of California in San Diego (see Cole (1996) and Blanton, Greene & Cole (1999)), and is still running today over two decades later. The ‘Fifth Dimension’ programme, described by Cole as “a specially constructed computer-mediated activity” (Cole, 1996, p. 288) was initially implemented in the USA, and aims to use the computer to mediate learning amongst disadvantaged elementary and middle school (Grades 3-8) pupils. Various computer games and activities are provided at various after-school locations, with the children working collaboratively in small groups as they move their ‘cruddy creature’ (personal identifier) through a maze by completing tasks, most but not all computer-based. They progress according to rules, contained in the Fifth Dimension

Constitution, which enable them to move up to higher levels and therefore always be appropriately challenged. They are assisted in their progress, and encouraged to reflect on what they were doing, by a cyber prankster known as the 'Wizard'. In addition, university students and staff adopt the dual role of researchers and 'wizard's assistants' in that they help children solve problems that they might otherwise not have been able to solve (thus specifically supporting learning within Vygotsky's 'zone of proximal development').

Blanton et al. (2006) have made a quantitative evaluation of the effects of participation in the Fifth Dimension (FD) programme on the cognitive and academic skills of the children. A number of studies that focus on the effects of Fifth Dimension experience on mathematical understanding and problem-solving were reported on:

- In the Mayer et al. (1997) study, pre- and post-tests assessing children's skill in comprehending arithmetic word problems were completed. The finding was that the pre-test to post-test gain for the treatment group (the children who were participating in the FD programme) was significantly greater than the gain for the comparison group (the children who did not attend the FD programme). This study was replicated with comparable results at two different FD sites. The results "provide evidence that children in the Fifth Dimension learn something about formal statements and mathematical equations in the course of playing computer games and that they are able to transfer that learning to similar non-computer-related tasks" (Blanton et al., 2006, p. 95).
- In the 'Puzzle Tanks' computer game study, children from an experimental and a control group were tested for their ability to transfer problem solving strategies to new games and to mathematics. Children who frequently attended the FD computer club made fewer errors and generated more sophisticated problem solving strategies than did equivalent children who had minimal FD experience, thus demonstrating that "experience in the Fifth Dimension promotes the development of mathematical problem-solving skills that transfer to new kinds of tasks" (Blanton et al., 2006, p. 97).

Perhaps the most important study in the context of the quantitative aspect of this dissertation is the study of the impact of participation in the FD programme on children's success in traditional forms of academic performance; in this case, end-of-grade mathematics achievement tests for pupils in Grades 3-6, administered by the US state of North Carolina (see Blanton, Moorman, Hayes & Warner, 1997). Again there were two groups: an experimental group of experienced FD pupils and a control group of non-FD participants; matched on gender and public school classroom. Each group completed pre-tests which were used as a covariate to control statistically for any pre-existing group differences, while the dependent measure consisted of math post-test scores on the North Carolina end-of-grade tests. The analysis showed a significant difference between the post-test scores for the two groups, with the experimental group showing higher scores and therefore greater end-of-grade achievement in mathematics. A step-wise multiple regression using the post-test score as the dependent variable was then computed – this showed that the largest single influence on post-test scores (other than, obviously, the pre-existing level of mathematical skill) was group membership (experimental or control).

Blanton et al. (2006) do caution though that the positive findings made in these studies may not only be due to the positive impact of exposure to the computer games but also due to other positive spin-offs from the programme, like the existence of helpful undergraduate-child relationships.

These FD studies are very useful in showing how computers can successfully impact pupils' attainment. However, as it deals with elementary and middle school pupils in an out-of-school setting - whereas my study is on high school pupils within school institutions – it is not entirely applicable.

The second significant study on ICT-enhanced learning I will review is the Apple Classroom of Tomorrow (ACOT) Project, funded by the Apple Corporation, which ran from 1986 to 1998. The fact that it is a longitudinal study, lasting over a decade, makes it unusual as there are few other similar studies with a similar lengthy duration. It started as a small research and development project in the USA, but the number of participating schools increased enormously over its 12 year duration and

the project even expanded into Europe. Its mission was “to deepen understanding of how technology can be used as a learning tool” (Fisher, Dwyer & Yocam, 1996, p. 1) – exactly what part of my research is all about - and placed a lot of emphasis on “conversations about learning” (Fisher et al., 1996, p. 2). The results of the ACOT study showed a number of very positive outcomes, including greater collaboration between pupils, increased pupil motivation and improved attitude to learning, and increased teacher job satisfaction and interdisciplinary work (including team teaching). However, although ACOT students generally performed well on standardised tests, adopting innovative pedagogies with ICT alongside preparing students for tests and examinations was found to be “highly problematic” (Somekh, 2007, p. 20).

3.2.2. Research on Computers and Mathematics Performance in Developed Nations

The ACOT study, useful as it is in showing positive results of computer use in classrooms, does not look specifically at Mathematics, the subject domain of my dissertation. The rest of my review will therefore focus on providing a broad overview of some of the most relevant studies concerning the impact of ICT on Mathematics attainment in schools, particularly but not exclusively to high schools as that is the focus of my research.

Many of these studies originate from the United Kingdom, where the education system is far removed from that in Cape Town, and most of the others originate in other relatively wealthy European or North American nations. This is unfortunate but unavoidable as it is only in those countries where computers have been used in schools for many years, and for which there are decades of research into ICT impact. It is questionable whether all the findings outlined below will be transferable to impoverished schools in a city at the foot of Africa, but at least they will provide a base view against which I can compare my research findings.

First of all, definitions of various terms need to be provided, as per Kirkpatrick and Cuban (1998). Computer-assisted Instruction (CAI) involves using computers to

provide drill exercises and tutorials. Computer-managed Instruction (CMI) is more elaborate than CAI in that the computer software also diagnoses areas in which pupils need more instruction, guiding pupils in their own learning and recording progress for the teacher. Barrow et al. (2007) and Olusi (2008) believe that most computerised instruction that is referred to in the literature is primarily CAI, but contains elements of CMI. Integrated Learning Systems (ILS) are courseware and managerial software packages that operate in a computer network environment (Walker & Senger, 2007).

Higgins (2001) summarised research undertaken by the Teacher Training Agency (TTA), and other research in the UK, into the role and potential of ICT in effective teaching and the development of pupils' understanding. He concluded that studies into the effects of CAI (Computer Assisted Instruction) in the UK, mainly in secondary and post-secondary educational settings, have been quite disappointing: "overall the benefit reported by these studies is relatively low and computer use has not generally [been] found to be as effective as other approaches such as peer tutoring or homework" (Higgins, 2001, p.167). However, this statement is not backed up by reference to particular studies, which is an obvious weakness.

Tienken and Wilson (2007), studying mainly US research into the effect of CAI, were also rather ambivalent: after providing a detailed literature review of research in the field in the past 20 years they concluded that "while some studies...have suggested positive results from CAI, other studies have raised questions about its efficacy. The results of CAI remain mixed." (Tienken & Wilson, 2007, p. 182).

Some of the positive findings regarding CAI include the research of Christmann, Badgett and Lucking (1997), who looked at the academic achievement of US pupils from Grades 6-12 who received either traditional instruction or traditional instruction supplemented with computer-assisted instruction across 8 areas of the curriculum, discovered a clear positive impact: on average, pupils who received computer-assisted instruction in addition to traditional instruction achieved better academically than did 58.2% of those receiving only the latter. Similarly, the meta-analysis by Waxman, Connell and Gray (2002) of 13 quantitative CAI studies published in peer-reviewed journals between 1997 and 2002 did find a positive average effect size for

CAI of 0.42 (an effect that is considered to be 'moderate' by social scientists). In a further positive instance of the benefit of CAI, Tienken and Wilson's (2007) study using a sample of seventh graders in New Jersey, USA, showed that use of web-based drill and practise exercises, when supplemented by the students presenting an explanation to the class of what they had learnt, did lead to a small but statistically significant improvement in the students' learning of basic computational skills.

Seo and Bryant (2009) completed a meta-study of CAI studies in mathematics education for pupils with learning disabilities (LD), focussing on examining the effects of CAI on the mathematics performance of pupils with LD. Whilst my dissertation is not focussed on this particular group of pupils, the findings of these researchers are, I believe, still relevant to this study as pupils with LD are often found in mainstream South African schools. The meta-study of Seo and Bryant (2009) covered all research reported from 1980 to 2008, though ultimately, due to various strict selection criteria, only 11 studies were selected. The results data of each study were analysed to determine the magnitude of the effectiveness of CAI by calculating effect size. The six studies that dealt with the Mathematics performance of pupils taught by CAI as opposed to traditional methods "showed mixed findings without large effect sizes (Seo & Bryant, 2009, p. 919): the pupils in the CAI groups outperformed their peers in the teacher-directed instruction groups, but failed to produce large effect sizes. This "quite disappointing" (Seo & Bryant, 2009, p. 926) set of findings should be taken along with the fact that "the effectiveness of CAI for students with LD could not be examined accurately due the critical methodological limitations found in the studies" (Seo & Bryant, 2009, p. 926).

One oft-cited work that determined a negative impact of computers on Mathematics performance is the Israeli study of Angrist and Lavy (2002). Their ordinary least squares analysis of the effect of CAI on the Mathematics results of thousands of 4th and 8th grade pupils in nearly 200 schools found "no evidence...that increased educational use of computers actually raised pupil test scores" (p. 737). In fact, the use of computers in the Mathematics classes had a marginally significant negative effect on the Mathematics results of the 8th grade classes they studied. Their conclusion, very relevant to the Khanya Project in a relatively poor country like South

Africa, is that “this significant and ongoing expenditure on education technology does not appear to be justified by pupil performance results to date...On balance, it seems, money spent on CAI in Israel would have been better spent on other inputs” (Angrist & Lavy, 2002, p. 761) [by which they were referring to reductions in class sizes and increased teacher training].

Higgins’ (2001) evaluation of Integrated Learning Systems (ILS) in the UK, showed that “at least for pupils aged 11-14, the ILS systems...were not effective in raising attainment in Mathematics, although they might possibly be helpful for remediation or as a ‘catch up’ solution, particularly for lower attaining pupils” (Higgins, 2001, p. 167). Wood, Underwood and Avis (1999), in their report on the use of ILS in the UK, concurred by stating that the software did assist in teaching core mathematical and English skills but that not all such successes were measurable through subsequent tests or exams. They even went so far as to suggest that the exclusive reliance on ILS as preparation for Key Stage 3 and GCSE (General Certificate of Secondary Education) exams might have had a negative effect.

Many BECTA studies have considered the impact of computers on pupils’ academic attainment. For example, an analysis carried out by BECTA (2001), found better results at Key Stage 3 (Grade 7 to 9) in schools using ICT to support Mathematics and Science compared to schools where it was not used to the same degree. Higher GCSE (Grades 10 and 11) results were also found in schools that used ICT more across the curriculum.

Two major BECTA studies that included an investigation on the effect of ICT on pupils’ attainments in mathematics are the ImpaCT and ImpaCT2 studies. The first study, as reported by Watson (1993), showed that pupils both in primary school (aged 8-10) and high school (aged 14-16) who used Logo and subject-based mathematics software achieved statistically higher scores in tests than those who were taught using traditional methods.

The ImpaCT2 Study (as reported in Harrison et al., 2002) was a major longitudinal study carried out from 1999 to 2002 in 60 schools in England, and which conducted a large-scale statistical analysis of data on ICT usage and attainment. It is, in my

opinion, the standout research in this field due to the considerable length, breadth and depth of its research. The part of the ImpaCT2 study that is most relevant to my research is the section that considered whether the use of ICT in school impacted positively on performance in National Tests and GCSEs.

The study, which covered a wide range of school levels (Key Stages 2 to 4, which equate approximately to Grades 3 to 11), used 'baseline' data (obtained from tests that the students had undergone about 18 months earlier) to predict student performance, and then compared it to their actual grades. This provided each pupil's 'relative gain score': if the relative gain score was positive the pupil had performed better than predicted, and vice versa. Pupils were in addition allocated to one of two groups, 'high ICT' or 'low ICT' depending on whether or not the amount of time ICT was used in that subject was below or above the median for that subject at that Key Stage. At each Key Stage, for each subject, ImpaCT2 asked 'did high ICT users have significantly higher relative gain scores than low ICT users?'

Harrison et al. (2002) found a statistically significant positive association between high ICT use and relative gain scores in some learning areas (for example, Science, English and Design & Technology) in some Key Stages, but interestingly for this dissertation never in Mathematics. However, they did find a positive, non-statistically significant relationship between level of ICT use and relative gain score in Mathematics in all the key stages, and in addition showed that in none of the comparisons (across all subject areas, including Mathematics) was there a statistically significant advantage to pupils with lower ICT use (in other words, ICT was never strongly associated with *poorer* performance in exams). Another interesting finding was that it seems pupil use of ICT across the board, not just in a particular subject, was required for significant positive impact.

In a later article, Harrison, Lunzer, Tymms, Fitz-Gibbon and Restorick (2004) reported on 3 previously unpublished comparative analyses of the same data from the ImpaCT2 study. These analyses were, firstly, on an individual pupil level; secondly, on a school-by-school basis; and thirdly, involved a multilevel modelling analysis. In all cases, a statistical analysis was made of the central hypothesis that "greater use of ICT in curricular study is associated with improved examination

performance” (Harrison et al., 2004, p. 320). The analyses showed that, of the 13 pupil-level comparisons, ten conformed to the central hypothesis; five of those showed significant differences favouring high ICT, and a further two narrowly failed to reach significance. “Overall, the findings constitute very strong evidence in favour of the hypothesis: greater ICT experience is strongly associated with superior performance in public examinations” (Harrison et al., 2004, p. 334). The results from the other analyses showed similar though slightly weaker support for the hypothesis.

However, due to my dissertation being about the subject of Mathematics, it is very important to add that the ImpaCT2 study findings for Mathematics at an individual pupil level were rather less encouraging, other than with the youngest group (Harrison et al., 2004):

- in Key Stage 2 (Grades 3 to 6), a significant ($p < 0.05$) and linear advantage associated with a higher use of ICT.
- in Key Stage 3 (Grades 7 to 9), a slightly negative association between higher use of ICT and performance in public exams.
- in Key Stage 4 (Grades 10 and 11), a positive, linear but not statistically significant association between higher ICT use and exam performance.

It should be noted that compared with the other core subjects of Science and English (but particularly the former), in Mathematics there is a far less positive relationship between ICT use and exam results. This might be because usage of ICT in Mathematics, particularly higher up in the school, remains relatively low. For example, the ImpaCT2 study (Harrison et al., 2002) reported that at Key Stage 3 (ages 11-14), 67% of pupils never or hardly ever used ICT in mathematics lessons; whilst at Key Stage 4 (ages 14-16) the figure was even higher (80%). Clements (2000), whose research was undertaken in the USA, observed a similar low level of use, particularly amongst the less able pupils. Furthermore, observations in schools consistently show that ICT in the Mathematics classroom is typically used for low cognitive level tasks like ‘drill and practise’ (Chalkey & Nicholas, 1997), which will have little impact on attainment.

3.2.2.1. Research showing Positive Impact on Particular Strands of Mathematics

Amidst this ambivalence, a number of studies have shown ICT to have produced positive effects in various strands of Mathematics, the subject domain of my dissertation. In fact, Cox et al. (2003), in a major review of the research literature into ICT and attainment, go so far as to state that “the effect of ICT on pupil’s attainment in mathematics is most evident regarding uses of ICT which link to specific mathematical skills and processes” (p. 17). Although my research does not investigate the impact of computers in specific mathematical learning areas (only on overall mathematical attainment), the following benefits in particular strands of Mathematics identified by research studies are definitely worthy of mention:

i) Geometry and Mensuration

- the use of Logo helped pupils to develop higher levels of geometric thinking and to learn geometric concepts & skills, and concepts of ratio and proportion (Clements, 2002).
- Grade 7 pupils in a school in the UK that completed the geometric reasoning section of their syllabus using dynamic geometry software (specifically, Geometer’s Sketchpad) did significantly better in a summative assessment than a group of equal ability that had learnt the same topic using only paper and pencil methods (Forsythe, 2007).
- pupils that used a computer tutoring programme Geometry Tutor that assisted whenever they strayed from correct reasoning, learnt geometry faster with such help (Wertheimer, 1990).
- 6th graders in Pennsylvania, USA, were taught concepts of area and volume using a computer-based programme in addition to traditional instruction. At the end of the course, pupils were tested and their scores compared with 8th graders who had received traditional instruction only. It was found that the 6th grade pupils performed better overall than the 8th grade pupils, especially on the more complex problems (Raghavan, Sartoris & Glaser, 1997).

ii) Algebra

- pupils using an algebra tutoring programme (Algebra Tutor), showed small gains on standardised Mathematics tests such as the Scholastic Aptitude Tests (SATs), and more than doubled their achievement in complex problem solving compared to pupils not using this technology (Koedinger et al., 1997).
- pupils using computer algebra software performed better in an intermediate algebra course than those without (Shaw, Jean & Peck, 1997). A similar study by Stephens and Konvalina (1999) on the performance of students using the algebra software MAPLE, found that intermediate algebra pupils that had used the software outperformed those that did not, in a common final examination, although the results were not statistically significant.
- computers can assist in the development of pre-algebra and algebra skills. Barrow et al. (2007) completed during the period 2003-2005 a major study in 3 urban school districts of the USA, involving 17 schools, 141 classes and 59 teachers. The research involved determining the academic impact of a popular instructional computer programme ("I can Learn"), designed to improve the aforementioned skills. They found that pupils randomly assigned to classes using the computer lab score at least 0.17 of a standard deviation higher on tests of pre-algebra and algebra achievement than pupils assigned to traditional classrooms. This was statistically significant at the 5% level, and can be interpreted to mean that the pupils assigned to a CAI classroom achieved 26% of a grade level more than their peers at the end of the semester. The estimated effect rose to 0.25 of a standard deviation when they estimated the effect on pupils that actually used the programme. There was some evidence that the impact of the programme was greatest on pupils in larger classes and those in classes in which pupils have poor attendance records. Their findings did show, though, that the CAI treatment was more effective for pre-algebra pupils than for algebra pupils.

iii) Data Handling

- pupils aged 13-15 that used computer-based data analysis packages outperformed the control group (who used sets of data on paper cards) and developed important data-handling skills previously only found among older pupils (Cox & Nikolopoulou, 1997).
- computers can assist with understanding graphical relationships (Hennessy, 2000). The study involved 13 and 14 year old pupils of diverse abilities at two different schools in England, who undertook a weather project to study relationships between temperature and latitude, and temperature and time of year. The study showed that through using the computers to draw graphs of the relationships, pupils showed significant gains (in post-project compared to pre-project tests) in diverse mathematical areas like determining the mean, mode and median of data, calculating range, and extrapolating and interpolating data.

One topic-based piece of research that shows clearly that using computers produced worse results than more traditional teaching methods is that of Wong and Evans (2007). Their study, which involved 64 Year 5 pupils in Sydney, Australia, investigated whether a computer based computer software package (Back to Basics Maths Multiplication) was better than pen and paper instruction (PPI) methods in improving pupils' basic multiplication fact recall. Pre-tests on the two groups showed no significant differences in scores, but post-test scores for the pen and paper group exceeded that of the group that had used the computer software package to prepare for the test (although both groups saw a significant improvement in test scores). Thus, "PPI was a more effective method of improving recall of basic multiplication facts" (Wong & Evans, 2007, p. 99). However, the researchers did note that the findings of this study were in contradiction to those of previous studies of the same issue, such as that of Williams (2000).

A recent landscape review of the impact of ICT in schools (Condie & Munro, 2007) analysed over 350 literature sources published since 2000 that related to the impact of ICT in UK schools. The literature researched varied in scale from large-scale

national surveys to case studies of single schools or, even, classes; and included 'hard' data from larger, quantitative studies and the 'softer' qualitative evidence from small-scale research.

Their highly equivocal conclusion is the following: "the evidence of the impact of ICT on attainment is, as yet, inconsistent, although there are some indications that in some contexts, with some pupils, in some disciplines, attainment has been enhanced. There is not a sufficient body of evidence in any of these areas, however, to draw firm conclusions in terms of explanatory or contributory factors" (Condie & Munro, 2007, p. 29).

In summary, I quote from the work of Barrow et al. (2007): "research on the success of computer technology in the classroom has yielded mixed evidence at best" (p. 1).

3.2.3. Research on Computers and Mathematics Performance in Developing Nations

When one reads literature reviews on ICT and Attainment, like that of Cox et al. (2003) or Condie and Munro (2007), one is struck by the large body of research that has been done in developed countries, and the almost complete lack of (reported) research in developing nations, like South Africa. It has been shown that the level of effectiveness of the computers in improving mathematical understanding is context-dependent (Noss & Pachler, 1999) and thus this dearth of research into this topic in disadvantaged schools (but particularly *high* schools) around the world is a serious omission that I aim to remedy in a small way in my study.

The only significant exceptions to this general lack that I was able to uncover in all my searching on ERIC (the Education Resources Information Centre database) and other databases are:

- i. the Chilean national Enlaces (links) programme, as reported in Hinostroza et al. (2002) and Somekh (2007);
- ii. the junior secondary school Nigerian study by Olusi (2008);

- iii. an Indian study on computer–assisted learning (CAL) by Banerjee et al. (2005)
- iv. the Turkish study on the use of dynamic geometry software, as reported by Isaksal and Askar (2005), and
- v. the South African study by Louw et al. (2008) into the effect of the use of MasterMaths (an educational Mathematics software programme) on Matric mathematics results.

It should be noted that only two of these studies, those of Olusi (2008) and Louw et al. (2008), were completed in what in South African terms would be considered a high school.

The *Enlaces* programme has formed an important part of the national Chilean programme of educational reform since the early 1990s, and by 2005 88% of primary schools and 85% of secondary schools were participants in *Enlaces* and equipped with computers, local networks, educational software and free, unlimited access to relevant web-based educational content (Hinostroza et al., 2002). In addition, the Ministry of Education, in partnership with 24 universities from around the country, provides long-term technical and pedagogical support to each school (such as training of teachers in the use of ICT in the classroom). *Enlaces* has established close links to the University of Bristol's Graduate School of Education and has used socio-cultural theory to inform the development of the initiative and its support mechanisms.

Some of the significant changes brought about by this programme is that teachers have reported changes in their pedagogy, particularly in the adoption of new roles such as 'scaffolding' pupils' learning and in producing 'activity guides' to provide structure for exploratory projects. In my research I will be investigating whether South African teachers are adopting similar roles.

In addition, pupils have done much more learning on their own and their motivation has increased. However, case studies of some of the schools in the *Enlaces* programme have not provided evidence of measurable gains on traditional national students' assessment tests, though "they show that the students participating in these projects could learn other content, and had the opportunity to develop abilities

defined as cross-curricula and practised ICT related skills. The challenge now is to deepen the identification and definition of these impacts and opportunities, and eventually include them as part of the national assessment tests.” (Hinostroza et al., 2002, p. 468).

Olusi's (2008) research took place in Edo state, Nigeria. Two hundred and seventy junior secondary school pupils were randomly assigned to one of two groups, a CAI group and a traditional classroom. Pre-tests showed that there were no significant differences in Mathematics scores between the two groups prior to the experiment. After an unspecified period the two groups were tested again, and it was determined statistically that significant differences existed between the means of the two groups – in other words, “computer aided instruction significantly influences students' understanding of mathematics at junior secondary school” (Olusi, 2008, p. 753). However, Olusi's methodology is not clearly set out and so his results should be viewed with some caution.

Banerjee et al. (2005) reported on research that they had undertaken in Vadodara, a city in Western India. The intervention they studied was a two year long CAL programme for over 15 000 children in Grades 2 to 4, whereby for two hours a week an experimental group worked on computers in pairs, playing educational computer games that involved solving Mathematics problems of varying levels of difficulty, whilst the control group carried on with the normal teaching regime. Pre-tests of the pupils in the two groups showed that, with the exception of the Grade 3 group, there were no significant differences in Mathematics scores prior to the intervention. Overall, mid- and post-intervention test scores showed that the CAL programme had had a substantial, statistically significant positive effect on Mathematics achievements, increasing Mathematics scores by 0.35 standard deviations in the first year of the intervention and 0.47 in the second year. It was equally effective for all pupils, from the strongest to the weakest academically.

Isaksal and Askar's (2005) research took place in Ankara, Turkey, and involved a study of 64 7th grade pupils from one school, and was carried out in 2001-2. One third of the group were instructed in a variety of topics using traditional chalk-and-talk methods, one third the same material using Autograph (dynamic geometry software)

and the last third the same material using spreadsheet-based (Microsoft Excel) instruction. At the end of the treatment, all the pupils wrote the same 'Mathematics Achievement Test' (MAT) as a post-test. Statistical analysis of the results showed that the mean scores of the Autograph- and traditionally taught groups were significantly higher than those of the Microsoft Excel group. However, there was no mean significant difference between the scores of the Autograph- and traditionally taught groups. The researchers surmised that a reason for this lack of difference might be that the MAT was completed on paper and required only reading and understanding of text-based mathematics word problems; thus the benefits obtained from using the dynamic geometry software to detect, for example, relationships between shapes, were not measured.

The other significant study in a poorer nation on the topic of computer use and pupil performance is the quantitative study by Louw et al. (2008) into the effect of the use of MasterMaths on Matric mathematics results in a sample of schools in the Western Cape province of South Africa. This study forms an extremely important basis for the quantitative piece of my research as its focus is very similar to mine: my investigations also look at the impact of computers and Mathematics software on Matric Mathematics results in part of the Western Cape. However, my research differs in that I have not focussed specifically on MasterMaths as the chosen software, and have used much more recent Matric data, from different schools to those sampled by Louw et al. (2008).

Louw et al. (2008) used a quasi-experimental design to obtain comparative data on pupil performance by choosing five experimental and five control schools. Then, for each of the two groups, they compared the difference in marks obtained by the pupils in mathematics at the end of Grade 11 with the marks obtained in the 2003 Grade 12 final examination. The five experimental schools were all Khanya schools that had had access to the computers installed by the Khanya Project for at least one year. In the five control schools, on the other hand, the Mathematics curriculum was not yet being delivered by software - but they were chosen to be a match to the schools of the experimental group in terms of geographical location, pupil level of poverty and school management rating.

They compared, for each of the matched school pairings, the average difference between the Grade 11 and Grade 12 mathematics results of the pupils in the experimental and control groups, and found that “the evidence in favour of the effectiveness of the intervention is...not clear” (Louw et al., 2008, p. 45).

They then obtained information from the log files on the computer network servers of three of the experimental schools (the log files of the other two were not available) and analysed how frequently and for how long the pupils logged onto the MasterMaths programme. They found that generally the pupils spent very little time logged onto the programme and logged on infrequently, but of course this varied from pupil to pupil. They followed this up with correlational analyses of the relationship between the amount of time spent on MasterMaths and improvement in mathematical performance and found a moderately positive, statistically significant correlation. A similar correlation was shown to occur between the number of log-ins and improvement in mathematical performance.

They pointed out that it is unlikely that time spent on MasterMaths is the only predictor of improvement in Mathematics, and that it is possible that the pupils who spent a lot of time using MasterMaths are alike in other ways and that these other similarities, not the use of MasterMaths, are the cause of their improved performance. This led Louw et al. (2008) to conduct further correlation and regression analyses. In particular, they conducted a multiple regression analysis with a list of “predictors of improved performance”. These predictors related to teaching practises in the classroom (e.g. pupils use the board in Mathematics lessons), social differences between the pupils (e.g. gender, home language) and, of course, specific interventions brought about by the Khanya project. The results of this analysis showed that “the strongest of these predictors...is the strength of the [Khanya] intervention, and its predictive capacity does not appear to be reducible to any other variable in our analysis” (Louw et al., 2008, p. 48).

In conclusion then, they found that that there “is only equivocal support for the effectiveness of the intervention on the basis of the quasi-experiment” (Louw et al., 2008, p. 49), but that “the amount of time that learners spent [using MasterMaths] was significantly correlated with an improvement in mathematics performance”

(Louw et al., 2008, p. 49). There “is a clear, but not conclusive indication that the Khanya intervention improves mathematics performance in Grade 12 learners” (Louw et al., 2008, p. 49).

As mentioned above, the quantitative aspect of my research will replicate much of the statistical work of Louw et al. (2008), though in different schools and with more recent data. What will be interesting to see is whether the impact of the computers on mathematical performance has increased or decreased a few years after Louw et al’s study, bearing in mind that in some Khanya schools the 2007 matric students will have had access to computers and software for 5 years; their entire high school career. Furthermore, the qualitative aspect of my research on HOW the computers are being used to teach Mathematics was not covered at all in the Louw et al. (2008) case – this is a significant gap which I will address with my mixed methods research design.

3.3. Research on the Importance of *How* Computers are Used

Many researchers – and this point will be repeated below – have shown that the mere presence of computers in the classroom, or their haphazard use, is not going to bring about improvement in pupil performance (see for example the literature review of Burns & Ungerleider, 2003). Roschelle, Pea, Hoadley, Gordin and Means (2000) put it thus: “just because computer technology can lead to improvements in learning does not mean that it will do so simply because technology is infused into the classroom. Studies overwhelmingly suggest that computer-based technology is only one element in what must be a co-ordinated approach to improving curriculum, pedagogy, assessment, teacher development and other aspects of school structure” (p. 77-78).

Similarly, Guile (1998), while fervently believing in the huge potential of ICT in improving education, emphasises that teachers will need to change the way they plan and deliver their lessons significantly to bring about this improvement – for example, they will need to move away from traditional pedagogical styles, like didactic teaching. He believes that teachers will have to design new contexts and

learning processes to support learning with ICT. The emphasis of Guile throughout is the central role of the teacher in using the technology effectively so as to bring about positive change. It is arguments like these that have encouraged me to not only undertake a quantitative analysis, but also a qualitative analysis; to see exactly how the teachers are using the computer tools at their disposal to teach Mathematics and whether their pedagogical practices differ across the face-to-face and computer lab contexts.

Condie and Munro (2007), in a landscape review of the use of ICT in schools in the UK, have pointed out that the way in which ICT has been used has changed dramatically in that country over the years. Prior to 2000, according to Condie and Munro (2007), much of the use of ICT in schools was in supporting drill or practise of previously taught skills and concepts, or to assist pupils with special educational needs, or as a reward when other work had been completed. Pupils tended to use the computers individually, in the corner of the classroom. In more recent years, however, there has been far more use of collaborative, investigative and problem-solving ICT activities designed to develop increasingly independent pupils who explore and find out information for themselves (Hennessy, Deaney & Ruthven, 2005). This is true across the curriculum, not just in Mathematics. These changes in the way ICT is used in the classroom are very significant, as it is shown later in this literature review that certain ways of using ICT are much more effective than others at bringing about improved understanding and thus academic attainment.

How important is the way in which computers are used in determining whether there will be improved academic attainment? The simple answer, as illustrated by research, is “extremely!” For example, when one investigates the nature of the ILS systems, which were shown to have limited impact on improved attainment in the section above, one can gain an understanding of the reasons why it had little effect on pupil performance. As Noss and Pachler (1999) point out, ILS was based in the behaviourist drill and practise tradition, which can lead to a passive mentality in which children seek only the ‘right’ answers and are not motivated to think about underlying reasons for their answers. With the ILS system it almost seemed as though the teacher was redundant, but it was soon realised that the computer alone was not enough to bring about understanding. Of course, similar comments could be

made about much of the computer-assisted instruction reviewed in the previous section. Noss and Pachler (1999) talk about the need to change to a 'dual interaction view' where "the computer is used to provide a context for meaningful learning to take place; [but] teachers...have a crucial role to play, for instance, in providing lead-in, interaction and exploitation tasks to render ICT-based stimulus material effective" (p. 203). This emphasises again the critical need in my study to determine whether the Cape Town teachers are playing their roles as required.

Wenglinsky's (1998) study of the impact of ICT on mathematics performance in the US is very illuminating. He analysed the data of the 1996 National Assessment of Educational Progress (NAEP), in particular the technology use among a representative national sample of 4th- and 8th-graders. What he was interested in was not only how often the pupils used computers at school but *how* they used them, and how these impacted on academic achievement, as measured by scores in a core mathematics assessment. He compensated for pupil socio-economic status, class size and teacher characteristics to ensure that "all relationships between technology and educational outcomes reported...represent the value added by technology for comparable groups of [pupils] with comparable teachers in comparably sized classes" (Wenglinsky, 1998, p. 26).

His findings are that "technology does matter to academic achievement, with the important caveat that whether it matters depends upon how it is used" (Wenglinsky, 1998, p. 32). This statement illustrates yet again that a simple quantitative analysis of computer use versus academic attainment, although useful to indicate a link (if there is one), is insufficient and needs to be complemented by a qualitative study, involving lesson observations in order to see how the ICT is being used and whether it is impacting pedagogy.

So, what did Wenglinsky (1998) determine as important in terms of how computers are used? The levels of use of computers seemed not to matter – in fact, extremely high levels of use were found to be counter-productive. It was when the teachers were well trained in the use of computers and the computers were used to teach higher-order concepts (e.g. through simulations and applications), that computers were associated with significant gains in mathematics achievement. This was

especially true in the case of the 8th-graders, where students using computers for higher-order thinking skills showed gains of 0.42 of a grade level (i.e. a gain of approximately 15 school weeks), while those with a teacher who had received professional development on computers showed gains of 0.35 of a grade level (i.e. approximately 13 school weeks). On the other hand, in the case of the 8th-graders for which the computers were used to teach lower order cognitive skills (e.g. drill and practise Mathematics software programmes); their use was negatively associated with academic achievement.

Harrison et al's (2002) conclusion on the findings of the ImpaCT2 study in the UK discussed in the previous section is highly illuminating: "there is no consistent relationship between the average amount of ICT use reported for any given Key Stage and its apparent effectiveness in raising standards. It therefore seems likely that the type of use is all important" (p. 3). They conclude that "there is evidence that, taken as whole, ICT can exert a positive influence on learning, though the amount may vary from subject to subject as well as between key stages, no doubt reflecting factors such as the expertise of teaching staff, problems of accessing the best material for each subject at the required level, and the quality of the ICT materials that are available" (Harrison et al., 2002, p.132). It is factors like these that may well be critical in determining the influence of ICT on learning in the disadvantaged schools in Cape Town that I am researching.

Another interesting UK study providing some evidence linking ICT with pupil attainment is from ongoing work by BECTA, where Ofsted inspection data has been statistically analysed to see whether there is a link between the quality of ICT provision and use within schools and pupil achievement in core subjects (BECTA, 2003). It should be pointed out that the data obtained from Ofsted is not entirely objective as it is derived from judgements made by HMI inspectors from what they observe during visits to schools, rather than objective measurements.

At secondary level it was shown (BECTA, 2003) that the quality of ICT resources was related positively to the quality of ICT learning opportunities, which in turn associated positively with pupil achievement at Key Stage 3 and GCSE level (Grade 7 to 11). It was also shown that amongst secondary schools with good quality ICT

resources, the average percentage of pupils attaining the benchmark Level 5 at Key Stage 3 in English, Mathematics and Science was considerably higher in schools which made good use of their technology than in schools where ICT use was unsatisfactory. A similar positive relationship was found at GCSE level. This point again speaks to the critical importance of determining how the computers are being used; something I will determine in my study. A further interesting finding was that in secondary schools the positive association between good achievement and better quality ICT learning opportunities only held true in schools where the leadership was good or very good, thus implying that “school leadership influences the relationship between ICT learning opportunities and pupil achievement” (Pittard, Bannister and Dunn, 2003, p. 8).

Cox et al. (2003) echo what has been said before by pointing out in their review of studies of ICT and attainment that “there is a strong relationship between the ways in which ICT has been used and the attainment outcomes. This suggests that the crucial component in the... use of ICT within education is the teacher and her pedagogical approaches... Insufficient understanding of the scope of an ICT resource leads to inappropriate or superficial uses” (p. 3-4).

Cox et al. (2003) conclude their review of the impact of ICT on attainment in mathematics by stating that “the research evidence described...shows that ICT can have positive effects on pupil’s learning of different concepts and skills in mathematics at both primary and secondary levels” (p. 20), but do add the cautionary point that “the evidence is not so clear regarding whether ICT can have a larger effect on pupils’ attainment than other teaching methods, although there are examples of ICT contributing to the learning of specific skills and concepts which would be difficult to teach so effectively using other methods” (Cox et al., 2003, p. 20).

It is abundantly clear that “there is not a simple message...that ICT will make a difference simply by being used” (Higgins, 2004, p. 5), but rather that “it is more important to think about how computers are used in schools” (Higgins, 2004, p. 6). The latter point is particularly interesting for this dissertation, where I use qualitative

methods to study how computers are used to teach mathematics at a high school level.

In the previous section on the link between ICT use and attainment, many of the conclusions drawn by researchers were rather tame and equivocal. To this can be added the point made by Pittard et al. (2003) that “while a study may be able to demonstrate an improvement in a pupil over time, it is very difficult (and sometimes impossible) to determine whether the use of ICT was critical, or played a role in improved attainment, because so many other factors will have played a part...Additionally, ICT provision and use is likely to be very closely related to factors like quality of teaching and learning more generally, pupil characteristics, and quality of school leadership. For these reasons, isolating ‘ICT’ as a separate factor is often not meaningful or desirable, and understanding its links with other factors is a key facet of studying its impact” (p. 4).

Harrison (2005) concurs by saying that evidence from research literature shows that it is “extraordinarily difficult to demonstrate a direct relationship between implementation of new technology and improved attainment as measured by national standardised assessment measures” (p. 156). “Increasingly, simple causal models of the impact of ICT are being replaced by models which acknowledge a complex set of interactions between the learner, the task and new technology, a set of interactions which do not posit an inevitable causal linkage between ICT and attainment, but rather propose that useful learning occurs only when certain conditions are met” (Harrison, 2005, p.156)

The ‘certain conditions’ that Harrison refers to and which are required for there to be a positive impact on understanding and performance, have been shown to include the following:

- the teachers need to be well trained in the use of computers in general and the content-specific software (BECTA, 2000; Howell & Lundell, 2000).
- the computer software needs to give the students feedback – such as through the computer ‘marking’ of work. However, Higgins (2004) feels it is critical that

computer feedback in Mathematics is monitored to “ensure the pupils are learning what they are supposed to learn” (p10).

- the software chosen must be appropriate to the learning tasks (Chang, Sung & Chen, 2001; Thorpe & Roberts-Young, 2001).
- discussion must take place about what has been learnt, in small groups or whole class settings, in order to develop pupil’s thinking and understanding properly. This was clearly shown in a study by McClain and Cobb (2001) in which computers were used to analyse statistical data in a 7th and 8th grade US mathematics class.
- ICT must be firmly embedded and integrated into classroom activity on an almost daily basis, not just an occasional add-on (Passey & Rogers, 2004).
- Home use of computers for schoolwork. This was shown to be a contributing factor to the statistically significant association between ICT and achievement in the ImpaCT2 study (Harrison, 2005).

In addition, it has been shown that teachers’ pedagogies have a large effect on pupil’s attainment, particularly significant being aspects like the type of technologies that were selected, the ways in which they were used, and the extent to which teachers had planned and prepared for the lessons (Cox et al., 2003).

Higgins (2001) states that, overall, the evidence from all the different approaches to using ICT in primary Mathematics “suggests that to develop understanding the teacher is needed to mediate the learning from ICT activities. It is this mediation which helps them understand how the specific learning ‘connects’ to other mathematical activities...The implication is therefore that use of ICT to develop understanding will require a careful pedagogical match between the specific goals of a lesson, the ICT, and how it is used, then the way this learning is made meaningful or ‘bridged’ by the teacher” (p. 168). This illustrates again the significant, indeed vital role played by the teacher when using ICT in their classroom, an area I will research in my dissertation by means of classroom observations.

Passey and Rogers (2004), in their study on the motivational impact of the use of ICT on pupils in the UK, made a further interesting observation which could explain

why there are mixed reports on the impact of ICT on attainment. They stated that their findings suggested that teachers were most commonly using ICT to support internalisation (the ways in which ideas and knowledge that are presented can be taken into the mind through the senses) and externalisation processes (the ways in which ideas and knowledge in the mind can be related to others through processes such as speaking and writing) more strongly than internal cognitive processes (reasoning, comparing, analysis, evaluating and conceptualising). Thus, “if attainment is linked to internal cognition, then current practice with ICT will have less impact upon attainment than it does upon other parts of the learning process” (p. 5).

3.4. Research on Variations in Semiotic Mediation; an Indicator of Pedagogical Variation

A critical question is whether the use of computers in the study of school Mathematics causes any modification of pedagogy. This is potentially a very large topic, so I have narrowed the focus down to just one way of looking at pedagogical change: changes in teacher talk. This section of my literature review thus identifies research that has been done on variations in semiotic mediation between Mathematics teaching venues, as an indicator of an alteration in pedagogy.

As described in the Conceptual Framework chapter, as per Hasan (2005) I use the term semiotic mediation as a short form for ‘semiotic mediation by means of the modality of language’, and define semiotic mediation as ‘the mediation of something by someone to someone else by means of the modality of language’ (p. 3).

Studies in the field of semiotic mediation in the mathematics classroom, as evidenced by a search in the ERIC (the Education Resources Information Centre) database, are extremely thin on the ground. One outstanding study is that of Zolkower and Shreyar (2007) in which they presented a Vygotskian-inspired analysis of how a teacher mediated a “thinking aloud” whole-group discussion in the 6th grade mathematics classroom in the USA. The discussion was aimed at finding patterns in a triangular array of consecutive numbers, with the ultimate intention of developing recursive and direct algebraic formulae.

Zolkower and Shreyar used the concept of systematic functional linguistics (SFL) developed by Halliday (1973, 1978) and Halliday and Hasan (1989) as a framework for analysing portions of the classroom discussion, to ascertain how the teacher guided the pupils to discover the hidden patterns and thus “enlarged the mathematical meaning potential” (Zolkower & Shreyar, 2007, p. 178) of their pupils. In particular, the researchers dissected the transcriptions, breaking each verbal interaction down into clauses, and then determining the function and mood of the speech in that clause. The five speech functions they used are statements, offers, questions, commands and checks, while the moods are either indicative or imperative, with various sub-groups under each of these. The intention of their analysis – one which they undoubtedly achieved – was “to illustrate the power of SFL for studying the inner grammar of classroom interactions so as to illuminate the complexities and subtleties in the teacher’s mediating role” (Zolkower & Shreyar, 2007, p. 200).

Another excellent study in this field is that of Hardman (in press), who investigated variations in semiotic mediation across two contexts: face-to-face mathematics lessons and computer lab mathematics lessons, in four Grade 6 classes in disadvantaged primary schools near Cape Town, South Africa. She divided each verbal interactions into one of four main groups (each with sub-groups): instruction, question, evaluation and regulation, and by means of chi-squared tests determined that there was a statistically significant relationship between context and language use, with a conclusion that “it is evident that across the four schools, there is a change in the use of language as an instructional tool between the face-to-face and computer lessons” (Hardman, in press, p. 12). In particular, in the latter lesson context there is dramatically less mathematical instruction than in the former due to the amount of instructional time lost in technical issues relating to the computer: “what becomes clear is that the instructional object of the computer lessons is in fact the development of students’ technical skills and knowledge around computer *use* rather than the development of mathematical understanding (Hardman, in press, p. 12, italics hers).

Hardman’s (in press) study provides a counterpoint to my study of variations in semiotic mediation across mathematics lessons in different contexts in a

disadvantaged *high school* in Khayelitsha, Cape Town. It appears that such research has not been completed before at the high school level.

In my analysis of variations in semiotic mediation across different contexts, I have chosen not to use SFL in its entirety. However, I have used some of Zolkower and Shreyar's (2007) ideas, together with the analytical framework developed by Hardman (in press), in order to develop a framework by which I can analyse verbal interactions within different contexts.

3.5. Chapter Summary

In this chapter I have summarised some of the considerable research completed around the world into the impact of computers on pupil's mathematical achievements, and have shown that the results, though generally encouraging, are far from conclusive. The surfeit of research in this field in developed countries and the comparative scarcity in developing nations is a concern, so my research in poor schools in South Africa will be noteworthy in helping to determine whether or not the findings from elsewhere in the world are relevant in the African context.

Studies of this issue in developing nations are particularly important because the education systems are so different in such countries. In developed nations, "CAL replaces time spent in well-equipped classrooms with high quality instructors. It is easy to imagine that computers can make a significant improvement in schools in developing countries even if they are not useful in the developed world" (Banerjee et al., 2005, p. 8). They support this idea by commenting that "the idea of using computers is particularly attractive in areas where the number of qualified teachers is limited and the quality of existing teachers is notoriously poor" (Banerjee et al., 2005, p. 8-9). They were, of course, talking about India, but the same comments could apply to the South African education system in which my study is based.

In addition, I have investigated what researchers have found to be the best ways of using the computers in the classroom so as to ensure that it is likely that academic development will take place. A common refrain is the importance of using the

computers in particular ways to maximise impact, as computers alone are merely machines. As Roschelle et al. (2000) point out, “models of successful technology use combine the introduction of computer tools with new instructional approaches and new organisational structures” (p. 90). I will attempt in my study to see whether the Cape Town teachers in disadvantaged schools have made these necessary changes.

Finally, I have reported on the minimal research that has gone into variations in semiotic mediation between the computer lab and the conventional face-to-face classroom, as evidence of changes in pedagogy brought about by the introduction of computers. My research has the potential of adding significantly to the yet-thin, almost non-existent body of knowledge in this area.

The dissertation moves on in the following chapter to consider the different research designs (quantitative and qualitative) that are normally used within educational research, and explains why I have decided to choose a combination of the two through the use of a ‘mixed methods’ design. The chapter also outlines the methods and procedures I have used to collect the data I have utilised for my research: the Matric Mathematics results and the observation data in one case study school in Khayelitsha, Cape Town.

CHAPTER FOUR

RESEARCH DESIGN & METHODOLOGY

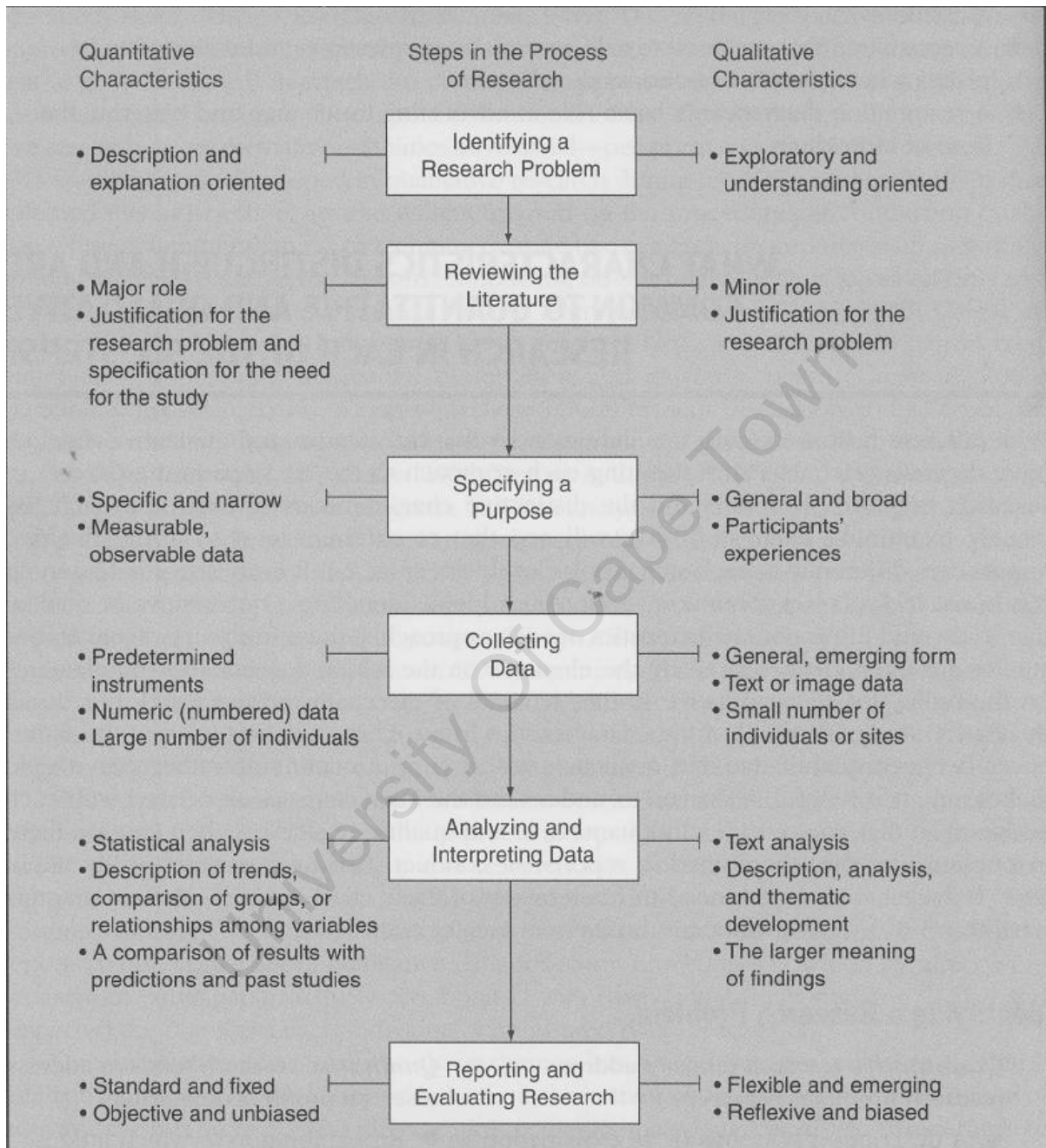
4.1. Introduction: Quantitative and Qualitative Research Methods

There was traditionally one type of educational research: quantitative; which dominated educational enquiry for most of the 20th century (Creswell, 2008). From the late 1960s, however, qualitative research began to grow in popularity as an alternative research method in the field of education. Creswell (2008) defines the two types as follows: “Quantitative research is a type of educational research in which the researcher decides what to study; asks specific, narrow questions; collects quantifiable data from participants; analyses these numbers using statistics; and conducts the inquiry in an unbiased, objective manner. Qualitative research is a type...in which the researcher relies on the views of participants; asks broad, general questions; collects data consisting largely of words (or text) from participants; describes and analyses these words for themes; and conducts the inquiry in a subjective manner” (p. 46).

Struwig and Stead (2001) add that quantitative research generally involves large representative samples and a fairly structured data collection procedure, with the focus typically being to test a hypothesis (a statement regarding the relationship between two or more variables that can be tested). Qualitative research employs a far greater variety of research methods, such as participant observation, interviews, archival source analysis, focus groups and content analysis. In addition, it tries to describe or understand human behaviour within the natural, concrete context in which they occur, rather than to explain and predict it (Babbie et al., 2001).

Both research methods follow the same 6 steps in the process of research, yet each step is completed in a different manner depending on which method you have chosen. Table 1 below, taken from Creswell (2008, p. 52) outlines the steps and the distinctive manner in which each method approaches the completion of each task.

Table 1: Characteristics of Quantitative and Qualitative Research on a Continuum in the Process of Research
 (source: Creswell, 2008, p. 52)



4.2. Research Types within the Field of ICT and Education

Both the main groups of research methods described above have been used to measure the impact of ICT on children's' learning and teachers' pedagogy (Cox, 2003):

- i. quantitative studies, involving large numbers of pupils and usually designed to measure changes in understanding before and after the use of ICT; and
- ii. qualitative studies, involving in-depth case studies of small groups of pupils in which detailed records are kept of all the ICT-related activities, the contributions of the teacher, the amount of ICT use by each pupil etc.

Both methods have their problems. For example, in quantitative studies, where there is the use of the control and experimental groups, it is difficult to isolate the ICT effects on the experimental group since other factors – like increased pupil motivation or teacher enthusiasm due to the use of ICT – might have impacted on subsequent performance. Similarly, in qualitative studies, the big question is whether the findings for a particular group can legitimately be generalised to broader society since there are always a number of unanswered questions, such as “would other teachers’ pupils have similar learning outcomes?” (Cox, 2003).

The limitations of both the methods described have resulted in a number of researchers combining the methods, to “try to improve the validity of the results and the generalisability of the findings’ (Cox, 2003, p. 162). One way in which this is commonly done is to conduct a large-scale quantitative study, and then conduct case studies of a sub-sample of the cohorts to investigate the range of factors affecting ICT impact and to illuminate the large-scale data. This is akin to the mixed methods approach outlined below.

4.3. The ‘Mixed Methods’ Research Design

There has traditionally been a gulf between qualitative and quantitative research, with researchers typically considering themselves to be either a quantitative or a qualitative researcher. However, in recent decades a combination of both approaches has become more popular and accepted. This approach has been categorised as using ‘mixed methods’ (this name is derived out of the work of Professor Manfred Max Bergman of the ‘Institut für Soziologie’ in Basel, Switzerland (<http://soziologie.unibas.ch/index.php?id=49>)). Creswell (2008) defines a mixed methods research design as “a procedure for collecting, analyzing and mixing’ both

quantitative and qualitative research and methods in a single study to understand a research problem” (p. 552). There are four main mixed methods designs used in educational research: triangulation, embedded, explanatory and exploratory designs.

The benefits of using a mixed methods design are that having both quantitative and qualitative data, together, “provide a better understanding of your research problem than either type by itself” (Creswell, 2008, p. 552). In some cases, one type of research (qualitative or quantitative) is not enough to address the research problem adequately. More data is needed to expand, elaborate on, or explain the first set of data.

4.4. My Research Design

My research is based on the ‘mixed methods’ design as described above. In particular, I have chosen an explanatory mixed methods design (Creswell, 2008) in that I first collected quantitative data and later, in a second phase, qualitative data in order to better understand the general picture and to help to explain the results of the statistical analysis.

4.4.1. My Quantitative Research – an Outline

First, in order to establish the impact of technology on mathematical performance in sampled schools, the study undertook a quantitative analysis of mathematical performance by comparison of the Matric Mathematics results and enrolment of various schools in the EMDC East region. Detailed explanations as to how the samples that were tested were chosen are covered in the next chapter. I have chosen the EMDC East region as the geographical focus of my study for I believe that the results of schools in this region will be indicative and typical of all urban schools in the greater Cape Town area.

The mathematical software systems provided to the high schools in the Khanya Project are one of two South African-produced systems:

MasterMaths (<http://www.mastermaths.co.za/>) or CAMI Maths

(http://www.camiweb.com/index.php?option=com_content&task=view&id=45&Itemid=82).

Both are examples of what is termed Computer Assisted Instruction (CAI), defined as involving the use of computers and computer software to provide drill exercises and tutorials (Kirkpatrick and Cuban, 1998). The school that I used as a case study for my observations used foreign funding to purchase a different (US produced) software system, Plato Learning (www.plato.com), but the way that this system operates is not very different from MasterMaths and CAMI Maths. More detail about the Plato system is provided later in this chapter.

The data that I used was secondary in nature, as it used data already collected and categorised at the end of the 2007 Matric exams. The data itself was obtained from a high-ranking employee of Khanya, but she accessed it from the data banks of the Western Cape Education Department. The details of the statistical analysis of the data, completed by using the software package SPSS Statistics version 17.0 are described in detail in the next chapter.

This statistical analysis points towards the impact computers may have on student performance. However, a statistical analysis is only able to show that the computer does or does not impact on performance; it is not able to show *how* the computer is being used. This is a critical lack since research has shown that it is not the computer itself that is responsible for positive learning gains, but rather how the computer is used by the teacher (Wenglinsky, 1998; Cox et al., 2005). Thus, in order to develop an understanding of why and how the computer impacts on pedagogy and how teachers are in fact using it, the second part of my research involved undertaking a qualitative case study of one Khanya school in a township incorporated into the EMDC East.

4.4.2. My Qualitative Research – an Outline

4.4.2.1 Selecting the Case Study School

The initial idea was to undertake case studies of two different schools, chosen randomly from a list of all the twelve high schools in the EMDC Central that had had MasterMaths installed in Khanya-supported computer laboratories since at least early 2005. The random choice was made by first listing the schools alphabetically and then numbering them from 1 to 12. Thereafter a random number generator on the web (<http://www.random.org/integers/>) was used to generate a list of 3 numbers. The idea was that the first 2 numbers would be the schools that I would use for my case studies, with the third number providing a back up school in case one of the other schools was found to be not suitable for the study (by, for example, not having a functional computer lab) or was not interested in allowing me access to the school for research purposes.

On phoning schools X, Y and Z – the three schools generated randomly – and speaking to the Heads of Mathematics at each, I discovered that none of the three was using the Khanya labs for Mathematics lessons. In order to see how prevalent this problem was I phoned all 9 of the other schools on my original list, and after numerous phone calls and left messages obtained usable information from 6 of them.

For the nine schools for which I had information I found the following:

- only one school was using the computer laboratory for Mathematics lessons on a weekly basis.
- Mathematics classes in two other schools used the computer laboratory for their Mathematics classes once or occasionally twice a month.
- All six other schools stated that they are never or almost never able to use the Khanya labs for Mathematics lessons. Five of the schools stated that the reason for this state of affairs was that the laboratory was used entirely for Computer Application Technology (CAT) lessons (CAT is an FET course on how to use computers and various computer software programmes) or by other subjects, while one stated that the problem was technical: there were

problems with the server and Khanya support was so poor that the computer lab was de facto not functional.

It is apparent that the Khanya programme is not yet functioning as well on the ground as it is intended to, with the consequent issue for my research being the difficulty of finding a school where the Khanya labs were indeed functioning as alternative Mathematics classrooms on a fairly regular basis.

As a result of this finding, I decided instead to purposefully sample one school, which could be used as a case study of best practise teaching with technology within a township school. The idea with qualitative research is to gain an in-depth understanding of a small number of sites – even just one – rather than trying to study large numbers of sites shallowly and then trying to generalise (Babbie et al., 2001).

A township school was selected due to the fact that they are the schools which (in general) are the most underperforming in South Africa (Taylor, Muller and Vinjevoid, 2003), and because schools such as these are specifically the target of the Khanya intervention. It was felt that the issues and problems surrounding the use of ICT in Mathematics classes in the best practise township school would be slightly less than a typical township school but nonetheless would be similar due to its location and student cohort.

The choice was made to observe lessons in School A, a specialist Mathematics, Science and Technology school in Khayelitsha that has classes only in the FET band (Grade 10-12). Their entire pupil cohort of 175 pupils (2 classes of roughly 30 pupils each in each grade) is selected from schools in the neighbouring areas, mainly Khayelitsha and Philippi, at the end of Grade 9. The entire pupil body consists of disadvantaged African pupils, almost exclusively Xhosa speaking.

An illustration of the academic success of School A is given by their recent Matric results. For example, in both 2007 and 2008 their Matric pass rate was a perfect 100%, while in 2007 (the last year in which aggregates were used in the South African Matric system) 2 pupils scored an overall 'A' aggregate, 17 got 'B' aggregates and a further 24 'C' aggregates. Their Matric Mathematics results are

also noteworthy for a township school. In 2007, their Higher Grade average mark was about 53% (with 2 'A's and 4 'B's) and their Standard Grade average 55%. In 2008, under the new FET system in which the two Mathematics options are Mathematics Core and Mathematics Literacy, all pupils wrote Mathematics Core (the higher level), attaining an average percentage of nearly 66%, with 12 'A's, 13 'B's and 14 'C's. This is a phenomenal achievement, especially when contrasted with the dismal Matric Mathematics results in most township schools (Taylor et al, 2003).

Both the principal and Head of Mathematics at the school were very amenable to and supportive of my research, and observations were able to take place over a period of two weeks in August 2009.

4.4.2.2. The Participants

There are 6 Mathematics classes at the school, 5 of which are taken by 2 teachers (whom I will call Mrs Cupido and Mr Mhorah – not their real names), both of whom participated in my research by allowing observations of their classes. The third Mathematics teacher takes only one class, a Grade 10 class, and was not requested to be involved in my research study.

Mrs Cupido is both the principal of the school and the Grade 12 Mathematics teacher. She is in her mid-forties with excellent qualifications (an under-graduate B.SocSc, majoring in Mathematics, a post-graduate teaching diploma, a B.Ed, and is currently completing an M.Ed part-time). She has 25 years of high school Mathematics teaching experience. Despite this impressive academic background, she has not been provided with any formal training in using the computer software, and rates herself 6 out of 10 in terms of her competency in using ICT in teaching Mathematics. She explained in my interview with her that she is almost entirely self-taught: the computer skills she has learnt have come from “just doing and fiddling around with the programme and the software”.

Mr Mhorah is the Head of Mathematics at School A, and teaches three Grade 10 and 11 Mathematics classes. He is in his mid-thirties, with a B.Sc in Mathematics and Statistics, a teaching diploma, and 13 years of high school Mathematics teaching experience. He rates himself as a 6 or 7 out of 10 (“not yet up there”) in terms of how

comfortable he is in using ICT in teaching Mathematics and, except for one or two brief afternoon workshops, has not had any formal training in using the computer software. His ICT knowledge has come primarily through input from his teaching colleagues and from using the software himself.

4.4.2.3. Plato: The Computer Software Programme

The computer software programme utilised at School A is an American product called Plato, selected by the school and associated FET College in preference to the typical Khanya alternatives (MasterMaths or CAMI Maths).

The Plato software has two main categories of Mathematics activities. Firstly, tutorials, where the programme leads students through a topic by asking brief, simple questions that lead a pupil step-by-step in small increments of understanding. This would be suitable for pupils to use to self-study a particular topic that they, for example, may have missed due to an extended illness. Secondly, assessments, which are essentially Mastery Tests, and which are typically written after a topic has been covered either in the classroom or by means of the tutorials mentioned above, and which indicate how much the pupil understands of the topic at that point in time. The pupils get immediate feedback in the form of a score on the Mastery Test. If their score is 8 out of 10 or better the software allows them to move on to the next tutorial, otherwise they have to repeat the tutorial another time and repeat the Mastery Test (which has different questions to the first time).

4.4.2.4. The Observations and Method of Analysis

In order to ascertain whether the computer impacted on pedagogy, face-to-face and computer lab lessons of each Mathematics teacher were observed. A total of ten Mathematics lessons of between 45 and 55 minutes long each were observed at School A: six in the computer laboratory and four in the classroom. Six of the observed lessons were taken by the one teacher; the other four by the other. Each teacher was observed for at least two lessons in each of the venues. A total of five different classes were observed, two Grade 10 classes, one Grade 11 and two Grade 12 classes - this represented 83% of all the Grade 10-12 classes in the school. In all lessons, I acted as a non-participant observer in that I did not become involved in any way with the activities in the classroom or computer lab.

In addition, a 40 minute one-on-one interview was held with each of the two teachers in the week immediately after the final observations, with the purpose of elucidating more information on topics such as their academic and teaching backgrounds, how they feel they use the computers in the classroom, and how they believe it has impacted their pedagogy. I went into each interview with a prepared interview schedule consisting of 28 open- and closed-ended questions (see Appendix 1 at the end of this dissertation); but in practice I did divert from the schedule at times in order to ask additional probes so as to explore particular answers more thoroughly.

Each of the lessons observed was recorded on a video camera by Mr Lance McLeod of UCT, and then transcribed verbatim. Both of the interviews were recorded on an audio-taping device and then transcribed verbatim. An analytical framework was then developed by which the different verbal utterances of the teachers could be categorised (see Table 2 below). The focus on teacher talk is because it is the primary tool used in the classroom to mediate and because it carries pedagogy within it.

Table 2: 'Type of Talk' Categories

CATEGORY	SUB-CATEGORY	EXAMPLE
FEEDBACK	Praise/ encouragement	Well done!
	Criticism	That's a poor effort
	Correction of error	No, that's not the correct answer
STATEMENTS	Information	There are only 5 minutes left in the lesson
INSTRUCTIONS	Department	Please sit down!
	Academic – Mathematics direction	Please do exercise 3 on page 65
	Academic – IT direction	Press this button
QUESTIONS	IT related	Is anyone still not logged on?
	Mathematical factual (looking for factual, brief answers)	Is this the x or y axis?
	Mathematical assistance (probing for deeper understanding; enabling metacognition)	Why is this answer incorrect? What would happen if...?
	Other	
EXPLANATIONS	Math statements (used to explain concepts)	In a right angled triangle we can use Pythagoras' Theorem
	Rationale (providing deeper mathematical understanding)	The reason that...

The categories and sub-categories were largely adapted from the work of Gallimore and Tharp (1993) and Anghileri (2006) on the means by which teachers can assist pupils' academic performance and enable them to transition from other-assistance to self-assistance (internalisation and automatization), but the concept of the framework itself was inspired by the work of Hardman (in press). The same framework was applied in both the computer lab lessons and face-to-face lessons, although obviously in the latter there were no interactions around the use of the computers.

The lesson transcripts were then analysed in order to determine whether the presence of computers has altered pedagogy, as indicated by variations in semiotic mediation between the two teaching contexts (in other words, how the teachers' talk varied between face-to-face and computer lessons). The focus on teacher talk rather than, say, teacher actions is due to the fact that according to Vygotsky and socio-cultural theory, the most widespread tool for pedagogy is talk (Vygotsky, 1981). The analysis was completed by tallying the number of verbal utterances (with the unit of analysis being a sentence) within each category, in each of the two teaching contexts.

In order to determine if there were statistically significant relationships, three categorical variables were set up (as defined below), and chi-squared tests for independence were performed on them, two at a time, using the SPSS software package. The chi-squared test is the perfect test to use in this situation since it explores the relationship between two categorical variables (each with two or more categories), and compares the observed frequencies that occur in each of the categories with the values that would be expected if there was no association between the two variables being measured (Pallant, 2007).

The three categorical variables are:

- i. **Location of the lesson:** lessons took place in two different types of contexts: the conventional classroom (face-to-face) and the computer lab.
- ii. **Type of talk:** All the verbal utterances were counted, using 13 different sub-categories grouped into 5 main 'types of talk': feedback, statements, instructions, questions and explanations (see Table 2).
- iii. **Scale of Interaction:** all verbal interactions between teacher and pupils were placed into one of two categories: whole class (when the teacher was interacting with the whole class, usually teaching the whole group but also including occasions when he/she was speaking with one pupil whilst the whole class was listening), and individual (when the teacher was interacting with an individual only; the rest of the class being involved with their own work).

Finally, the transcripts of the computer lab lessons and the teacher interviews were analysed in order to ascertain how the teacher was using the computers as a tool to educate the pupils, and the issues facing the use of computers at this particular school.

The results of all these analyses are outlined in the following chapter.

4.5. Reliability, Validity and Ethics

4.5.1. Validity

Validity in research is a measure of the extent to which an instrument used measures what it claims to measure, and whether appropriate interpretations or inferences are drawn from the instrument's scores (Ary, Jacobs, Razavieh & Sorensen, 2006).

4.5.1.1. Validity in my Quantitative Research

The most important types of validity in quantitative research are internal and external validity.

Internal validity requires showing that “the inferences about whether the changes observed in the dependent variable are, in fact, caused by the independent variables...rather than by some extraneous factors” (Ary et al., 2006, p. 291).

In this research the pre- and post-Khanya intervention testing was with different Matric Mathematics groups, which cannot be avoided as each Matric group write their Matric final exam only once. This is a possible threat to internal validity, although this threat is minimised due to the fact that the number of pupils involved in the sample pre- and post-intervention is very large and from the same schools, and the pupil and staff cohort is unlikely to have changed significantly in terms of ability, motivation, experience and so on in the few years between the results. An advantage of this testing of two different groups is that the maturation effect (a change in results simply due to the passage of time); the testing effect (the general

rule that subjects do better on a post-test because of familiarity with the format of the test etcetera); and the statistical regression threat (the tendency that subjects who score very high or low on the pre-test tend to score closer to the mean in the post-test), are not relevant.

There is an instrumentation threat to internal validity in that there is a change in the instrument used during the study: two different Matric exams are used. However, this threat is minimised by the fact that from year to year the (national) examiners attempt to ensure that the Matric exam remains of a similar standard.

There is perhaps a small threat due to selection bias between the control and experimental groups: it is possible that the one group contains schools that produce better Mathematics results than the others, independent of the Khanya intervention. This threat is overcome to a large extent by large samples and the fact that both the control and experimental groups in this research contain schools from a similar geographical location, and these have pupils of a similar socio-economic status and racial background.

There is no threat to internal validity due to the experimenter effect, as the researcher was not involved with the Matric exams in any way, nor is there a Hawthorne effect (the tendency for subjects to alter their behaviour simply due to participating in an experiment), as the pupils whose Mathematics results were used were not aware that their results would be analysed in this way.

External validity refers to “the validity of the inferences about whether the findings of the study would generalise to other subjects, settings and objects.” (Ary et al., 2006, p. 314). The ideal is that the study should provide information about a larger realm of subjects and conditions than were actually investigated. This research is externally valid in that the education administration district (EMDC East) used to provide subjects for the study was randomly chosen from all the districts in Cape Town. In addition, within this district all schools within a particular Khanya ‘wave’ were selected, except for the deliberate exclusion of certain schools that were markedly different in pupil population to the others. This was done in order that the schools tested statistically were relatively homogenous pupil-wise and thus ‘like’ could be

tested against 'like'. The data used was objective Matric results data, thus there is no possibility of a 'reactive effect' (a reaction to the experience of participating in the experiment) or 'experimenter effect' (an influence on their performance due to interactions with the experimenter).

4.5.1.2. Validity in my Qualitative Research

Maxwell (1992) argues for five kinds of validity in qualitative research. It is against these that the validity of my research should be measured.

- Descriptive validity requires the data to be fully and accurately recorded, with no selective or distorted accounts. To this end, this study video-taped all the observation lessons, and each lesson was transcribed verbatim by an independent party. The extracts reprinted in this study were double-checked for their accuracy by this researcher and are fully representative of what happened in that lesson.
- Interpretive validity requires the research to catch the meanings and interpretations that the situations and events have for the participants themselves. This was done by holding post-observation interviews with the teachers, to ensure a greater degree of understanding of how they viewed what had transpired in the classroom and lab.
- Theoretical validity refers to an account's validity as a theory of some phenomenon, and is threatened when the researcher fails to pay sufficient attention to competing understandings or discrepant data. This threat is minimised in the current study by paying attention to competing interpretations of the data.
- Generalisability refers to "the extent to which one can extend the account of a particular situation or population to other persons, times or settings than those directly studied" (Maxwell, 1992, p. 293). This research is internally generalisable in that the findings are able to be generalised within the school beyond the lessons actually observed. This research is not necessarily

externally generalisable from my case study school to other schools, however, but that is acceptable in qualitative research. As Maxwell (1992) says, “qualitative researchers rarely make explicit claims about the external generalisability of their accounts. A qualitative study may...provide an account of a setting or population that is illuminating as an extreme case or ‘ideal type’.” (p. 294).

- Evaluative validity refers to the application of an appropriate evaluative framework to the objects of the study. The threat is that the researcher’s own evaluative agenda might intrude; so to this end this researcher has endeavoured to avoid evaluating (judging) what he has studied.

4.5.2. Reliability

Closely tied to notions of validity are those of reliability. However, reliability means different things in quantitative and qualitative research.

4.5.2.1. Reliability in my Quantitative Research

In quantitative research, reliability “is essentially a synonym for dependability, consistency and replicability over time, over instruments and over groups of respondents....For research to be reliable it must demonstrate that if it were to be carried out on a similar group of respondents in a similar contexts, then similar results would be found” (Cohen, Manion and Morrison, 2007, p. 146).

As the quantitative aspect of this research was concerned with an analysis of Matric exam results (test data), the threats to reliability in tests and exams need to be considered. I have based my analysis below on the reliability checklists for tests and exams provided by Cohen et al. (2007).

With respect to the examiners and markers, the chances of inter-rater unreliability (different markers giving different marks for the same work); errors in marking; or the Halo effect (a pupil who is judged to do well or badly in one assessment is given undeserved favourable or unfavourable assessment respectively in other

assessments) is possible but unlikely given the fact that the marking of Matric exams is done at a central venue with a common mark scheme, and there are a significant number of checks and re-marking of the markers' work to ensure consistency between markers.

It is also unlikely that there will be unreliability with reference to the pupils themselves, as they would have been highly motivated to achieve well in what is their school-leaving examination; their own teachers were not marking the work (thus the relationship between teacher and pupil, good or bad, would have less effect); and the exams would have been administered in familiar surroundings (their own schools) and in a familiar manner (under the same conditions as their trial Matric exams).

There might be some unreliability with the exam items themselves (in other words, some form of test bias), due to issues like poorly worded or translated questions; questions which are culture bound or which may favour one gender over the other, etcetera. However, as this was a Matric final examination in which the exam had been drawn up by a panel of examiners, each checking and double-checking the other; and since this was a Mathematics exam in which issues of language might be argued to have less influence due to the increased use of universally recognised symbols in the place of words; the unreliability of the exam items is likely to be low.

4.5.2.2. Reliability in my Qualitative Research

Whereas quantitative researchers speak of reliability, qualitative researchers speak of dependability (Ary et al., 2006). In qualitative research there will be less expectation of exact replicability; variability will occur because the context of studies changes. However, in order for the study to be dependable, the variation must be able to be tracked or explained (Ary et al., 2006).

One of the best ways to establish dependability is to use an audit trail, by which others can determine how decisions were made (Ary et al., 2006). In the context of this research, a full audit of the raw data gathered in the interviews and observations is possible as all these are stored on DVDs or audiotapes or in computer files. Any independent, third-party auditor will be able to examine this researcher's study in

order to attest to dependability. In addition, the findings from the data and the inferences made can similarly be checked to ensure they are logical and grounded in the data – this has been done by my research supervisor.

A further reason why this research can be considered dependable is due to the use of an analytical framework to assist in coding the ‘teacher talk’. The utilization of the analytical framework increases the likelihood of objectivity in the coding of the verbal interactions in the classroom and computer lab.

Finally, there is some triangulation of the data (triangulation can be defined as “the use of two or more methods of data collection in the study of some aspect of human behaviour” (Cohen et al., 2007, p. 141). This is due to the fact that in this research the observations on the manner in which the teachers use the computers to teach Mathematics was backed up with post-observation interviews with the teachers themselves.

4.5.3. Ethical Considerations

I have conducted my research on ethical principles. I obtained permission for my research through the required channels: both from a top Khanya official and from the Western Cape Education Department (see Appendix 2).

In terms of the participants in this study (the teachers I observed), their anonymity was protected by assigning an alias to them and their school when reporting on the data. Before the observations began, they were fully briefed on the true purpose and nature, aims and implications of the study, including the fact that the lessons would be video-recorded. The participants subsequently gave me informed, uncoerced consent regarding their participation in the study through their completion of a ‘participant consent’ form – see Appendix 3. No incentives were offered to the teachers to encourage them to participate in the study; they willingly chose to be part of it.

During my observations of the lessons, I ensured that I stayed in the background at all times, acting as a non-participant observer, and thus did not influence the lessons in any way. In addition, I was respectful of the research site at all times. During the post-observation interviews of the teachers I used ethical interview practices.

4.6. Chapter Summary

This chapter has outlined the dominant research methods used in educational research, and explained the choice for my research of the 'mixed methods' design, which combines quantitative and qualitative aspects. The methods used in obtaining the research data – the Matric Mathematics results and the school observation – were described, as were the methods used to select the case study school for the observations. The case study school and the Mathematics teachers that participated in my study are described. Finally, I argue for the reliability, validity and ethics of my research.

The next chapter moves on to describe how this data was analysed and what was discovered. The results of the data analysis are interpreted and discussed in detail.

CHAPTER FIVE

ANALYSIS, INTERPRETATION AND DISCUSSION

5.1 Introduction

This chapter is divided into three main sections, one for each of the major data analyses undertaken for this dissertation. Firstly, the statistical analysis – by means of four different tests - of the Matric Mathematics results and enrolment is presented. Secondly, the statistical analyses of the verbal communications within the classes that were observed – in particular the variations in semiotic mediation across the contexts of traditional classroom and computer lab – are reported upon. Finally, the chapter provides a descriptive analysis of how the teachers in the case study school use the computers as a tool in teaching their pupils, with particular emphasis on whether there were any differences between the manner in which they taught in the classroom as opposed to the lab. An interpretation and discussion of all the results is also furnished.

5.2. Data Analysis and Interpretation: Matric Mathematics Results

In this section I describe the different statistical tests that I applied to the 2007 Matric Mathematics data from various Khanya schools, in order to determine whether the Khanya intervention has impacted positively on Matric Mathematics results. The reasons for choosing the particular samples that I did are also presented, as are the analyses and interpretation of the results from these tests.

It is important to note that the logic behind the Khanya intervention, as stated by Louw et al. (2008), is this: “the principal cause of the low achievement levels in Mathematics was assumed to be the low capacity of teachers, and the ICTs would compensate for low-capacity teachers” (p. 43). Put another way, “the Khanya computers and software were expected to provide the coverage of the curriculum that poorly trained teachers were not able to provide” (Louw et al., 2008, p. 43). The Khanya project was, therefore, implemented in order to impact positively on

students' mathematics results through the provision of computers and mathematics software.

Louw et al's (2008) study, based on results in the 2003 Grade 12 final examination, provide a qualified 'yes' as an answer to the question as to whether the Khanya intervention has actually succeeded in improving mathematics marks. My quantitative analysis, based on more recent data – the 2007 Matric results - represents an attempt to re-answer this question, and look at various new questions not answered by Louw et al. (2008), such as whether the intervention resulted in an increase in Higher Grade (as opposed to Standard Grade) Mathematics enrolment.

5.2.1. The Tests

I have performed four statistical tests using Matric Mathematics results from Khanya schools in the EMDC East (one of the school administration districts in Cape Town) only. There are four such administration districts in the greater Cape Town area, and the EMDC East was chosen randomly. There is no reason to think that the results obtained by analyses within this district would be any different to those from any other district within greater Cape Town, as all the districts contain a mixture of wealthy and impoverished suburbs/townships.

5.2.2. The Mean Student Score

In order to be able to use the statistical package SPSS for analysis, the data needs to be numeric – for this reason the Matric results needed to be converted from grades to points. The points allocation used by UCT for Matrics who wrote before 2008 was selected as a suitable conversion table (see Table 3 below):

Table 3: UCT’s admission rating system for the South African School Leaving Qualification

ACADEMIC LEVEL	ADMISSION POINTS BY SYMBOL					
	A	B	C	D	E	F
Higher Grade	8	7	6	5	4	3
Standard Grade	6	5	4	3	2	1

Unfortunately, in the Matric HG results I received from Khanya and which I have used for my analyses no ‘F grade’ totals are indicated. Instead, all F grades are grouped under ‘fail’ (as an F is indeed a higher grade fail). However, this should not be a significant problem as this (minor) absence is consistent across all the data.

After using the above table to convert grades to points, I generated an average score for each pupil. The formula used to generate this is quite simple: for each year and each wave I multiplied the number of A grades, B grades et cetera obtained by the pupils in each of the groups by the UCT points allocation. These were then summed and the total divided by the total number of students who wrote Matric Mathematics. I have termed this final answer the ‘mean student score’ (MSS).

As an example, here is how I calculated the mean student score for the 2007 Matric Mathematics results of the so-called Pilot schools (the first group of schools given computers by the Khanya project) – see their results in Table 4 below

Table 4: 2007 Matric Mathematics results from the Khanya ‘Pilot’ schools

ACADEMIC LEVEL	NUMBER OF CANDIDATES BY SYMBOL						
	A	B	C	D	E	F	FAIL
Higher Grade	1	1	1	2	2	-	24
Standard Grade	7	9	11	15	59	37	52

By multiplying, in turn, the number of candidates in each symbol category in Table 4 by the corresponding admission points score from Table 3, and then dividing by the total number of 'pilot school' pupils, I obtained their mean student score as follows:

$$\begin{aligned} & (1*8 + 1*7 + 1*6 + 2*5 + 2*4 + 7*6 + 9*5 + 11*4 + 15*3 + 59*2 + 37*1) / \\ & (1+1+1+2+2+24+7+9+11+15+59+37+52) \\ & = 370 / 221 \\ & = 1.674 \end{aligned}$$

It is this MSS that I tested to see if there are in fact significant differences between the experimental and control groups (in the first test), and before and after the intervention (in the second test). The reason for the allocation of particular schools to either the experimental or control groups, and the results of the statistical analyses performed, are described below.

5.2.3. Test 1: Comparing the 2007 Matric Mathematics Results of an Experimental and Control Group

The first test involves comparing the 2007 Matric Mathematics results between two groups, an experimental group and a control group. The unit of analysis is individual schools, as we are looking for comparisons of whole-school results as opposed to those of individual pupils. The size of the study sample is 31 high schools. The experimental group consists of all 14 EMDC East high schools in the Khanya Pilot, second & third waves² (and thus which received their Khanya labs from 2001 to 2003). Pupils at these schools would thus have had at least four years of access to the computer facilities, assuming they were used. The control group is all 17 EMDC East high schools in the Khanya sixth and seventh waves, which received their computer labs in the period between late 2005 and 2007. Pupils at these schools would thus have had little opportunity, on average around one year, to use the computer facilities.

² The different 'waves' mentioned refer to the different phases of implementation of the Khanya intervention, with the 'pilot wave' being the first group of schools that received the Khanya computers.

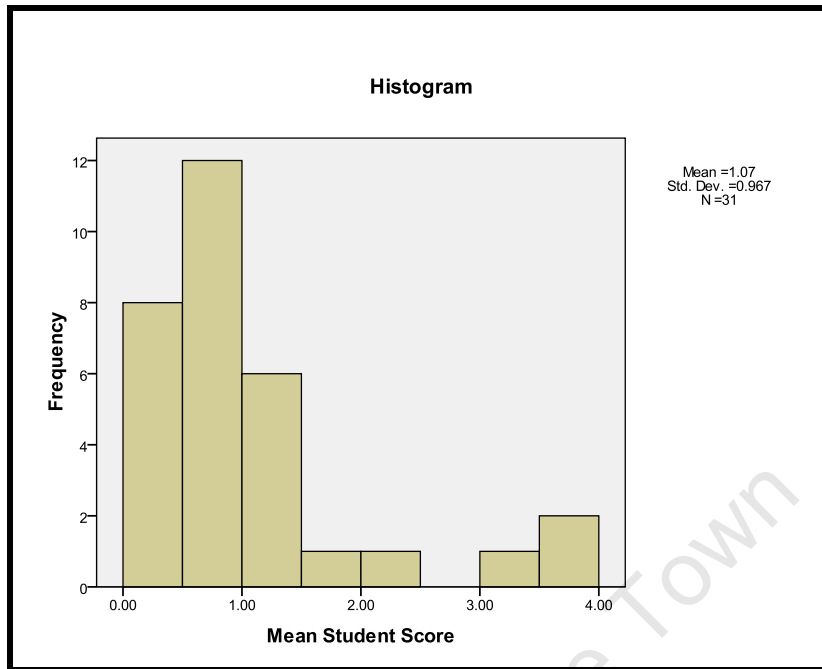
The ideal test to use to check whether there is a significantly higher set of marks for the experimental group is the t-test for independent samples (the samples are independent because the schools in each group are different). As the t-test is parametric, it assumes that the data is normally distributed and has equal variation, and so this needed to be tested first.

The Kolmogorov-Smirnov test for normality indicated a significance value of 0.001 (see Table 5). This value, since it is well below 0.05, shows that the data is not close to being normally distributed. This conclusion is supported by a study of the histogram of the distribution, and the normal Q-Q plot of the MSS (see Graphs 1 and 2). In the former, the strong positive skewness is clearly evident, whilst in the latter the dots showing observed versus expected (normal) values do not form anything like a straight line.

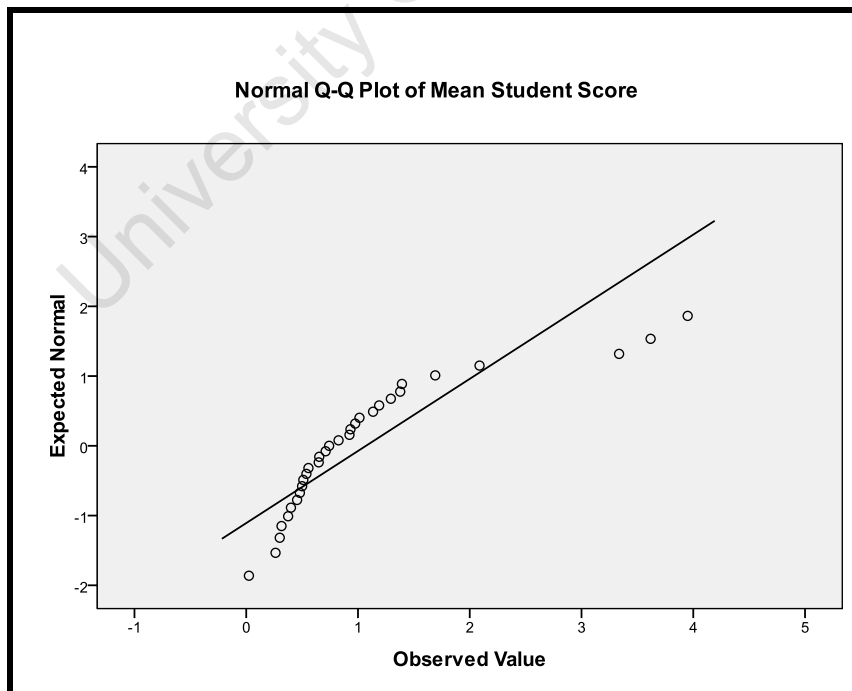
Table 5: Kolmogorov-Smirnov test for normality (Test 1)

TEST RESULTS^a			
	Statistic	df	Sig.
Mean Student Score	.208	31	.001
a. Lilliefors Significance Correction			

Graph 1: Histogram of Mean Student Score (Test 1)



Graph 2: Normal Q-Q Plot of Mean Student Score (Test 1)



A non-parametric Mann-Whitney U test, which does not require the assumption of normality, was thus performed on the data instead. The test revealed no significant

difference in the mean student score of the experimental group (mean rank = 18; n = 14) and the control group (mean rank = 14.35; n = 17), U = 91; z = -1.11; p = 0.266 (see Tables 6 and 7 below).

Table 6: Mean Student Score Ranks (Test 1)

TEST RESULTS				
	Group	N	Mean Rank	Sum of Ranks
Mean Student Score	2 c	17	14.35	244.00
	3 e	14	18.00	252.00
	Total	31		

Table 7: Mann-Whitney U test results: mean student score (Test 1)

TEST RESULTS	
Mann-Whitney U	91.000
Wilcoxon W	244.000
Z	-1.111
Asymp. Sig. (2-tailed)	.266
Exact Sig. [2*(1-tailed Sig.)]	.279 ^a
a. Not corrected for ties.	
b. Grouping Variable: Group	

The effect size statistic was also calculated using the formula $r = \frac{|z|}{\sqrt{N}}$. This gives a value of $r = 0.2$, which indicates a small to medium effect size using Cohen's (1988) criteria of 0.1 = small effect; 0.3 = medium effect and 0.5 = large effect. In other words, a small to medium amount of the variance between the control and experimental groups' Mathematics results is explained by whether or not the students had access to computers.

On re-analysis of the schools within each of the experimental groups, it became clear that the mean student scores of certain schools were acting as outliers, with mean student scores vastly superior to the other schools in the sample: School A in the experimental group, and Schools B, C and D in the control group.

It was decided to re-define the 2 groups by excluding these 4 schools, with justification as follows:

- School A is a specialist Mathematics, Science and Technology school in Khayelitsha, with their entire pupil cohort cherry-picked from schools in the neighbouring areas at the end of Grade 9. Since this is effectively an elite township school, the pupil body is unlike those of your average township school and should therefore be excluded to ensure a comparison of like versus like.
- Schools B, C and D are all examples of ex-Model C schools. Model C schools were, during the Apartheid years, schools for White pupils only, but that stipulation fell away in the early 1990s and the racial mix of the pupil body of many of these schools (including the three in this study) has changed dramatically since then. Nonetheless, these schools generally have far better facilities (including access to computer labs for many years before they were supported by the Khanya Project), better qualified teachers and a wealthier pupil body than your average township school and should therefore be excluded for the same reason as above viz. to ensure a comparison of like versus like.

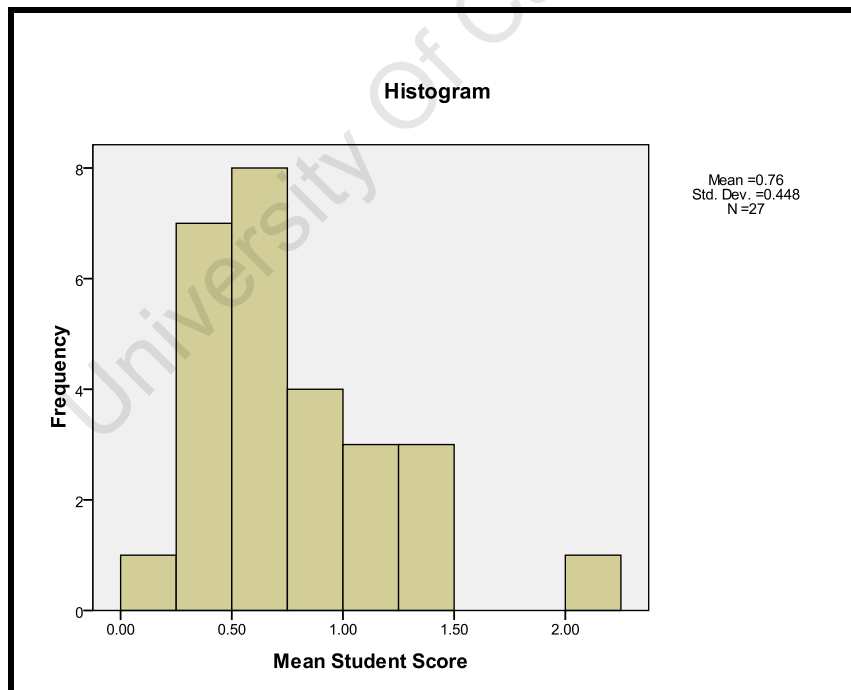
With these re-defined groups, the Kolmogorov-Smirnov test for normality indicated a significance value of 0.2 (see Table 8). This value is above 0.05 and thus shows that the data is normally distributed.

Table 8: Kolmogorov-Smirnov test for normality (Test 1 – redefined groups)

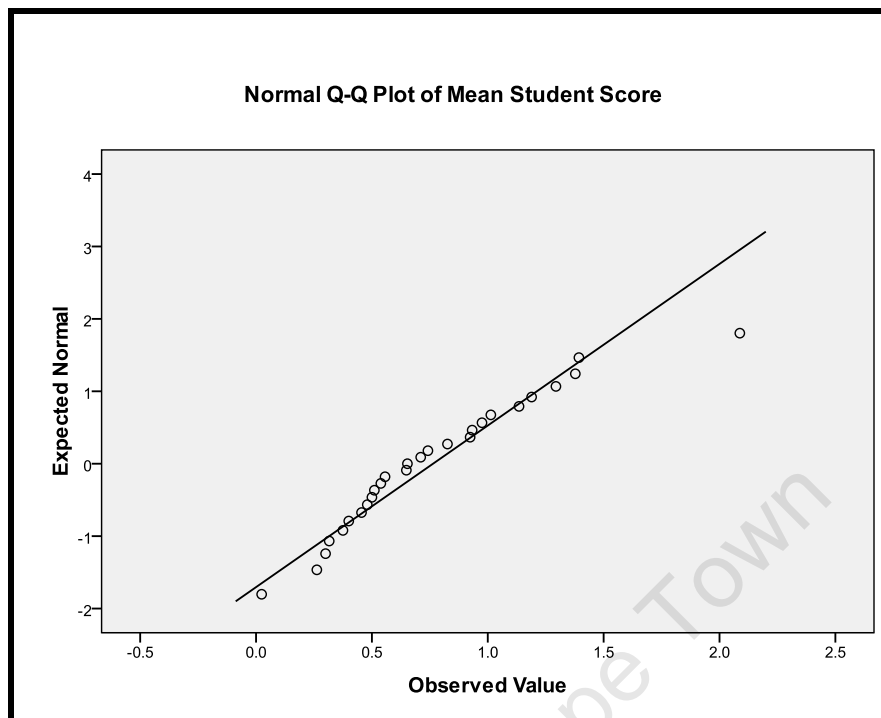
TEST RESULTS ^a			
	Statistic	df	Sig.
Mean Student Score	.122	27	.200*
a. Lilliefors Significance Correction			
*. This is a lower bound of the true significance.			

This conclusion is supported by a study of the histogram of the distribution, and the normal Q-Q plot of the MSS. In the former, a bell-shaped outline of the bars is evident (although there is still a slight positive skew); whilst in the latter the dots showing observed values follow the expected (normal) values line quite closely (see Graphs 3 and 4).

Graph 3: Histogram of Mean Student Score (Test 1 – redefined groups)



Graph 4: Normal Q-Q Plot of Mean Student Score (Test 1 – redefined groups)



Under these circumstances, a t-test for independent samples may be performed with the re-defined groups. Levene's Test for the Equality of Variances gives a significance value of 0.4129, which is greater than 0.05, and thus we can assume equal variances for the two groups (another requirement for the t-test for independent samples to be appropriate) (see Table 10).

The results of the independent samples t-test to compare the mean student scores of the re-defined control and experimental groups reveal that there is no significant difference between the results for the control schools (mean = 0.6106, std deviation = 0.365) and the experimental schools (mean = 0.9286; std deviation = 0.484); $t(25) = 1.938$, $p = 0.064$ (2-tailed) (see Tables 9 and 10 below).

Table 9: Group Statistics (Test 1 – redefined groups)

TEST RESULTS					
		N	Mean	Std. Deviation	Std. Error Mean
Mean Student Score	e	13	.9286	.48358	.13412
	c	14	.6106	.36505	.09756

University Of Cape Town

Table 10: Independent Samples t-test results (Test 1 – redefined groups)

TEST RESULTS											
		Levene's Test for Equality of Variances		t-test for Equality of Means						95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper	
Mean Student Score	Equal variances assumed	.676	.419	1.938	25	.064	.31806	.16411	-.01993	.65605	
	Equal variances not assumed			1.918	22.297	.068	.31806	.16585	-.02563	.66175	

The effect size statistic eta squared was calculated using the formula

$$EtaSquared = \frac{t^2}{t^2 + (N1 + N2 - 2)}. \text{ This gave a result of eta squared} = 0.131,$$

which indicates a small effect size using Cohen's (1988) criteria. In other words, only a small amount of the variance between the re-defined control and experimental groups' Mathematics results is explained by whether or not the students had access to computers.

5.2.4. Test 2: Comparing Matric Mathematics Results Before and After the Khanya Intervention

The second test involves comparing the 2003 and 2007 Matric Mathematics results for Khanya schools in the 4th and 5th waves (a sample of 11 different schools). Schools in these two waves received their Khanya labs and software in the period from 2004 to mid 2005. Essentially this test will enable a comparison of results before and after the Khanya intervention, since in 2003 none of these schools would have had the Khanya facilities, and by 2007 they would have all had them for at least 2½ years.

The ideal test to use to check whether there is a significantly higher set of marks for the group post-intervention is the paired samples t-test. As the t-test is parametric it assumes that the data is normally distributed and has equal variation, and so as before this needed to be tested first.

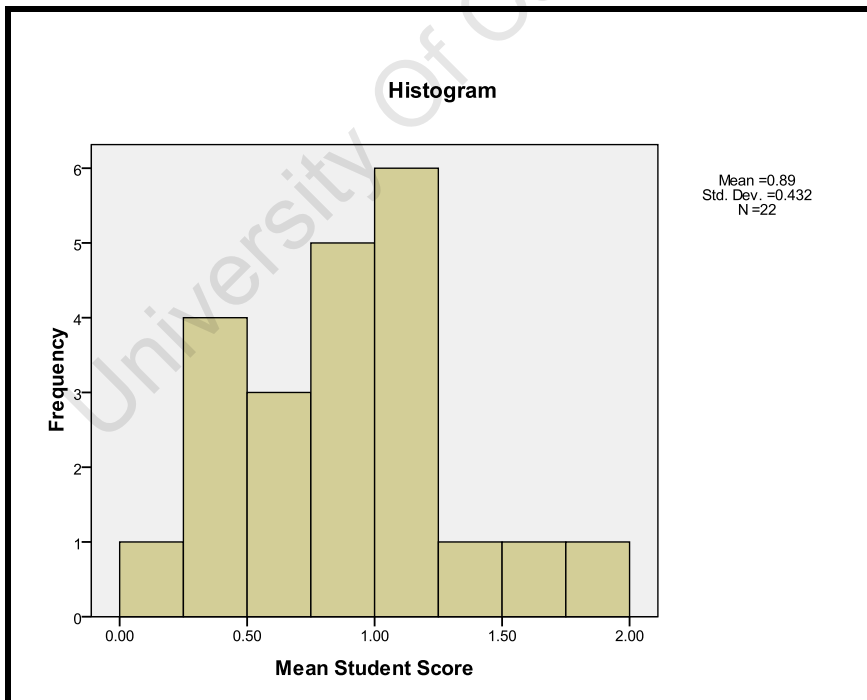
The Kolmogorov-Smirnov test for normality indicated a significance value of 0.2 (see Table 11). This value, since it is above 0.05, shows that the data is indeed normally distributed.

Table 11: Kolmogorov-Smirnov test for normality (Test 2)

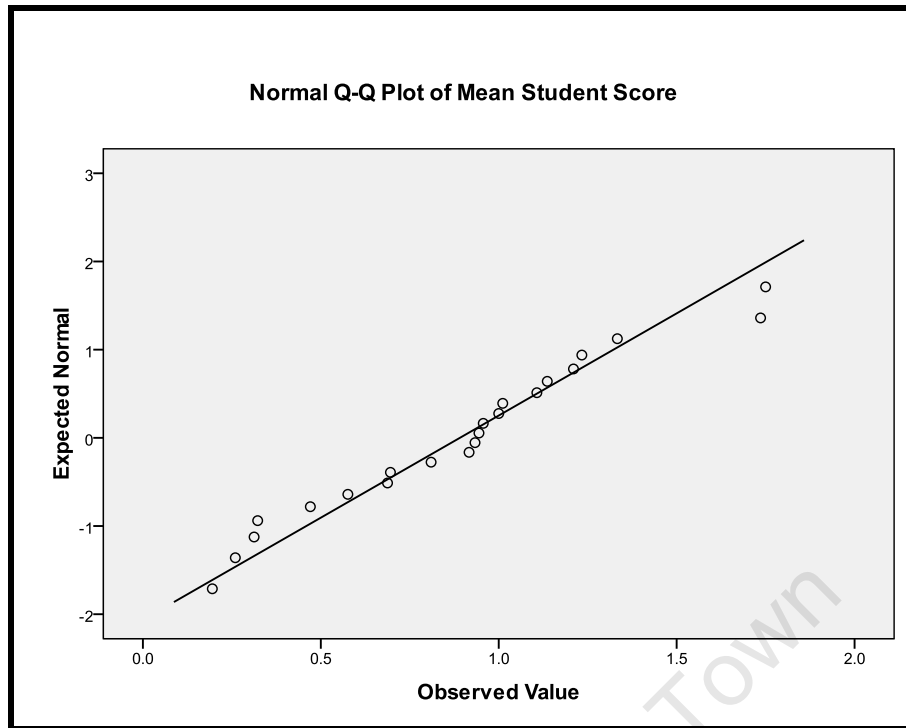
TEST RESULTS ^a			
	Statistic	df	Sig.
Mean Student Score	.115	22	.200*
a. Lilliefors Significance Correction			
*. This is a lower bound of the true significance.			

This conclusion is supported by a study of the histogram of the distribution, and the normal Q-Q plot of the MSS (see Graphs 5 and 6). In the former the reasonably bell-shaped appearance of the data is clearly evident, whilst in the latter the dots showing observed versus expected (normal) values lie almost in a straight line.

Graph 5: Histogram of Mean Student Score (Test 2)



Graph 6: Normal Q-Q Plot of Mean Student Score (Test 2)



A paired samples t-test was thus conducted to evaluate the impact of the Khanya intervention on the mean student score (MSS). There is no statistically significant change in the MSS from before Khanya (mean = 0.955; std deviation = 0.382) to after Khanya (mean = 0.827; std deviation = 0.486), $t(10) = 0.958$, $p = 0.361$ (see Tables 12 and 13).

Table 12: Paired Sample Statistics (Test 2)

TEST RESULTS				
	Mean	N	Std. Deviation	Std. Error Mean
Mean Student Score (before Khanya)	.9549	11	.38195	.11516
Mean Student Score (after Khanya)	.8267	11	.48608	.14656

Table 13: Paired Samples t-test results (Test 2)

TEST RESULTS								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Mean Student Score (before Khanya) - Mean Student Score (after Khanya)	.12818	.44366	.13377	-.16987	.42624	.958	10	.361

The effect size statistic eta squared was calculated using the formula

$$EtaSquared = \frac{t^2}{t^2 + N - 1}$$

This gave a result of eta squared = 0.084, which indicates a very small effect size using Cohen's (1988) criteria. In other words, only a very small amount of the variance between the Mathematics results pre- and post- Khanya intervention is explained by whether or not the students had access to computers.

5.2.5. Further Tests

So, in summary, the above tests have indicated that the Khanya intervention has not brought about a significant improvement in overall Matric Mathematics results. There are other questions that could then be asked, however, such as:

- Did the Khanya intervention at least ensure a greater pass rate at Matric Mathematics? If this were true of the intervention, it would be a most pleasing and important finding, and would indicate that the

computers have been a success at improving the grades of the lowest achievers.

- Did the Khanya intervention bring about a greater (percentage) enrolment in Higher Grade rather than Standard Grade Mathematics? Again, if this were true it would be most encouraging as it is indeed the stated desire of education authorities to have more pupils write the exams at the former rather than the latter level, as Higher Grade Mathematics is one of the key requirements for entrance to critical university courses like engineering.

Both these questions were answered statistically by means of further statistical tests.

With regard to the first question above, for each school in the same sample group as for Test 2, I determined for both 2003 and 2007 the total number of passes at both Higher Grade and Standard Grade level, and the total number of Matric Mathematics candidates. These figures were then used to calculate a percentage pass for each school. This was the raw data on which I carried out my paired samples t-test.

The Kolmogorov-Smirnoff test for normality indicated a significance value of 0.2 (see Table 14). This value, since it is above 0.05, shows that the data is indeed normally distributed.

Table 14: Kolmogorov-Smirnoff Test for Normality (Test 3)

TEST RESULTS ^a			
	Statistic	df	Sig.
% passing (before Khanya)	.198	11	.200*
% passing (after Khanya)	.149	11	.200*
a. Lilliefors Significance Correction			
*. This is a lower bound of the true significance.			

A paired samples t-test was thus conducted to evaluate the impact of the Khanya intervention on the percentage of pupils passing Mathematics at Matric level. The results of this test showed that there is no statistically significant change in the pass percentage from before Khanya (mean = 40.9; std deviation = 16.3) to after Khanya (mean = 35.8; std deviation = 17.4), $t(10) = 0.878$, $p = 0.401$ (see Tables 15 and 16).

Table 15: Paired Samples Statistics (Test 3)

TEST RESULTS				
	Mean	N	Std. Deviation	Std. Error Mean
% passing (before Khanya)	40.91	11	16.32	4.92
% passing (after Khanya)	35.80	11	17.40	5.25

Table 16: Paired Samples t-test results (Test 3)

TEST RESULTS								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
% passing (before Khanya) - % passing (after Khanya)	5.115	19.324	.5.826	-7.867	18.096	.878	10	.401

With regard to the question around whether the Khanya intervention has caused an increase in the number of Matric Higher Grade Mathematics candidates, for each school in the same sample group as for Test 2, I determined for both 2003 and 2007 the number of higher grade candidates and total candidates. This was then converted to a percentage; used as the raw data for my tests.

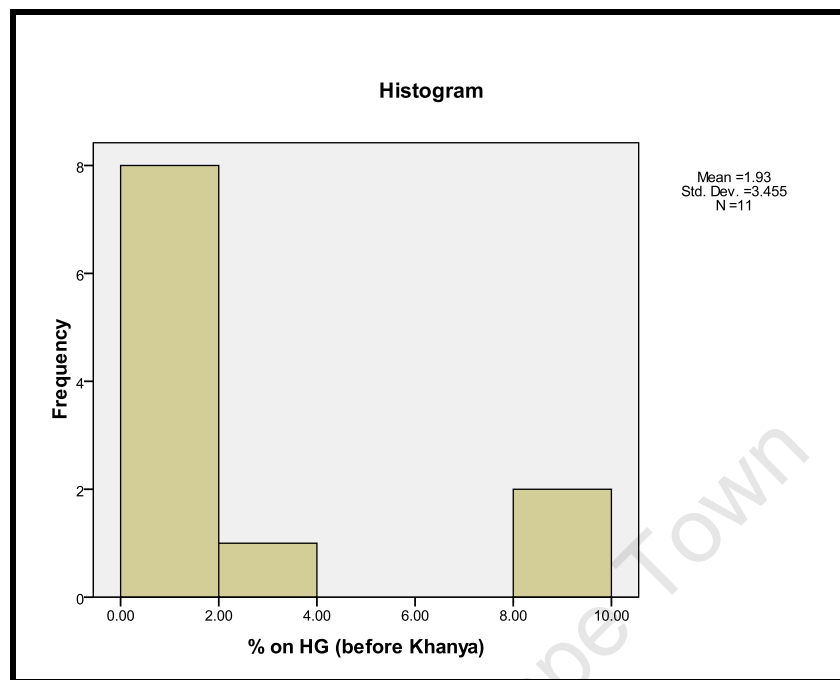
In order to ascertain whether I could use a paired samples t-test, I carried out a Kolmogorov-Smirnoff test for normality. The tiny significance value of 0.001 (see Table 17) showed clearly that the data was clearly not normally distributed.

Table 17: Kolmogorov-Smirnoff Test for Normality (Test 4)

TEST RESULTS ^a			
	Statistic	df	Sig.
% on HG (before Khanya)	.349	11	.001
% on HG (after Khanya)	.348	11	.001
a. Lilliefors Significance Correction			

This was confirmed by the highly asymmetrical histogram of the data (see Graph 7).

Graph 7: Histogram of HG Percentage (before Khanya)



The consequence of this lack of normality is that instead of carrying out a paired samples t-test, I carried out the non-parametric alternative, the Wilcoxon Signed Rank Test. This test revealed no significant difference in the percentage of pupils enrolled in Higher Grade Mathematics after the Khanya intervention compared with before, with $Z = -1.153$ and $p = 0.249$ (see Tables 18 and 19). The median score of percentage HG enrolment did not change from pre-intervention to post-intervention, staying at 0% (see Table 20).

Table 18: Wilcoxon Signed Rank Test - Ranks (Test 4)

TEST RESULTS				
		N	Mean Rank	Sum of Ranks
% on HG (after Khanya) - % on HG (before Khanya)	Negative Ranks	2 ^a	2.50	5.00
	Positive Ranks	4 ^b	4.00	16.00
	Ties	5 ^c		
	Total	11		
a. % on HG (after Khanya) < % on HG (before Khanya)				
b. % on HG (after Khanya) > % on HG (before Khanya)				

Table 19: Wilcoxon Signed Rank Test Results (Test 4)

TEST RESULTS	
	% on HG (after Khanya) - % on HG (before Khanya)
Z	-1.153 ^a
Asymp. Sig. (2-tailed)	.249
a. Based on negative ranks.	

Table 20: Wilcoxon Signed Rank Test – Descriptive Statistics (Test 4)

TEST RESULTS				
	N	Percentiles		
		25th	50th (Median)	75th
% on HG (before Khanya)	11	.0000	.0000	2.2500
% on HG (after Khanya)	11	.0000	.0000	8.9300

The effect size statistic was also calculated using the formula $r = \frac{|z|}{\sqrt{N}}$. This gives a value of $r = 0.25$, which indicates a small to medium effect size using Cohen's (1988) criteria of 0.1 = small effect; 0.3 = medium effect and 0.5 = large effect. In other words, a small to medium amount of the variance between the percentage of pupils enrolled in Higher Grade Mathematics is explained by whether or not the students had access to computers

5.2.6. Interpretation of the Test Results

Results from these tests appear to indicate that the Khanya intervention has not brought about a significant improvement in the sample schools' Matric Mathematics results. In addition, calculations of effect size statistics showed that any variances in mean student scores were typically only influenced in a small way by the Khanya intervention.

In fact, if one looks at the mean student score of the schools in the sample used for the second test (pre- and post-intervention), one can see that after the Khanya intervention the MSS has actually *decreased* (from 0.955 to 0.827, a decrease of 13.4% – see Table 12). Similarly, the percentage of pupils passing Mathematics at Matric level has also decreased after the Khanya intervention, from 40.9% to 35.8% (see Table 15).

One needs to interpret these observations carefully, however, as it is not correct to infer from this that the Khanya intervention has brought about the deterioration of results. This is because, firstly, the statistical analyses showed that there was no statistically significant change in the pre- and post-intervention results in either direction, and secondly, the Khanya intervention, by which access to computers is enabled, is only one of the many factors that influence Matric Mathematics results, as will be shown in the next section.

5.2.6.1. Other factors influencing Mathematics results

There are many other factors that will influence Matric results in South Africa, as shown by the summary on factors influencing pupil performance produced by Taylor et al. (2003). These include a number of factors which, whilst extremely significant in influencing Matric results, would probably not be relevant in this instance as there would almost certainly be only a minimal change in these over the 4 year period (2003 to 2007) between the pre-Khanya results and post-Khanya results used in the above analysis:

- Race
- Gender
- Settlement type (urban suburb, urban township, rural etc)
- Parental income or household wealth (socio-economic status)
- Family structure
- Education level of parents
- Language use and language of instruction
- Pupil-teacher ratios (class sizes)
- The school's physical resources and facilities

However, the following influential factors might well have changed in the sample over the 4 year period, mainly due to the inevitable turn over of staff at schools:

- Teacher qualifications
- The teaching method utilised by the teachers
- Availability and variety of learning materials
- School ethos – particularly the presence of a joint vision between staff and pupils regarding the future of the school and the importance of a strong work ethic
- The level of effectiveness of the school management
- The level of discipline of pupils and teachers
- Community relations – whether or not the students, staff and parents are working together to facilitate good education

It might be that in a number of the schools in the EMDC East that were tested pre- and post-Khanya intervention there has been a decline in the quality of some or all of these measures listed above. If that were the case, it would certainly explain why the MSS has declined. Many of these variables are very difficult to measure (especially retrospectively) and, where they *are* quantifiable, access to such data for a student like me will be extremely difficult due to their sensitive nature. This makes controlling (statistically) for these factors very difficult. In addition, the samples I am using are simply not large enough to attempt such highly complex models, and such an analysis is beyond the scope of a mixed method Masters dissertation.

The consequence of this is that I have not attempted to work any of these factors into my current analyses. However, their influence is large and could provide excellent research opportunities for those interested in pursuing this line of investigation.

One other factor not mentioned by Taylor et al. (2003) but which is obviously significant in the context of determining whether or not the use of computers has made a difference to Mathematics results, is the frequency of use of the mathematics software. Louw et al. (2008) performed correlational analyses on the relationship between improvement in Mathematics performance and the amount of time spent on the MasterMaths system, and found it to be positive, statistically significant and moderate in strength ($r = 0.37$; $n = 125$; $p < 0.001$). (MasterMaths is a Mathematics software programme that is used by many Khanya schools and which provides tutoring support).

Unfortunately, as has been shown by the study of Louw et al. (2008) into the use of MasterMaths in Khanya schools in the Western Cape, pupils spend very little time using the software provided by Khanya. In three of the experimental schools used in Louw et al's (2008) study for which log files of MasterMaths usage were available, over a six month period Matric pupils logged onto MasterMaths an average of only 7 times, for an average total of little over 2½ hours (158 minutes). This raises the critical question as to how effective an intervention like Khanya can be if the advanced technology it

provides is used so seldom. As Louw et al. (2008) state: “the statistics reported...are so low as to raise serious concerns about the implementation of the intervention” (p. 45). Again, if Louw et al’s (2008) findings in this area are also true of the schools that I tested pre- and post-Khanya intervention then it is no wonder that the intervention has had no positive effect on Mathematics results.

Certainly, the problems of lack of time on the computers as illustrated by Louw et al’s (2008) study are evident in the case study school – School A – that I observed in Khayelitsha too. School A is linked to an FET College and, as such, some of the facilities are shared between the two institutions. In particular, the computer lab has to be shared between School A and the FET College, which results in it being extremely difficult for the Mathematics teachers to take their classes to the lab. As Mr Mhorah pointed out in my interview with him: “the problem we have now is... [that] we don’t have enough time where we can visit the lab when it will be free; because in most cases when the labs are free to be used by [School A] there will be Information Technology (IT) lessons there and at times they will be used by the college”. The only way to increase lab access, he said, was to make “internal arrangements whereby we can swap with the IT teacher. If he is teaching theory then he can come into our classroom ... [and] we can go to the lab”, or to use the labs after school and college hours (late in the afternoon or on Saturday mornings).

Mrs Cupido pointed out that until 2008 the Mathematics classes of School A were timetabled in the computer labs once a week each, but that throughout 2009 they were not able to visit the labs at all, until the period of my observations in August, due to an increased College use of the labs and problems with the Plato (mathematical) software. She is hoping to make arrangements so that in future each class will get to the computer lab in a Mathematics lesson at least once a 2 week cycle, though she was not able to elaborate on the practicalities of how that could be arranged.

This first part of the chapter has outlined various statistical analyses of Matric Mathematics results, which determined that no significant improvements in results or even in Higher Grade enrolment have come about through the Khanya intervention. However, though academic improvements are not traceable through statistical analyses, the computers are nonetheless still technological tools and if used would be expected to have some pedagogical impact. The rest of the chapter is consequently devoted to outlining the findings of my research into *how* the computers and software are being used in township schools and how they have impacted one aspect of pedagogy, namely semiotic mediation. This is done by means of a case study of one such school in Khayelitsha, Cape Town.

5.3. Data Analysis and Interpretation: Classroom Observations

As outlined in the Research Design and Methodology chapter, I undertook approximately 10 hours of classroom observations in a Khayelitsha school; half of the time observing Mathematics lessons in computer labs and half the time in a conventional classroom. The 50:50 split was to allow me to compare pedagogies in the two venues. This section outlines the analysis of the data collected, plus the interpretation thereof.

The analysis of the observations focussed on two issues:

- i. variance in semiotic mediation, particularly the use of language, between the different contexts (conventional classroom and computer lab), as an example of tool use impacting pedagogical change.
- ii. how the teachers mediated mathematical concepts within the computer lab, using the computers as a technological, concrete teaching tool.

This portion of the study draws primarily on Vygotsky's (1978) notion of tool mediation: the idea that the use of tools, both abstract and concrete, is the means by which individuals achieve a higher level of understanding than could be achieved by pursuing a natural line of development alone.

5.3.1. Analysis of the Variation in Semiotic Mediation in the Mathematics Classroom

As mentioned in the Methodology chapter, an analytical framework was developed which allows for a categorisation of all the verbal utterances made by the teacher in the conventional and computer lab lessons (see Table 2). Each of the observed lessons was transcribed verbatim, and the transcriptions analysed according to the analytical framework, using a sentence as the basic unit of analysis.

In addition to separately categorising the verbal utterances in the two different teaching venues, it was further decided to break down into two groups the interactions in terms of who was being addressed by the teacher. The first group was called 'class' and included all verbal interactions in which the teacher was either addressing the entire class or individuals within a whole class setting. The second group, called 'individuals', included all verbal interactions between the teacher and individual pupils in which the other pupils in the room were not involved (this included, therefore, one-on-one assistance while the class was working on individual tasks both in the computer laboratory and/or the classroom).

The summary of the tallies for each of the teachers in each context (computer lab or face-to-face classroom) is provided in Tables 21 and 22 on the next few pages. These tallies are taken from the raw data, which can be found in Appendix 4.

Table 21: Summary of Tallies: Computer Lab Lessons (numbers overall; percentages by teacher and overall)

		AVERAGE NUMBER OF INTERACTIONS (combined teachers)		PERCENTAGE OF INTERACTIONS (combined teachers)		PERCENTAGE OF INTERACTIONS (separate teachers)			
		CLASS	INDIVID	CLASS	INDIVID	Mr Mhorah		Mrs Cupido	
						CLASS	INDIVID	CLASS	INDIVID
feedback	praise / encouragement	0.3	1.7	0.4	1.3	0.2	0.7	1.1	3.7
	criticism	0.5	1.3	0.5	1.0	0.2	0.7	2.2	2.5
	correction of error	1.7	3.5	1.8	2.7	2.2	2.4	0.0	3.7
statement	information	13.2	3.7	14.4	2.8	12.9	2.1	22.2	5.6
instruction	deportment	6.7	5.2	7.3	4.0	7.0	4.2	8.9	3.1
	academic - Mathematics	4.3	6.3	4.7	4.9	4.8	4.7	4.4	5.6
	academic - IT	12.5	20.8	13.7	16.1	10.9	18.3	27.8	8.1
question	IT related	5.7	9.0	6.2	7.0	6.1	7.7	6.7	4.3
	Mathematics factual	9.5	18.0	10.4	14.0	12.4	14.5	0.0	11.8
	Math assistance	0.5	4.2	0.5	3.2	0.7	3.4	0.0	2.5
	other	10.7	12.5	11.7	9.7	10.0	8.6	20.0	13.7
explanation	Mathematics statement	19.5	32.9	21.4	25.5	25.5	25.6	0.0	24.8
	rationale	0.5	2.5	0.5	1.9	0.7	1.1	0.0	5.0
	IT usage	5.8	7.5	6.4	5.8	6.3	5.9	6.7	5.6
	TOTAL NUMBER	91.4	129						
	% OF TOTAL	41.7%	58.3%						

The above table illustrates the computer lab verbal interactions, for each sub-category, divided into class or individual interactions and summarizes them as percentages of the whole, both in total and for each of the two teachers separately. Of interest, for example, is the relatively high percentage of academic IT (13.7%; 16.1%) instructions given by both teachers in comparison with, for example, a much lower level of instructions (4.7%; 4.9%) related to Mathematics. This focus on IT is balanced out when we look at explanations: note the high percentage of utterances related to mathematical statements (21.4%; 25.5%) compared with IT usage (6.4%; 5.8%).

Table 22: Summary of Tallies: Traditional Classroom Lessons (numbers overall; percentages by teacher and overall)

		AVERAGE NUMBER OF INTERACTIONS (combined teachers)		PERCENTAGE OF INTERACTIONS (combined teachers)		PERCENTAGE OF INTERACTIONS (separate teachers)			
		CLASS	INDIVID	CLASS	INDIVID	Mr Mhorah		Mrs Cupido	
		CLASS	INDIVID	CLASS	INDIVID	CLASS	INDIVID	CLASS	INDIVID
feedback	Praise / encouragement	0.5	1.0	0.2	2.7	0.0	2.1	0.5	3.8
	criticism	0.5	0.8	0.2	2.0	0.0	3.1	0.5	0.0
	correction of error	1.0	4.0	0.4	10.7	0.2	13.5	0.8	5.7
statement	information	22.8	0.0	8.8	0.0	6.7	0.0	12.6	0.0
instruction	deportment	6.0	2.0	2.3	5.4	3.0	8.3	1.1	0.0
	academic - Mathematics	13.0	5.8	5.0	15.4	4.7	17.7	5.6	11.3
question	Mathematics factual	39.5	7.5	15.3	20.1	16.1	16.7	13.9	26.4
	Math assistance	3.8	0.3	1.5	0.7	0.8	0.0	2.7	1.9
	other	47.8	2.8	18.5	7.4	25.9	9.4	5.6	3.8
explanation	Mathematics statement	113.3	13.0	43.9	34.9	41.9	29.2	47.6	45.3
	rationale	9.8	0.3	3.8	0.7	0.8	0.0	9.1	1.9
	TOTAL NUMBER	257.8	37.3						
	% OF TOTAL	87.4%	12.6%						

As with Table 21, Table 22 indicates what percentage of teachers' utterances are aimed at the whole class and what percentage is aimed at individual students in the face-to-face lesson. Perhaps the most interesting finding here is that very large percentages (43.9%; 34.9%) of teacher utterances are in the form of mathematical statements. This is interesting given research findings that indicate that the traditional lesson lends itself more to instruction in mathematics than does the computer laboratory (see Hardman, 2005b and in press for example).

Tables 21 and 22 lend themselves to further analysis. The key question for this section of the dissertation is to determine whether the teachers' talk in the face-to-face Mathematics classroom differs from that in the computer lab. In this regard, three observations can immediately be gleaned from the above tables:

1. the number of individual interactions as a percentage of the whole is far higher in the computer labs than in the face-to-face lessons: in the former over half (58.3%) of the interactions were with individuals whereas in the latter the corresponding figure is only roughly one in eight (12.6%).
2. the number of verbal interactions in the face-to-face lessons is significantly higher than the number in computer lessons: an average of about 295 per lesson in the former and 220 in the latter, a difference of slightly over one-third (34%).
3. the interactions related directly to computer use (this includes the categories of IT-related instructions, questions and explanation) form a significant portion of the total interactions in the computer lab, for both teachers. In Mr Mhorah's case, 28.2% of the verbal interactions are of this type, while for Mrs Cupido the percentage is 26.3%.

The first observation is unsurprising, as in the computer lab the typical lesson format was to get the pupils onto the Plato programme and working individually as soon as was possible. On only one out of the six computer lab lessons that were observed did any significant whole class teaching take place. The computer lab lessons were primarily used as an opportunity for the pupils to determine their level of understanding of particular Mathematics topics by means of (individually) completing examples presented by the software programme, and it is thus no surprise that most of the interactions were one-on-one.

In contrast, in the case of the face-to-face lessons the typical lesson format was for the teacher to present new material to the entire class for the majority of the lesson. It was typically only in the last 20-25% of the lesson that pupils were given opportunity to complete individual exercises in their exercise

books. At this stage of each lesson the number of verbal interactions declined significantly as much of the time there was silence as the pupils worked quietly on their own work. This explains why the overall percentage of individual interactions ended up as only 12.6%.

The second observation above is similarly expected, as during the face-to-face lessons (as outlined above) the vast majority of the lesson is spent with whole class- explanations and questions, with only a relatively small percentage of individual time. Whereas during the whole class phase there are constant verbal interactions, during the individual phase there are significant silences; thus it is not unexpected to find that in the context where there is more whole class teaching there are a greater number of verbal interactions.

In Table 23 on the next page, the verbal interaction percentages of each teacher in each sub-category are provided, with the emphasis on a comparison across teaching contexts. This will enable an analysis of variations in semiotic mediation from the computer lab to the traditional classroom.

Table 23: Summary of Individual Teachers' Interactions (percentages, face-to-face versus computer lab lessons)

		PERCENTAGE OF INTERACTIONS (Mr Mhorah)		PERCENTAGE OF INTERACTIONS (Mrs Cupido)		PERCENTAGE OF INTERACTIONS (combined teachers)		PERCENTAGE OF INTERACTIONS BY CATEGORY (combined teachers)	
		FACE-TO-FACE	COMP LAB	FACE-TO-FACE	COMP LAB	FACE-TO-FACE	COMP LAB	FACE-TO-FACE	COMP LAB
feedback	praise / encouragement	0.3	0.5	0.9	2.8	0.5	0.9	2.6	4.0
	criticism	0.4	0.5	0.5	2.4	0.4	0.8		
	correction of error	1.9	2.3	1.4	2.4	1.7	2.3		
statement	information	5.8	6.7	11.0	11.6	7.7	7.6	7.7	7.6
instruction	deportment	3.7	5.4	0.9	5.2	2.7	5.4	9.1	25.3
	academic - Mathematics	6.4	4.8	6.3	5.2	6.4	4.8		
	academic - IT	N/A	15.1	N/A	15.1	N/A	15.1		
question	IT related	N/A	7.0	N/A	5.2	N/A	6.7	34.4	31.8
	Mathematics factual	16.2	13.6	15.5	7.6	15.9	12.5		
	Math assistance	0.7	2.2	2.6	1.6	1.4	2.1		
	other	23.8	9.2	5.4	15.9	17.1	10.5		
explanation	Mathematics statement	40.2	25.6	47.3	15.9	42.8	23.8	46.2	31.3
	rationale	0.7	0.9	8.2	3.2	3.4	1.4		
	IT usage	N/A	6.1	N/A	6.0	N/A	6.1		
	TOTAL %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Of immediate interest in this table is the apparently significant difference between the percentage of “instructions” in the face-to-face lesson (9.1%) and those in the computer lesson (25.3%). If we look at the category of “explanation” we can see a less dramatic, but nonetheless interesting, difference between face to face (46.5%) and computer lessons (31.3%). This finding is in line with findings reported by other research in South Africa (see Hardman, 2005) that shows that the classroom is the place where more explaining of mathematics happens, while the computer laboratory is predominantly a practice site for knowledge already acquired.

If we look at the overall verbal interactions within the computer lab (see the Table 23 summary), we can see that there is a fairly even spread across the three categories of explanations (31.3%), questions (31.8%) and instructions (25.3%) with by far the single highest sub-category being that of simple Mathematical explanations (23.8%). There was very little feedback, positive or negative, in these lessons (only 4.0% of the total verbal interactions), whilst 7.6% of the verbal communications were in the form of information statements.

Within the face-to-face Mathematics classroom (see the Table 23 summary) the two categories of explanation (46.2%) and questions (34.4%) completely dominate the verbal communication, with the sub-category of simple Mathematical explanations accounting for close to one half (42.8%) of the total. The other categories of instructions (9.1%), information statements (7.7%) and feedback (2.6%) contribute a combined total of only 19.4%. These figures tell us that Mathematics teaching within the conventional classroom is, as could perhaps be expected, primarily about ensuring that the pupils understand the work that is being presented.

If we look at the break-downs for the individual teachers, again using the data from Table 23, we can easily notice considerable differences in some sub-categories between their teacher talk across the two teaching contexts. Noteworthy examples are that both Mr Mhorah and Mrs Cupido (but especially the latter) provide mathematical explanations far more frequently in the face-to-face lessons than in the computer labs (40.2% v 25.6% for Mr Mhorah, and 47.3% v 15.9% for Mrs Cupido). Mrs Cupido also asks far more Mathematics questions in the traditional classroom (15.5% of the total interactions) compared with the computer lab (only 7.6% of the interactions). There is also a major difference in the percentages of 'other' questions between each teaching context, for both teachers, though interestingly in Mr Mhorah's case he asks more of these types of questions in the face-to-face classroom, whereas with Mrs Cupido it is the other way round.

An interesting observation is that in both of the teaching contexts the level at which both explanations and questions are pitched is pretty low. In the computer lab only 3.5% and in the face-to-face lessons only 4.8% of the verbal interactions were of the type that could be classified as providing or probing for deeper Mathematical understanding. These included explanations that looked at the *reason* for an answer being right and wrong (beyond the obvious), and questions that didn't just want a simple right/wrong answer but an answer that indicated true understanding of how the mathematics worked ("why is this answer incorrect?") and/or attempted to get the pupils to extend their understanding by stretching their thinking into new, unseen contexts (for example, "what would happen if...?").

There was quite a substantial difference between the two teachers in terms of how frequently they explained or questioned more deeply. Whereas in both the computer lab and traditional classrooms Mr Mhorah had a very low percentage of these interactions (3.1% and 1.4% respectively), Mrs Cupido had significantly higher percentages in these sub-categories, particularly in the face-to-face lessons where 10.8% of the interactions were of these types. This could perhaps be explained by her greater teaching experience and/or the fact that she was teaching older pupils (Grade 12s compared with Mr Mhorah's Grade 10s and 11s).

The predominant format of interactions between teacher and pupil in both contexts can be characterised by the IRE (Initiate, Respond and Evaluate) discourse, described originally by Sinclair and Coulthard (1975) and discussed in the conceptual framework chapter of this dissertation. This discourse structure is common in many classrooms around the world (Hardman, in press) and "the general consensus is that the IRE structure is potentially limiting in terms of developing authentic communicative interaction because the teacher asks closed questions that close rather than open discussion" (Hardman, in press, p. 7). If used to close discussion, closed questions are not able to encourage the

development of higher cognitive functions as they do not take the child into new territory, merely dealing with what the child already knows. They thus do not assist in extending the child's knowledge and understanding as they, in Vygotskian terms, are not aimed at the Zone of Proximal Development (Vygotsky, 1986).

Hardman (in press) does add an interesting new slant on this argument, however. She notes that disadvantaged rural South African schools are characterised by "extreme asymmetrical power relations between teachers and taught" (p. 7) – in particular this plays out in that teachers completely dominate the talk time, and pupils get little opportunity to have their say. Hardman (in press) argues that in such contexts, "and in most schooling contexts, closed questions that require only single answers can serve as tools to at least give students access to talk time" (Hardman, in press, p. 7).

5.3.2. Statistical Analysis: Chi Squared Tests

Simply relating the percentage of each category in each context (as I have done above) is illuminating, but does not tell one categorically whether there is a variation in the semiotic mediation between the two contexts (conventional classroom and computer lab). For this, a quantitative analysis is required.

5.3.2.1. Categorising the Data

As explained in the Methodology chapter, three categorical variables were set up:

- **Location of the lesson:** the conventional classroom (face-to-face) and the computer lab.
- **Type of talk:** the 5 main categories of talk, as described in Table 2: feedback, statements, instructions, questions and explanations.
- **Scale of Interaction:** whole class or individual.

The relationship between each of these three categorical variables was determined by performing chi-squared tests for independence on them, two at a

time. The results of these analyses, and the interpretation of the results, appear below.

5.3.2.2. The Relationship between the Location of the Lesson and Type of Talk

The cross tabulation table produced by this analysis is shown in Table 24 overleaf:

University Of Cape Town

Table 24: Cross Tabulation Table – Location of Lesson and Type of Talk

			Type of Talk					Total
			Feedback	Statements	Instructions	Questions	Explanations	
Location of Lesson	Face-to-Face	Count	31	91	107	406	545	1180
		% within Location of Lesson	2.6%	7.7%	9.1%	34.4%	46.2%	100.0%
		% within Type of Talk	36.5%	47.4%	24.2%	49.2%	56.9%	47.2%
		% of Total	1.2%	3.6%	4.3%	16.2%	21.8%	47.2%
	Computer Lab	Count	54	101	335	420	412	1322
		% within Location of Lesson	4.1%	7.6%	25.3%	31.8%	31.2%	100.0%
		% within Type of Talk	63.5%	52.6%	75.8%	50.8%	43.1%	52.8%
		% of Total	2.2%	4.0%	13.4%	16.8%	16.5%	52.8%
Total		Count	85	192	442	826	957	2502
		% within Location of Lesson	3.4%	7.7%	17.7%	33.0%	38.2%	100.0%
		% within Type of Talk	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	3.4%	7.7%	17.7%	33.0%	38.2%	100.0%

What this table illustrates is the total numbers (counts) and percentages of each type of 'teacher talk' category, within each of the two teaching contexts, as well as as a percentage of the total.

The results of the chi-squared test appear in Table 25.

Table 25: Chi Squared Test Results - Location of Lesson and Type of Talk

TEST RESULTS			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	135.453 ^a	4	.000
Likelihood Ratio	141.017	4	.000
Linear-by-Linear Association	67.253	1	.000
N of Valid Cases	2502		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 40.09.			

One of the assumptions of a chi-squared test is that each cell should have an expected frequency of at least five (Pallant, 2007). The footnote 'a' in the table above shows that this assumption has not been violated in this test.

The chi-squared value for this test is 135.453, with an associated significance level of 0.000. As this significance value is smaller than 0.05 we can conclude that our result is significant, which means that there is some association between the location of the lesson and the type of talk used. This is due in the main to:

- the significantly higher percentage of instructions in the computer lab compared with the traditional classroom – Table 24 shows that about three-quarters (75.8%) of all the instructions occur in the computer lab, and
- the substantially higher percentage of feedback interactions in the computer lab (nearly two-thirds (63.5%) of these occur in the lab)

- the higher percentage of explanations in the face-to-face classroom (56.9% of all the explanations).

In order to determine the effect size for a crosstab table like this, one needs to consider the Cramer's V coefficient from the table below. This coefficient is a type of correlation coefficient and ranges between 0 and 1, with higher values indicating a stronger association between the two variables.

Table 26: Cramer's V coefficient – Location of Lesson and Type of Talk

TEST RESULTS			
		Value	Approx. Sig.
Nominal by Nominal	Phi	.233	.000
	Cramer's V	.233	.000
N of Valid Cases		2502	

The Cramer's V coefficient value of 0.233 (see Table 26) represents a medium to large effect (Pallant, 2007). Thus, there is a moderate to strong association between the location of the lesson and the type of talk in each.

It appears from the tables providing the totals of the each type of talk in each location (see Tables 21 and 22), that this association results principally from the fact that the teaching in the face-to-face classroom is much more explanation-dominant and has a far smaller percentage of instruction-related verbal utterances than is the case for the lessons in the computer lab.

5.3.2.3. The Relationship between the Location of the Lesson and the Scale of Interaction

The cross tabulation table produced by this analysis is shown in Table 27:

Table 27: Cross Tabulation Table – Location of Lesson and Scale of Interaction

			Class or Individual interaction		Total
			Whole Class Interaction	Individual Interaction	
Location of Lesson	Face-to-Face	Count	1031	149	1180
		% within Location of Lesson	87.4%	12.6%	100.0%
		% within Class or Individual interaction	65.3%	16.1%	47.2%
		% of Total	41.2%	6.0%	47.2%
	Computer Lab	Count	548	774	1322
		% within Location of Lesson	41.5%	58.5%	100.0%
		% within Class or Individual interaction	34.7%	83.9%	52.8%
		% of Total	21.9%	30.9%	52.8%
Total	Count	1579	923	2502	
	% within Location of Lesson	63.1%	36.9%	100.0%	
	% within Class or Individual interaction	100.0%	100.0%	100.0%	
	% of Total	63.1%	36.9%	100.0%	

What this table illustrates is the total numbers (counts) and percentages of whole class and individual interactions within each of the two teaching contexts, as well as as a percentage of the total.

The results of the chi-squared test appear in Table 28

Table 28: Chi Squared Test Results - Location of Lesson and Scale of Interaction

TEST RESULTS			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	564.717 ^a	1	.000
Continuity Correction^b	562.746	1	.000
Likelihood Ratio	605.632	1	.000
Linear-by-Linear Association	564.491	1	.000
N of Valid Cases	2502		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 435.31.			
b. Computed only for a 2x2 table			

The footnote 'a' in the table above shows that once again the assumption regarding the minimum expected frequency has not been violated in this test.

The chi-squared value for this test is 564.7, but as this is a 2 x 2 table (each variable has only two categories), we need to use Yates' Correction for Continuity, which compensates for the overestimate of the chi-squared value in a 2 x 2 table (Pallant, 2007). Thus, the value we need to use is that under 'continuity correction' above, viz. 562.746. Its associated significance level of 0.000 is smaller than 0.05, thus we can conclude that our result is significant: there is some association between the location of the lesson and the scale of interaction.

The reason for this association is primarily due to the following statistics that can be read off from Table 27:

- significantly more of all the individual interactions take place in the computer lab (83.9%, against only 16.1% in the traditional lessons), and
- substantially more of the whole class interactions occur in the face-to-face classroom (nearly two-thirds (65.3%) of all the whole class interactions).

In order to determine the effect size, one needs to consider the phi coefficient from the table below. The phi coefficient is a type of correlation coefficient and ranges between 0 and 1, with higher values indicating a stronger association between the two variables.

Table 29: Phi coefficient – Location of Lesson and Scale of Interaction

TEST RESULTS			
		Value	Approx. Sig.
Nominal by Nominal	Phi	.475	.000
	Cramer's V	.475	.000
N of Valid Cases		2502	

The phi coefficient value of 0.475 (see Table 29) represents a large effect (Pallant, 2007). Thus, there is a strong association between the location of the lesson and the amount of interaction with the whole class as opposed to individuals.

This is to be expected, as within the computer lab the majority of every lesson revolved around the pupils working individually on tasks, one pupil per computer. Other than when the teacher needed to alert the whole class to a general problem he or she had noticed, or needed to instruct them all to do something, the interactions typically involved the teacher giving academic or other assistance to individuals.

5.3.2.4. The Relationship between the Type of Talk and the Scale of Interaction

The cross tabulation table produced by this analysis is shown in Table 30:

Table 30: Cross Tabulation Table –Type of Talk and Scale of Interaction

			Type of Talk					Total
			Feedback	Statements	Instructions	Questions	Explanations	
Class or Individual interaction	Whole Class Interaction	Count	23	170	217	522	647	1579
		% within Class or Individual interaction	1.5%	10.8%	13.7%	33.1%	41.0%	100.0%
		% within Type of Talk	27.1%	88.5%	49.1%	63.2%	67.6%	63.1%
		% of Total	.9%	6.8%	8.7%	20.9%	25.9%	63.1%
	Individual Interaction	Count	62	22	225	304	310	923
		% within Class or Individual interaction	6.7%	2.4%	24.4%	32.9%	33.6%	100.0%
		% within Type of Talk	72.9%	11.5%	50.9%	36.8%	32.4%	36.9%
		% of Total	2.5%	.9%	9.0%	12.2%	12.4%	36.9%
Total	Count	85	192	442	826	957	2502	
	% within Class or Individual interaction	3.4%	7.7%	17.7%	33.0%	38.2%	100.0%	
	% within Type of Talk	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
	% of Total	3.4%	7.7%	17.7%	33.0%	38.2%	100.0%	

What this table illustrates is the total numbers (counts) and percentages of each category of 'teacher talk' within each of the two different scales of interaction, as well as as a percentage of the total.

The results of the chi-squared test appear in Table 31.

Table 31: Chi Squared Test Results - Type of Talk and Scale of Interaction

TEST RESULTS			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	146.396 ^a	4	.000
Likelihood Ratio	153.648	4	.000
Linear-by-Linear Association	14.457	1	.000
N of Valid Cases	2502		
a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 31.36.			

As in both previous tests, the footnote 'a' in the table above shows that the assumption regarding the minimum expected frequency has not been violated in this test.

The chi-squared value for this test is 146.396, with an associated significance level of 0.000. As this significance value is smaller than 0.05 we can conclude that our result is significant, which means that there is some association between the type of talk used in the lesson and the scale of interaction. This association is due to the fact that, as shown in Table 30, the percentage of teacher talk in all categories except instructions varies dramatically across the scale of interaction. For example:

- nearly nine out of every ten statements (88.5%) are made to the whole class, and
- nearly three out of every four pieces of feedback (72.9%) are given to individuals, and

- 67.6% of all the explanations are made to the whole class.

In order to determine the effect size for a crosstab table like this, one needs to consider the Cramer's V coefficient from the table below. This coefficient is a type of correlation coefficient and ranges between 0 and 1, with higher values indicating a stronger association between the two variables.

Table 32: Cramer's V coefficient – Type of Talk and Scale of Interaction

TEST RESULTS			
		Value	Approx. Sig.
Nominal by Nominal	Phi	.242	.000
	Cramer's V	.242	.000
N of Valid Cases		2502	

The Cramer's V coefficient value of 0.242 (see Table 32) represents a medium to large effect (Pallant, 2007). Thus, there is a moderate to strong association between the type of talk used in the lesson and whether the interaction is with the whole class or just individuals.

An analysis of the tallies found in Tables 21 and 22 indicate the reason for the chi-squared test producing this conclusion: when dealing with individuals there was a far higher percentage of feedback and instructions, and a much lower percentage of statements. The former could perhaps be caused by the teachers preferring to praise and/or correct individuals privately rather than in front of the class and because of the increased number of individual IT instructions as a means of assisting pupils struggling with the use of the computers. The latter could be because the teachers generally made statements providing general information to the whole class rather than individuals.

5.3.2.5. Conclusions

All three chi squared tests above are significant, showing at least a medium to strong association between any two of the three variables; location, talk type and scale of interaction. This clearly illustrates, most importantly, that there is a considerable difference between what happens in the conventional classroom compared with the computer lab. Not only are the verbal utterances significantly different but so also is the scale of interaction. These statistical tests thus corroborate what was clear simply by looking at the contingency tables (see my analysis earlier in this chapter).

5.3.3. Extracts from Lessons illustrating Variation in Semiotic Mediation across Different Teaching Contexts

This section provides various verbatim extracts from observed lessons that illustrate the variations in semiotic mediation between Mathematics lessons in the traditional classroom compared with the computer lab that were identified in the previous two sections.

In the computer lab lessons, a striking finding is that over a quarter (27.4%) of all the verbal interactions were directly related to the use of the computers, either through explanations or instructions on IT usage, or IT related questions. The majority of these interactions revolved around logging-on issues or the precise use of the computer software.

Two extreme examples of an IT-dominated lesson are shown below in Extracts 1 and 2. These extracts are both taken from a 20 minute period of Grade 11 class time in the computer lab in which every single interaction revolves around IT rather than Mathematics.

Extract 1 is from the first part of the lesson and shows the one-sided communications from the teacher as he assists the pupils to log onto the Plato software programme and choose the correct Mathematics assignment.

Extract 1

1 **Mr Mhorah:** So for now, let us log into the programme. Then we try to
2 move fast on the first part that you have done, so that at
3 least we will get to new work, maybe within 5 minutes, so
4 that we can continue.
5 Remember, the group name is in capital letters and your
6 user name is in small letters and your password must
7 also be in small letters. There you have our last
8 assignment there, and you try to move fast through your
9 work today, in less than 5 minutes please.
10 *(Addressing a classroom assistant off camera)* You may
11 also assist us.
12 *(Camera resumes after brief break)* ...your surname and
13 initial, not space. The group name is cosat11, then your
14 password is your own secret. Cosat11. No space please.
15 Please, do we have some who are still not registered?
16 We are all registered?
17 *(To student in row C who is having an issue)* What is it?...
18 If it asks you to for that... I think it is 10002. Then submit.
19 Then your log in name.
20 *(To another student)* What is it? Those are the things you
21 will have to... so it started from where you had visited...
22 so at least you can start from there.
23 *(To the next student)* Is it the beginning? The very first
24 stage? Or maybe...
25 *(Addressing the whole class)* People, when we log on, if
26 you want maybe to look at the next exercise. If you log on
27 and you go to the last assignment, the Grade 11
28 assignment, the trig assignment. On the trig assignment,

29 if you click there, there must be right angles on top. Is it
30 so? There must be right angles. If you click on the right
31 angles, what is on the right angles. Then, maybe, if you
32 want to go to the next activity, you can just go onto the
33 next activity. Are we together? You can just go to the
34 next activity.
35 *(To the first female student in the row)* Okay, that Grade
36 11 trig, click that one. Yes, so I am saying that these are
37 the identities and equations. We haven't done the
38 identities, so from the identities we will learn nothing. So
39 click on the right angles there.

The entire extract above is about IT: issues like logging on with group names and passwords (see lines 5 – 14) and finding the correct exercises to do (see lines 25 – 35). Mathematics doesn't come into it although, of course, the purpose of the IT discussions is to pave the way to get to the Mathematics (which did occur later in this lesson, shortly after the interactions presented in the above transcript).

Extract 2 (see below) is taken from a little later in the same 20 minute section of a Grade 11 lesson that deals entirely with IT issues. By this stage, the pupils have all logged on successfully, and the extract covers a conversation in which the teacher is trying to assist a pupil with the completion of a particular mathematical problem presented by the computer programme. The solution of the problem relies on the use of the Theorem of Pythagoras, and the pupil is struggling to find out how to take the square root of a number using the Plato programme (see line 3). As can be seen from the interaction (lines 4 – 23), the teacher also struggles to do this, eventually enlisting the aid of a visiting teacher to assist in solving the problem (lines 24 – 39).

Extract 2

- 1 **Mr Mhorah:** So we are now saying, square root of AB squared. Can
2 you try AB squared?
- 3 **Pupil:** How do I get a square root...?
- 4 **Mr Mhorah:** Is it, what about this, try this one? (*Points to the on*
5 *screen calculator*)
- 6 **Pupil:** This one?
- 7 **Mr Mhorah:** Yes, try that one.
- 8 **Pupil:** And then what, because it explains that on the calculator?
- 9 **Mr Mhorah:** Sorry, it's AB and then if you want a squared, say AB
10 then you want it to be squared. Let me just see...Okay,
11 remove this calculator here. Lets close it. Type in your
12 response AB is equal to... AB squared... try it. And that
13 one? Shift and this one. There it is. Remove that one
14 please. Remove that 8 then square it. Okay 2...
15 (*Continues to try to input the answer.*)
- 16 Can we move on? Put in AB, then shift and this one...
17 power two
- 18 **Pupil:** I normally click shift....
- 19 **Mr Mhorah:** Yes, you just did two. Okay. Then you are saying it is
20 minus what?
- 21 **Pupil:** AC

22 **Mr Mhorah:** Minus AC. Squared. Try again. Square that. So I think
23 for this one, how do the do this one?
24 Sir, (*speaking to a visiting teacher*)...can you just come
25 here? ...That is the correct answer but the programme is
26 not accepting it. You see what, we want to find BC ...
27 BC. So we want the square root of B...A... B squared
28 minus AC squared.

29 **Visiting teacher:** I think as you did before it's the exponential.

30 **Mr Mhorah:** It is not giving us that option now.

31 **Visiting teacher:** Um, can you use the calculator, maybe?

32 **Mr Mhorah:** The calculator also...

33 **Visiting teacher:** This is exponential here.

34 **Pupil:** See... how to put that AB, BC into the calculator

35 **Visiting teacher:** Yeah, yeah I see what you mean. And did you try
36 parentheses? (the visiting teacher attempts to type the
37 calculation into the programme.) Try it like this? (*This
38 managed to solve the problem and the pupil was able to
39 continue with the next problem*)

This high percentage of IT usage interactions as illustrated by Extracts 1 and 2 can perhaps be explained, at least in part, by the fact that the pupils of the school being observed had not used the Plato programme for nearly a year, due to issues around computer room access and problems with the software itself. This point was elaborated on by Mrs Cupido who, in her post-observation interview, said that the lessons I observed in the computer lab were amongst the first in a long time and that “if [the Plato programme] had to be used regularly it would have been different ... [in that] they [the pupils] would have known exactly what to do and they wouldn’t have to work on prompts from the teacher for small little things like forgetting passwords”.

It can be expected therefore, that the percentage of IT related interactions will decrease significantly as technical and usage issues were resolved once and for all. Certainly, this development would be critical, because otherwise far too much valuable potential learning time is being lost in this way. It is pertinent to add at this point that, in the post-observation interviews, both teachers indicated that they felt that one of the major problems with using ICT to teach Mathematics is that it simply takes up too much time and that it would make it impossible to complete the syllabus if too much time was spent in the labs. A significantly reduced percentage of interactions directly related to the use of the computers would allow pupils to be able to make much more progress in each Mathematics lesson in the computer lab.

Hardman (in press) found, in a study of Grade 6 Mathematics lessons in computer labs in four previously disadvantaged primary schools in the Western Cape, that “teachers focus primarily on teaching children the technical skills required to engage with the computer...What becomes clear is that the instructional object of the computer lesson is in fact the development of students’ technical skills and knowledge around computer use rather than the development of mathematical understanding.” (p. 12).

My findings, in a slightly different context due to it being a selective high school, albeit still in a disadvantaged area in the Western Cape, do not corroborate this. Although, as has been mentioned above, a high proportion

(27.4%) of verbal interactions and thus class time in the labs is spent on computer issues, this time was aimed at facilitating the use of the computers for Mathematics, and the object of the lesson was definitely to improve mathematical understanding and not simply computer skills. This observation is illustrated in Extracts 1 and 2 above: in Extract 1, the verbal interactions are primarily concerned with logging onto the computers, while in Extract 2 they are primarily about how to enter a particular mathematical function (the square root) correctly. The purpose of these interactions was not to teach the pupils how to use a computer per se, but rather so that they could make progress with mathematical learning *on* the computer.

One of the substantial differences between lessons in the classroom and those in the computer lab are the far greater percentage of instructions in the latter. In the instructions category there are three sub-categories: department; academic (Mathematics) and academic (IT). It is the preponderance of the latter type of instruction that is the primary reason for the much higher percentage of instructions in the computer lab.

In Extract 3 below, we see Mrs Cupido speaking to the Grade 12s near the beginning of their lesson in the computer lab. The five minute period covered by the extract is totally dominated by instructions; mostly to do with IT – see, for example, the series of IT instructions in lines 10–17 and 23–26.

Extract 3

1 **Mrs. Cupido:** So if you go to the Plato site... (*Students begin to log in*
2 *and Mrs. Cupido looks on and assists*)
3 (*about 50 seconds later Mrs Cupido continues*) They are
4 asking for an account number - try 1002. And I hope you
5 have written down your Plato log-in because I see some
6 confused faces looking at me... You wrote it down
7 somewhere, so you should have it... Come, quickly! 12M.
8 (*10 second pause*) Okay, who has the assignments
9 already? Now you see that a new assignment has been
10 added: it's Grade 12 mathematics. Open that, click on
11 there and then you see geometry, trigonometry and
12 trigonometry with assessments. So, go to the
13 trigonometry with assessments. Let's see what's in there.
14 No, that's not it - just the trigonometry, not the
15 assessments. Let's leave the assessments for now. Go to
16 the trigonometry quickly - the second last one says: laws
17 of sines and cosines. That is where I want you to go - you
18 need to do the tutorial. So, the very first one is the tutorial.
19 Okay, I'll repeat it again. You do Grade 12; Grade 12
20 mathematics.
21 (*addressing students in Row A*) Are you ready for me? I
22 can't help you if you forgot your password (*other pupils*
23 *laugh*). Okay, stay with me here. You go to Grade 12
24 mathematics, then you go to trigonometry, and then you
25 go to the second one - "Trig Identities and Equations" -
26 and then you go to "The Laws of Sines and Cosines".

Another significant difference between the lessons in the classroom and the computer lab is that the former is dominated by whole class teaching and the latter by individual assistance. In Extract 4 below, taken from midway through a Grade 10 computer lab lesson, one can see a typical set of individual interactions between Mr Mhorah and one pupil.

Extract 4

- 1 **Pupil:** Sir, when you are using Pythagoras and you want the
2 length of this line (*points to screen*), do you have to
3 change the sign?
- 4 **Mr. Mhorah:** To achieve what?
- 5 **Pupil:** Sign and ... (*voice trails off*)
- 6 **Mr. Mhorah:** No, you do not have to change the sign, because when
7 we are using Pythagoras there we are just looking for the
8 length of what? For example that is just a triangle - can
9 you see it? We cannot have a negative in a triangle. You
10 get it?
- 11 So... can you ask your question again properly?
- 12 **Pupil:** Lets say, if I want this side of the triangle and I'm given
13 these two other sides, then I say I must not... subtract the
14 two numbers...
- 15 **Mr. Mhorah:** We are going to subtract them.
- 16 **Pupil:** Ok
- 17 **Mr. Mhorah:** Because, you see what, it is actually coming from here.
18 (*begins to write the following on paper as he states it*)
19 Where you are saying hypotenuse squared is equal to
20 adjacent squared plus opposite squared.
21 Can you see it? So when you are given this one and this
22 one... so you want this one. Can you see it?
- 23 **Pupil:** Yes
- 24 **Mr. Mhorah:** If you want this one, you are going to make this one the
25 subject. You get it? So this one moves to this side which
26 makes it?

- 27 **Pupil:** Negative
- 28 **Mr. Mhorah:** Negative, so it will be “h” squared minus “a” squared is
- 29 equal to “o” squared. That is why we are subtracting.
- 30 Can you see it? Alright.

The above extract, which illustrates the teacher interacting with individuals, can be contrasted with Extract 5 below, taken from another of Mr Mhorah’s Grade 10 lessons, but this time in the conventional classroom. This 6 minute set of interactions, typical of most of the lessons in this context, involves entirely whole class teaching. Even the questions that Mr. Mhorah asks are asked in such a general fashion that, barring the question answered by Lwazi (see lines 63-65); all the questions are answered in unison by the majority of the pupils. The topic that they are covering is Transformations, and this extract about Reflections follows on from a discussion about mirror lines.

University Of Cape Town

Extract 5

- 1 **Mr. Mhorah:** For reflection we also need to have a rule that we use for
2 reflection. Are we together? To derive that rule we have
3 our point A, can you see it? (*points to the board on which*
4 *is written A (-3; 4) and A' (-3; -4)*) It is moved to A dash.
5 What has changed from A to A dash?
- 6 **Pupils:** (*in unison*) The side.
- 7 **Mr. Mhorah:** Which side?
- 8 **Pupils:** (*in unison*) y...
- 9 **Mr. Mhorah:** The sign of y has changed. What is the mirror line? The x
10 axis. Are we together. So we are saying, our mirror,
11 okay...(*writes "Reflection with x axis as the mirror line" on*
12 *the board.*) Okay, we want to see reflection so we are
13 saying Point A is our object—is that okay?—and this is
14 our image—A dash. So our object was what? (-3; 4). Our
15 image? (-3; -4). So what are we saying that has
16 changed?
- 17 **Pupils:** (*in unison*) The sign of y.
- 18 **Mr. Mhorah:** The sign of y. So let's make another point again, so that
19 you may watch. Alright. Let us have our other point that
20 we want to construct. I want to put, maybe, another point
21 here (*points to the board*). And I label that point—let me
22 label the point as B. Can you see it? Here is my point. Are
23 we together? Then we want to reflect our point B on the x
24 axis again. Can you see it? We want to reflect it on
25 the...?
- 26 X axis (*stated in unison with the pupils*). So I go to
27 transform, then reflect. Are you seeing where the image is
28 now?
- 29 **Pupils:** (*in unison*) Yes
- 30 **Mr. Mhorah:** Let me label this point. It is now B dash. My object is B,
31 my image...?
- 32 **Pupils:** (*in unison*) B dash.

33 **Mr. Mhorah:** Okay, so my object is... what are the coordinates of my
34 object.

35 **Pupils:** *(in unison)* (5; -2).

36 **Mr Mhorah:** And my image?

37 **Pupils:** *(in unison)* (5; 2).

38 **Mr Mhorah:** What has happened? What has changed?

39 **Pupils:** *(in unison)* The sign of y

40 **Mr. Mhorah:** Sign of what?

41 **Pupils:** *(in unison)* y

42 **Mr. Mhorah:** Are the numbers changing?

43 **Pupils:** *(in unison)* No

44 **Mr. Mhorah:** The numbers are not changing. Can you see it?

45 **Pupils:** *(in unison)* Yes.

46 **Mr Mhorah:** So, can we conclude or do you want us to have another
47 example. Can we conclude?

48 **Pupils:** *(in unison)* Yes.

49 **Mr. Mhorah:** But what if we have the wrong equation there?... *(pupils*
50 *laugh.)*

51 Okay, I think let us conclude from there. Let us conclude
52 from there. So, we are saying if our coordinates of the
53 object are (x; y), what will be our coordinates of the
54 image.

55 **Pupils:** *(in unison)* (x; -y)

56 **Mr Mhorah:** It will be (x; -y). Can you see it?

57 **Pupils:** *(in unison)* Yes.

58 **Mr. Mhorah:** This is what we are concluding. So, in general, let me
59 now put the rule here. *(writes the following on the board*
60 *as he states it)* In general, if the x axis is the mirror line,
61 then reflection is given by the rule (x; y) is mapped onto
62 (x; -y).

63 So whenever you see the object and the image satisfying
64 this condition then you must know that this is reflection.

65 If I may ask you, next time when you see this rule, how do
66 you know that this is reflection in the x axis (*many pupils*
67 *answer in chorus*).

68 Let us raise our hands please and say out our answers.
69 Ah, Lwazi?

70 **Lwazi (pupil):** x doesn't change, y changes sign.
71 **Mr. Mhorah:** It's only x that is...
72 **Pupils:** (*in unison*) Not changing
73 **Mr. Mhorah:** That is not changing, but the y is?
74 **Pupils:** (*in unison*) Changing sign.

University Of Cape Town

Extracts 4 and 5 above do illustrate a very typical pedagogical approach adopted by Mr. Mhorah that does not vary much between the classroom and the computer lab: his tendency to ask closed questions that require only one word or one phrase answers (see for example, lines 4-5, 7, 15 and 27-28 in Extract 5). The downside of this typical manner of teaching by Mr. Mhorah is that the lesson is highly directed. Wood (1994) identifies this pattern of interactions as being a funnel pattern, in that there is not much room for the pupils to provide differing answers; they are 'funnelled' into giving the answer the teacher wants. This, Wood (1994) believes, will significantly reduce the chance that the pupils will engage in meaningful thinking of their own.

However, the upside is that these questions, closed though they are, allow the pupils to get some access to talk time and therefore to participate in the lesson, which is unusual in many South African township schools (Hardman, in press). In addition, the simple closed questions are used as a tool to guide the pupils through the process of deriving a concept that was new to them. In this way, the questions did assist somewhat in mediating new understanding and providing a bridge between what was known and what was unknown. For example, in Extract 5 what was known was the concept of what a reflection was (this had been covered in a previous year), and what was not known was the rule for reflection of an object in the x-axis (reached in lines 54-57). The questions seem to have helped the pupils move through the Zone of Proximal Development, though this is uncertain as they were not tested on their understanding of these concepts in this lesson.

5.3.4. How the Teachers used the Computer as a Teaching Tool

Before illustrating how the teachers at School A used the computer as a pedagogical tool in their Mathematics classes, I wish to re-iterate the difficult conditions that they are operating under, with regard to lack of formal computer training (see Section 4.4.2.2) and computer lab access (see Section 5.2.6.1). If this is the trying situation faced by teachers in a best-case school

such as this one, just imagine what it is like for teachers in a more typical township high school.

In comparing the teaching in the conventional Mathematics classes compared with the computer lab classes, an important question to ask is whether the use of the computers added anything new to the lesson and/or whether there were any teaching strategies observed that were not found in the conventional classroom. The answer, based on my 10 hours of observations, is that very little, if anything innovative was added due to the availability and use of the computers. As shown in some of the extracts in the sections above and below, some of the computer questions did stimulate some interesting discussions and scaffolded learning experiences, but there is no reason why similar questions in a textbook might not have created the same type of interactions.

So, how did the teachers use the computers as a tool to mediate understanding? For the most part, the lessons continued as though it was a conventional classroom, except for the fact that the questions that the pupils were working on individually were being generated by the Plato Mathematics software programme rather than taken straight out of a textbook. The management of the classroom was somewhat different in that, as has been mentioned above, considerably less whole class teaching time, and a far greater number of individual teacher/pupil interactions took place in the computer lab.

However, it seemed as though the computer nonetheless merely acted as an electronic textbook; albeit with interesting graphics and instant identification of errors so that the pupil could move on only if the correct answer was entered. This use of the computer as nothing more than an on-screen textbook is clearly illustrated in extracts from two computer lab lessons, presented in the next section: Extract 6 (the book club example in Mrs Cupido's class) and Extract 7 (the pyramid's height example in Mr Mhorah's class).

Indeed, the teachers were not observed at any stage using the computer as a mediation tool in any way other than as a screen-based textbook. The Plato

programme was almost exclusively used as a means of supplying questions for the pupils, in a form of drill and practice; thus the fullness of opportunities for the use of the computer as a teaching tool were not utilised in the lessons observed.

Very seldom did I observe the teachers using the computers to deepen the pupils' understanding of concepts, in my opinion mainly due to the way the Plato software is designed (viz. as a Computer Assisted Instruction tool), though it may also be due to the inability of one or both of the teachers to initiate such higher-order discussions, or the inability or lack of desire of the pupils to look beyond superficial understanding.

This is not to say that the computer lessons were wasted, however, as in informal comments at the end of some of the lessons, the pupils indicated that they had thoroughly enjoyed their time and had benefited from the different question styles used by Plato and the opportunity to revise sections of work to see how much they knew.

In all six computer lab lessons that I observed, the software programme was used to assist the revision of previously taught material rather than to introduce them to new topics. This perhaps confirms the previous finding of Hardman (2005a) who stated that "the assumption underlying computer use in schools is that the computer will be used as a cognitive tool to impact on student's performance. Consequently, the object of the computer-based Mathematics lesson is assumed to be students' scientific (mathematical) concepts. However, findings from interviews with teachers indicate that teachers believe that the object of the computer lessons appears to be lower order cognitive skills (such as drill and practice) rather than the anticipated higher order conceptual development promised by the novel technology" (p. 264).

The questions provided by Plato needed to be completed on paper and then the answer typed into a block on the computer screen. The computer then gave immediate feedback through indicating whether the answer was right or

wrong. A pupil is not able to progress from one screen to the next until the correct answer had been placed in the block. This had the positive effect of slowing the pupils down and ensuring that they did not simply rush ahead with their work. Ideally, any misunderstanding or lack of comprehension needed to be dealt with at each step of the learning process, and both teachers frequently emphasised to the classes the importance of *understanding why* the answer was correct before moving on to the next screen.

However, the problem is that if a pupil punches in an incorrect answer the computer gives the correct one, so a lazier or less able pupil could circumvent the learning by simply punching in a wrong answer and then, straight afterwards, the correct answer as supplied by the software! Mr Mhorah felt that this did happen in his classes, and said that some pupils “will just punch in the correct answer from the computer without trying to determine why this is the correct answer... so I can say, the computers here and there are prone to misuse if [pupils] have no direction”. In my own observations of the classes at work, though, I did not notice such lazy behaviour very frequently, and instead noticed just how hard the majority of the pupils were trying to understand the work.

During the computer lab lessons, the teachers continually circulated the room to check that pupils were remaining on task and to assist pupils that were stuck. It is clear that they were not relying on the computer software alone to instruct the pupils and, indeed, they were usually kept very busy aiding pupils who were struggling with the use of the ICT or with the Mathematics. This was similar to the pattern observed in the conventional teaching classroom when the pupils were completing individual exercises from their textbook and again indicates the common pedagogy between conventional classroom and computer lab.

What is interesting is the way in which Mrs Cupido saw her role in the computer lab. She felt that in the conventional classroom she was the centre of attention, “but in the computer lab, then I have to keep a distance, because the [pupils] are interacting with the computer and the software there....So

there the computer is the centre of attention ...not me....It is them engaging with the software in this computer lab". She clarified later that she obviously was available to help if pupils were stuck or did not understand something, but it was clear her goal was mainly to be in the background.

In their post-observation interviews, both teachers felt that their pedagogy (teaching style) had been influenced by the availability of computers in schools. However, most of the examples they gave to back this up revolved around practical issues with the use of the computer and Starboard in the face-to-face classroom. For example, Mr Mhorah spoke about how the Starboard has ensured that he uses more and more accurate diagrams in Mathematics lessons than before, while the computer's storage capacity has meant that it is easier for him to set assignments and assessments for his classes. Mrs Cupido said that for her the computers were "just another tool to get to the same outcome", the outcome being the academic progress of the pupils. From their answers to the question on changed pedagogy and my observation of their computer lab lessons, it seems that the advent of computers has not produced a consequent change in teaching methods – other than the fact that Mrs Cupido tried to remain more in the background in the computer lab than the traditional classroom.

Both teachers I observed indicated in their post-observation interviews that although the computer was a valuable tool to assist pupils it took a very long time for the pupils to make much progress using it, and thus that it was not ideally suited to use to teach new material from scratch as, if that method was chosen, there was no way the syllabi would be completed on time. In his interview, Mr Mhorah went so far as to say that "what you can teach in five minutes [in a traditional classroom] can be done in maybe an hour when we are using Plato". Mrs Cupido concurred by stating, "it is time consuming. The pupils need a lot of time in the computer room for a particular topic if they are going to master it".

They felt that its greatest benefit was in the area of reinforcement of known knowledge (by assisting pupils with their revision), and to allow them to self-

study sections they missed for some reason or other. There are plans afoot for pupils to gain access to the computer labs after school and possibly also on Saturday mornings so that they could use Plato for these ends.

5.3.5. Extracts from Lessons illustrating the Manner of Use of the Computer

In Extract 6, taken from midway through a Grade 12 lesson in the computer lab, Mrs Cupido is assisting a pupil who is struggling with a word problem presented on the computer. The way she handled the discussion is an illustration of how simplifying the question by breaking it down aids pupil understanding.

University Of Cape Town

Extract 6

- 1 **Mrs Cupido:** Ooh, you don't like the word problems, neh? (*reads the*
2 *following question off the computer screen*) You have
3 joined a Science Fiction book club. As a new member,
4 you receive 8 books free. You must purchase a book
5 every 4 months. After x years (x is an integer) you have
6 received a total of $T(x)$ books from the club. Give an
7 equation for the function $T(x)$ in terms of x .
8 So, now, you see, this is now something which you don't
9 know where to start. Let me see if I can find it. I know if I
10 start I start with, say, year 0... I haven't done any years,
11 right? Um...how many books will I have?
- 12 **Pupil:** 8 books.
- 13 **Mrs Cupido:** 8 books, right! ... (*voice inaudible*)
14 Now, you must purchase one book every 4 months. So,
15 in one year, how many books would you have?
- 16 **Pupil:** 8 times 3 = 24.
- 17 **Mrs Cupido:** No, 8 times 1, what did you say?
18 (*Pupil's response is inaudible*)
- 19 **Mrs Cupido:** You see, this is how the club works. You get your 8
20 books free when you join, but then you must pay. You
21 have to buy a book every 4 months and you pay for the
22 book that you buy. So how many books would you have
23 ordered in one year?
- 24 **Pupil:** 8 books.
- 25 **Mrs Cupido:** No, no, not 8 books. Think about it. Every 4 months, I
26 must buy one book. So let's say you start the club at the
27 beginning of January. How many books do you have?
- 28 **Pupil:** 8 books.
- 29 **Mrs Cupido:** Now for the rest of the year, you are going to buy a book
30 every 4 months. So how many more books will you buy
31 for that year?

32 **Pupil:** 6 books, I mean 2 books.

33 **Mrs Cupido:** Not 2.

34 **Pupil:** 6?

35 **Mrs Cupido:** Every 4 months? Just think about it - it's very simple; it is
36 just a basic, basic problem. At the end of April you would
37 buy another book, at the end of August you would buy
38 another book, at the end of December you would buy
39 another book. So how many books would that be?

40 **Pupil:** 3 books?

41 **Mrs Cupido:** 3 books. So, for the first year, now you have $t=1$ would
42 be 8 plus the 3 books. Okay, but if you want to write it in
43 terms of the sub... (*inaudible*)... now T_2 (*representing the*
44 *second term*) what would that be?

45 **Pupil:** 8 plus 3 plus 3.

46 **Mrs Cupido:** You see, you get it now! But now, what they want you to
47 realize is that the number of years is x . That is what they
48 are saying - after x years. So if you look at the screen;
49 that would be times one. So x is 1 in this particular case.
50 And here your x is 2, in this particular case, because it is
51 2 years. So actually I can say that I have $3x+8$ as my
52 function. Does that make sense? Read the problem
53 again and think of a similar problem and make sure you
54 understand. (*Teacher moves on to a new pupil*).

In the above extract, it is clear that the pupil was struggling to understand the question, which was to determine function relating the number of books obtained in a time period of x years (see lines 2 - 7). Mrs Cupido tries to assist the pupil by providing a scaffolded learning experience. First, she brings the discussion down to the number of books the person would receive in only 1 year (lines 14 – 15). As the pupil still struggled to work this out (he gave four consecutive wrong answers; in lines 16, 24, 32 and 34), Mrs Cupido simplified her explanation even further by breaking it down to specific months of the year that the books might be received (see lines 35 – 39). Ultimately this simplification process enabled the pupil to offer correct answers relating to the number of books the person would have after one and two years (see lines 40 and 45), although interestingly Mrs Cupido provides the pupil with the full function answer (see lines 51 - 52) when it is unclear whether he had sufficient understanding to be able to generate this himself.

In this interaction, the teacher was assisting the pupil to move through their Zone of Proximal Development, by simplifying the question further and further until it was accessible to the pupil's ZPD. The teacher, through the careful use of questions, in effect provided a bridge between what was known by the pupil and what was unknown.

Wood et al. (1976) identifies the scaffolding approach of Mrs Cupido in this instance as bringing about a 'reduction in the degrees of freedom'; in other words, simplifying the task so that it could be understood by the pupil. Bliss et al. (1996) calls the step-by-step series of questions that Mrs Cupido provides, 'foothold scaffolds'.

Another scaffolded learning experience can be seen in Extract 7 below, taken from midway through a Grade 10 lesson in the computer lab. It involves the teacher aiding a pupil in understanding a word problem relating to how the ancient Egyptians were able to determine the height of the pyramids they had built by comparison with its shadow, given a short stick of known height that cast a measurable shadow.

The key to the problem is an understanding of ratio: the ratio of the shadow of the stick to the stick height is equal to the ratio of the shadow of the pyramid to the pyramid height.

Extract 7

- 1 **Mr Mhorah:** Can you read the problem to me?
- 2 **Pupil:** *(reads the problem as it appears on the computer screen)*
- 3 If the 3 feet walking stick casts a 5 feet shadow, and the
- 4 length of the shadow from the centre of the pyramid is
- 5 330 feet, what is, in feet, the height of the pyramid?
- 6 **Mr Mhorah:** So we are saying 3 feet of walking stick. Casts what?
- 7 How long is the shadow?
- 8 **Pupil:** 5 feet.
- 9 **Mr Mhorah:** 5 feet of shadow. *(he draws a triangle diagram on paper*
- 10 *to illustrate the stick and shadow)* So, this shadow, can
- 11 you see it? Then this is our stick. We are saying that a 3
- 12 feet stick casts a shadow of how many meters?
- 13 **Pupil:** 5 feet.
- 14 **Mr Mhorah:** Of 5 feet. Okay, move on.
- 15 **Pupil:** *(reading off the computer screen)* ...and the length of the
- 16 shadow from the centre of the pyramid is 330 feet
- 17 **Mr Mhorah:** Okay, the length of the what?
- 18 **Pupil:** The shadow.
- 19 **Mr Mhorah:** Okay, so we are saying, if 3 gives you 5, or if 5 gives you
- 20 3, what about 330? Is it supposed to give you more or
- 21 less?
- 22 **Pupil:** Less.

23 **Mr Mhorah:** Is it going to be less?³ Let me ask you, if one loaf of
24 bread cost 15 rand, Is that okay? Two loaves, are they
25 going to cost less or more?
26 **Pupil:** More.
27 **Mr Mhorah:** They are going to cost more. Is it okay? Let me ask you
28 another question, if 5 rand buys one loaf is 15 rand going
29 to buy less or more?
30 **Pupil:** More.
31 **Mr Mhorah:** It is going to buy more. That is the same idea that we
32 have here. So, is the pyramid height going to be more or
33 less than 330?
34 **Pupil:** It can be less, sir.
35 **Mr Mhorah:** It will be less. Are we together? So it will be...330 over 5
36 times 3. That is why here you've got ... where is it?
37 (*points to answer provided on computer screen as states*)
38 330 over 5 times 3. Can you see where that proportion is
39 coming from? Let it not just be a number that you... It is
40 actually coming from what you learned previously about
41 the proportions. You get it? Alright.

³ It seems that the teacher is in error here, because the correct answer is indeed 'less' (the answer for the pyramid height is less than 330). However, I have left the extract in the text as it is a good illustration of utilizing everyday concepts to explain scientific concepts.

The mediation in the ZPD in the above extract is focussed on the development of conceptual knowledge. Mr Mhorah, early on in the interaction, ascertained that the student did not have an understanding of how to obtain the answer that the question was asking for (in Vygotskian terminology, the student lacked an understanding of the scientific concept illustrated by the question). What the teacher did to assist in the development of this understanding was to utilise everyday concepts: he asked simple questions about concrete experiences about which the student would have had some understanding viz. the use of the examples of the cost of different numbers of loaves of bread (see lines 22 – 31). By connecting the subject matter knowledge to the teenager's lived experience in this way, he was able to make the concepts more personal and meaningful and thus also understandable.

This series of interactions could also be considered an example of the Level 2 scaffolding technique named by Anghileri (2006) as 'parallel modelling'. This is because the teacher has created and solved a task that shares some of the characteristics of the pupil's problem, so that the pupil might be able to solve the original problem.

It is important to note again, however, that despite the encouraging scaffolded teaching techniques witnessed in the computer lab lessons (as demonstrated in Extracts 6 and 7 above), there is no reason why an identical discussion could not have ensued if the question had been presented in a textbook rather than on a computer screen.

No examples were available from any of the five computer lab lessons observed that indicated a use of the computer in any way other than a drill-and-practice tool or an electronic textbook.

5.4. Discussion

5.4.1. Quantitative Findings: the Impact of Computers on Mathematics Performance

My findings regarding the impact of computers on academic performance in Mathematics are uniform. Whether one is looking at a before- and after-scenario regarding the availability of computers, or a comparison between schools with and others without computers; in neither case have my findings shown a significant change in Matric Mathematics results. Similarly, no significant changes were shown in the percentage of passes, nor in the percentage of Higher Grade candidates, before and after the Khanya intervention.

These findings contrast with the majority of previous studies which found a positive, beneficial relationship between the use of computers and Mathematics results – for example, the studies of Christmann et al. (1997), Waxman et al. (2002), Banerjee et al. (2005) and Harrison et al. (2004). My findings were more in line with the minority group that did not find a positive impact of computers on Mathematics results, such as Angrist and Lavy (2002), and Wong and Evans (2007). Some major meta-analyses of computers' impacts, such as those of Higgins (2001) and Tienken and Wilson (2007), agreed that whilst some studies have shown positive impacts other have shown none.

The closest study to mine, in terms of the location and scope of the study, is that of Louw et al. (2008), who studied the impact of the use of Khanya-provided MasterMaths remedial software on Matric Mathematics results of a small sample of schools in Cape Town. Their findings were slightly more positive than mine, but they nonetheless found “only equivocal support for the effectiveness of the intervention” (Louw et al., 2008, p. 49). Of great significance is their finding that the amount of time pupils spent using MasterMaths was significantly correlated with improved Mathematics results; in other words, the more time the pupils spent on MasterMaths the better were their results. As my study does not take into consideration how often on average the Mathematics software was used by the pupils of the schools in my

samples, and the small-scale telephonic survey I undertook would seem to indicate not very often at all, the failure to utilise the available computer software to teach Mathematics would most definitely help to explain the inability of my statistical tests to show positive correlations.

5.4.2. Qualitative Findings: the Impact of Computers on Semiotic Mediation

There has been minimal research into the impact of computers on semiotic mediation (teacher talk). The stand out work of Hardman (in press) in primary school (Grade 6) Mathematics lessons found that there was a statistically significant relationship between the type of language used and the lesson context (computer lab or traditional classroom). My findings, using a similar analytical framework, agree with hers in finding that in high schools there is also a statistically significant relationship between language and context. However, whereas she found that the instructional object of the Mathematics lessons she observed in the computer labs was to ensure that the pupils became better computer users, my findings were that the teacher talk around IT issues was aimed not at technical IT knowledge and skills but rather at ensuring that the pupils were able to engage effectively with the Mathematics software.

5.4.3. Qualitative Findings: the Importance of How Computers are Used

Past research has overwhelmingly shown that it is *how* the computers are used that will determine whether they have an impact on academic performance. For example, Noss and Pachler (1999) showed that if computers were used only for drill-and-practise, they would have little impact on pupil performance. Wenglinsky's (1998) findings corroborated this, finding that such use was negatively associated with academic achievement. However, when computers were used to teach higher-order concepts he found significant gains in mathematics achievement.

Wegerif (2004) suggested that if computer software generated only IRF type exchanges (I stands for initiation, R a response by the pupil and F feedback by the

computer) it would not have much impact. What was rather required was an IDRF exchange in which an additional component (D for discussion) was added.

What my observations in a case-study school showed was that the computers in the lab were primarily used in Mathematics classes for revision by means of loads of repetitive examples. This is akin to their being used for drill-and-practise. In addition, the exchanges produced by the computer software were almost entirely of the IRF style, with pupils typically working individually and silently through the problems generated by the Plato programme.

What these findings may provide is a further clue as to why the use of computers has not had the positive impact on Mathematics results as found by the majority of researchers: even when the Khanya computers *are* being used, they are used in a manner that will not bring about the desired level of improvement in Mathematics results.

On a more positive note, it was pleasing to note that the teachers at the case study school were reasonably well versed with the computers and the Plato software, and were motivated and skilled enough to use the computer-generated problems to mediate understanding. In particular, examples of the teachers providing scaffolding to enable the pupils to improve their understanding and move through the ZPD were noticed on a few occasions. Nonetheless, it remains true that the computer was at all times essentially used as an electronic aid, acting as little more than an on-screen textbook that provided immediate feedback (the marking of answers) and some interactive and graphics benefits.

5.5. Chapter Summary

This chapter presents the findings of this mixed method research project. The quantitative findings, aimed at elucidating the impact of computer usage on pupil performance, indicate that there is no statistically significant relationship between performance and computer usage in the schools sampled. It is important to note when considering this finding, however, that this study did not track how often the

computers were used by students. Further research in the area must include an investigation of frequency and consistency of computer usage; this was, however, beyond the scope of the current thesis.

The quantitative portion of the study threw up a number of challenges: most notably; given that computers do not appear to be impacting on performance, are they impacting on pedagogy? If so, how? This led to the qualitative investigation that sought to investigate how teachers use computers, and whether the computers impact on their pedagogical practices, through an analysis of teacher talk across contexts. Findings here indicate that teachers do indeed “talk” differently in the different contexts (the conventional classroom and the computer lab). Given that pedagogical practices impact directly on the pupils’ developing understanding of their world, we must anticipate that the impact computers have on pedagogy will filter through into pupils’ performance in due course. Again, this is an area suggested for future research.

University Of Cape Town

CHAPTER SIX

CONCLUSION

This chapter summarises the major findings of this research project, indicates some of the limitations of this study, and makes suggestions for future research into determining the impact of computers on Mathematics attainment in high schools in the Western Cape.

6.1. Summary of Findings

There were three main purposes for the research on which this dissertation is based:

- i. to test whether the Matric Mathematics results and enrolment at high schools in the EMDC East zone of Cape Town have been impacted by the availability of computers and mathematical software (as provided by the Khanya Project).
- ii. to determine whether pedagogy alters between the conventional classroom Mathematics lessons and those in the computer labs, with a focus on variation in semiotic mediation (teacher talk) between the two venues, in one school in the township of Khayelitsha, Cape Town.
- iii. to explore how teachers are using the computer as a tool to teach mathematics, at one school in Khayelitsha.

In particular, seven questions were posed and researched, in order to achieve the research purposes:

- i. Are Matric Mathematics results in EMDC East high schools that have Khanya computers better than those at EMDC East high schools without Khanya computers?
- ii. Have Matric Mathematics results in EMDC East high schools improved since the beginning of the Khanya intervention?
- iii. Did the Khanya intervention result in a higher pass rate in Mathematics in EMDC East high schools?

- iv. Did the Khanya intervention result in a higher percentage enrolment in Higher Grade mathematics in EMDC East high schools?
- v. Is there a variation in pedagogy between Mathematics classes in the computer laboratory and those in the conventional classroom, as evidenced by variation in semiotic mediation between the two locations in one school in Khayelitsha?
- vi. How do the Mathematics teachers at a school in Khayelitsha use the computers in the lab as tools to mediate mathematical concepts?
- vii. How does the qualitative follow up data help us to understand the quantitative first phase results a little better?

The first four questions were answered by statistical analyses of 2007 Matric Mathematics results of a sample of Khanya high schools in the EMDC East. In particular, a measure termed the 'mean student score', which essentially averaged the Mathematics grade score obtained by each Matric Mathematics pupil in the sampled schools, was used as the measure by which the first two questions were answered.

In order to answer the first question, a Mann Whitney U test was performed on an experimental group that had had a Khanya lab (and computers) for at least 4 years, and a control group that had had computers for (in most cases) a year or less. The results of the test showed no significant difference between the Matric Mathematics results of the two groups. Subsequently, four schools that had mean student scores that were outliers were removed from the groups and an independent samples t-test was applied to the new groups. This test again showed no significant difference between the Matric Mathematics results of the two (newly defined) groups, with a small effect size; thus the conclusion to Question 1 is that schools in the EMDC East with Khanya computers did not perform differently than those without.

To determine the answer to the second question, a paired samples t-test was performed on the Matric Mathematics results of a group of EMDC East schools, before and a few years after the Khanya intervention. What was ascertained was that there was no statistically significant change in the mean student scores before and after the Khanya labs were installed – in fact, a visual inspection of the results

show that the mean score actually declined after the introduction of the labs. Thus, certainly, Matric Mathematics results in the EMDC East have not improved since the Khanya intervention.

Using the same sample groups as for the second test above, further tests were performed to answer Questions 3 and 4. A paired samples t-test showed that there was no statistically significant change in the percentage of pupils that passed Matric Mathematics after the Khanya intervention, whilst a Wilcoxon Signed Rank test showed that there was no significant change in the percentage of pupils enrolled in Higher Grade Mathematics after the same intervention. So, there is a negative answer to the two questions as to whether the Khanya Project has brought about improved pass rates or increased Higher Grade Mathematics enrolment rates.

The results of all these tests thus produce a rather bleak picture of the apparent inability of the multi-million rand Khanya intervention to bring about the positive changes in Matric Mathematics results envisaged by the Project. As discussed in previous chapters, this research finding stands in contrast to the majority of the research that has gone before, in which a positive link was discovered between the use of computers and academic performance in Mathematics – see, for example, Christmann et al. (1997), Waxman et al. (2002), Banerjee et al. (2005), Blanton et al. (2006), and Barrow et al. (2007). It is important to remember, however, that there is not universal agreement of such a positive link: a number of studies into a link between Mathematics achievement and computer use failed to prove a positive link or, in some cases, actually showed the opposite – see, for example, Angrist & Lavy (2002), and Wong & Evans (2007).

The closest study to mine, in terms of geographical relationship, is Louw et al's (2008) study of the use of the software package MasterMaths on Matric Mathematics results, using an experimental group of 5 Khanya schools in the Western Cape and a control group of 5 non-Khanya schools. Their equivocal conclusion was that the "evidence in favour of the effectiveness of the [Khanya] intervention is... not clear" (Louw et al., 2008, p. 45). It would seem that my more recent study of the same intervention in different schools in the same city is even less positive about the connection between computer use and Mathematics performance than that determined by Louw et al. (2008).

It needs to be re-iterated, however, that this study does not attempt to isolate the numerous factors that impact on Mathematics attainment in Khanya schools; instead focussing on only one (the provision of computers and Mathematical software). The fact that providing these has not, in this instance, brought about an improvement in Matric Mathematics results could merely indicate that this intervention is insufficient to make a difference in isolation. Put another way, the other factors that are impeding the improvement in Mathematics results may be too strong to be overcome by this initiative alone. If and when these other impediments are overcome sufficiently then it is possible that the Khanya computers may prove their ability to impact Mathematics results positively.

Further to this, my research did not include a quantitative analysis of the number of hours that the computers were utilised by each of the schools included in the various samples used in the tests. The limited evidence that is available to answer this question - based on my phone calls to around a dozen or so disadvantaged schools in the Cape Town area; the data on computer usage from my Khayelitsha case study school; and the work of Louw et al. (2008) in the same city - would seem to indicate that various factors have restricted the use of the Khanya computers in the mathematics class to, in most cases, seldom or never. Obviously, the mere presence of computers in these schools is not going to be enough to bring about an improvement in Mathematics grades; they need to be utilised for the purposes envisaged by the Khanya Project to have a chance of causing a positive impact.

As Banerjee et al's (2005) very encouraging study of a computer-assisted learning intervention in Vadodara, India, showed, the key is making use of the computers that are already in the schools but are not being used. "The programme found a way to make these computers pedagogically useful in the treatment schools, without placing additional demands on teachers' time. It is the utilisation in this specific way and not the possession of the computers that had an impact" (Banerjee et al., 2005, p. 6).

Furthermore, the mere use of computers in the Mathematics classroom has been shown to be insufficient to bring about improved mathematical performance for the pupils (Guile 1998; Burns & Ungerleider, 2003). What is paramount is the way in which computers are used (Wenglinisky, 1998): is the Mathematics software being

used in order to bring about lower order cognitive development through drill-and-practice or is it facilitating deeper understanding of the topics? This question remains unanswered with reference to the Khanya intervention. My observations in one Khayelitsha township high school did shed some light on this issue, but much more research needs to be done by means of surveys of teachers and observations in a wide variety of classrooms.

In my case study, the Mathematics software chosen for use by the school was called Plato, which incorporates a drill-and-practise regime. It was not used by the teachers to teach new work, rather to revise work that had previously been taught in the traditional classroom. Used in this manner, although the pupils' comments were positive about its use and the software would have provided an alternative presentation and reinforcement of the work, it is likely – based on past research [for example, Chalkey & Nicholas (1997) and Noss & Pachler (1999)] - that it will be of limited benefit to the pupils, other than those who had missed the original lessons in the classroom and thus would be able to catch up missed material using the software.

What is encouraging to note is that although the computer software could have been used as a stand alone, with no input from the teachers, both teachers I observed continually roamed the computer lab to assist pupils that were stuck on technical or academic issues, and at times used well thought out question-and-answer scaffolding techniques to mediate greater understanding.

Even in this school, however, which is well-resourced with computer labs and well-trained teachers compared with the average township school in Cape Town, the Mathematics teachers are able to use the labs to teach their subject only very irregularly. The lessons I observed in the computer lab were clearly not the norm, as evidenced by the comments made during the teacher interviews.

Research question number 5 regarding variations in pedagogy as indicated by changes in semiotic mediation between the face-to-face classroom and computer lab was answered by means of an analysis of the 'teacher talk' observed within these two locations. A breakdown of the verbal interactions in the different venues showed

that a high percentage (nearly a quarter) of the communications dealt directly with the use of the computer. Although this could partly be explained by the fact that it had been many months since the pupils had used the Plato programme, it is worrying that so much teaching time is lost on what are essentially technical issues [see also Hardman (in press)]. It was also observed that in the computer lab a far higher percentage of the communications were with individuals than was the case in the traditional classroom, but there were overall a far higher number of interactions in the latter location.

In terms of the 'type of talk' used within each location, in the computer lab the vast majority of communications were explanations, questions or instructions (in roughly equal proportion), whereas in the classroom explanations and questions dominated the communication process. Very few of the explanations or questions in either location appeared to be aimed at ensuring deeper understanding of mathematical issues, with the main format of interaction being an IRE (Initiate, Respond and Evaluate) discourse.

Various chi-squared tests for independence were carried out in order to determine the bilateral relationships between each of the three categories: location of the lesson, type of talk, and scale of interaction. The results showed that there was a significant, moderate to strong association between the location of the lesson and the type of talk; a significant, strong association between the location of the lesson and the amount of interaction with the whole class as opposed to individuals; and a significant, moderate to strong association between the type of talk and the scale of interaction. These results prove that there indeed is a significant variation in semiotic mediation between the computer lab and the classroom, in the Khayelitsha high school I studied, which corroborates what Hardman (in press) discovered in her study of four primary schools near Cape Town.

In terms of Question 6 as to how the teachers used the computers as tools to further understanding, my observations indicated that in the few lessons in which the class was working in the computer lab, the computers were utilised primarily as a drill-and-practise tool; the way that is least likely to bring about a positive spin-off in Mathematics performance, according to the literature. It was evident that the

computer was essentially being used as an electronic textbook; albeit one with a lot more bells and whistles than a paper book.

Finally, as asked by my seventh and final research question, did the qualitative follow-up data help in any way to make sense of the quantitative data? I believe that it does, in that the non-impact of the Khanya intervention on Matric Mathematics in EMDC East high schools is better understood when one observes a school in action, as I did with my one case study in Khayelitsha. In particular, the fact that even in this 'best case' township school the pupils rarely use the computers and software in learning Mathematics, due mainly to scheduling constraints, means that the computers can de facto not make a difference to Mathematics results.

6.2. Shortcomings of my Study and Suggestions for Future Research

My research, being as it is for a Masters dissertation, is restricted in scope and duration, and this is perhaps its biggest limitation. In terms of the quantitative analysis of Matric results, the samples used are fairly small, although large enough to make the statistical findings valid. In addition, I did not control for the numerous other factors that might have played a role in affecting the Matric Mathematics results, other than the presence or absence of the computers. In terms of the observations, the use of only one case study school (with its two Mathematics teachers) provides useful but limited information; it would have been more useful and informative to have observed two or three different schools.

The findings of my research would seem to indicate that the vast sums of money poured into the Khanya Project are in vain, as there has been no apparent improvement in Matric Mathematics results, pass rates or Higher Grade enrolments, and no indication that schools with the Khanya facilities perform any better than those without. However, before such a drastic conclusion is made, one should bear in mind that my research did not include determining how frequently the pupils are using the computers and Mathematics software in the schools whose academic performance I analysed. Thus a further critical question should be researched: how

many hours per school week or month are the Khanya labs being used to teach and learn Mathematics, in high schools in one school district of Cape Town? This could be done by means of a survey of the Heads of Mathematics at each of the schools, and by an analysis of the pupil usage logs for the Mathematics software programmes, if they are available.

A strong recommendation is that Khanya themselves do a similar audit, in order to see which schools are using the labs as intended and which are not. Reasons for non-compliance should be determined and addressed as far as possible, whether it is due to difficulties in accessing the labs for use in Mathematics; technical problems with the equipment; teacher lack of confidence due to insufficient computer training; or any other factor.

Once the recommended data on computer use has been collected and analysed, similar questions to the ones I have posed could be used to collect and analyse data on Matric Mathematics performance, with a 'true' experimental group consisting of schools that are actually using the Khanya Mathematics software regularly and frequently (and a control group of 'new' Khanya schools or schools at which the computers are not being used for Mathematics teaching). It would be useful to have a common basis for comparing the schools, to ensure (as far as is possible) that one is comparing like with like; for example, results for a common examination sat by all the pupils prior to the Khanya intervention could act as a pre-test.

In addition, further lesson observations should be made in at least 2 or 3 of the schools that are using the software as frequently as intended, in order to ascertain how exactly these teachers are using the computers as a tool to mediate understanding. This will perhaps be of more use than my case study, as the teachers observed will be entirely familiar with the computers and software due to their frequent engagement with these resources, and so a truer indication of how the teachers are using the equipment to improve the teaching and learning process can be made, probably sans the non-educational technical issues.

A final suggestion for future research is in the area of how computers alter pedagogy. My study of variations in semiotic mediation as a marker of changes in

pedagogy is useful and, seemingly, breaks new research ground, yet there is much opportunity for further research in and around this field.

Despite the limitations mentioned in this section, my findings remain a valuable addition to the extremely limited research that has been completed in two main areas: firstly, research in developing nations regarding the link between Mathematics attainment levels and use of computers, and secondly, research into variation in semiotic mediation between the traditional classroom and computer lab.

What is clear is that the road ahead to improved Mathematics results in the Western Cape province of South Africa is a long and potentially bumpy one. Perhaps the solution does lie, at least in part, with computers and Mathematics software, but a great deal more research is needed in situ to ascertain that. For the meanwhile, the key perhaps is using the computers as a motivating tool; as Mrs Cupido says, “we [the teachers] should constantly strive to find out ways that we can make the learning experience for [pupils] more exciting and complete. Computers do play a role in that”.

University Of Cape Town

REFERENCES

- Anghileri, J. (2006). Scaffolding practices that enhance mathematical learning. *Journal of Mathematics Teacher Education*, 9(1), 33-52.
- Angrist, J., & Lavy, V. (2002). New evidence on classroom computers and pupil learning. *The Economic Journal*, 112(October), 735-765.
- Ary, D., Jacobs, L.C., Razavieh, A., & Sorensen, C. (2006). *Introduction to research in education* (7th ed.). Belmont, CA: Thomson Wadsworth
- Askew, M., Brown, M., Rhodes, V., William, D., & Johnson, D. (1997). *Effective teachers of numeracy: Report carried out for the TTA*. London: King's College.
- Babbie, E., Mouton, J., Payze, C., Vorster, J., Boshoff, N., & Prozesky, H. (2001). *The practice of social research*. Oxford: Oxford University Press.
- Banerjee, A., Cole, S., Deflo, E., & Linden, L. (2005). *Remedying education: Evidence from two randomised experiments in India* (National Bureau of Economic Research, Working Paper No. 11904). Retrieved January 22, 2010, from <http://www.nber.org/papers/w11904>
- Barrow, L., Markman, L., & Rouse, C.E. (2007). *Technology's edge: The educational benefits of computer-aided instruction* (WP 2007-17). Retrieved November 28, 2009, from <http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED505645>
- BECTA. (2000). *ImpaCT2: Emerging findings from the evaluation of the impact of information and communication technologies on pupil attainment*. (National Grid for Learning (NGfL) and BECTA. Summary of 2004 doc). Retrieved May 16, 2008, from <http://publications.becta.org.uk/display.cfm?resID=25841>

- BECTA. (2001). *The secondary school of the future – A preliminary report to the DfEE by Becta*. Coventry: Becta.
- BECTA. (2003). *Secondary Schools – ICT and standards: An analysis of national data from Ofsted and QCA*. Coventry: Becta.
- Blanton, W.E., Moorman, G.B., Hayes, B.A., & Warner, M.L. (1997). Effects of participation in the Fifth Dimension on far transfer. *Journal of Educational Computing Research*, 16(4), 371-396.
- Blanton, W.E., Greene, M., and Cole, M. (1999). Computer mediation for learning and play. *Journal of Adolescent and Adult Literacy*, 43(3), 272-278.
- Blanton, W., Mayer, R., McNamee, G., & Shustack, M. (2006). The quantitative effects of Fifth Dimension participation on children's cognitive and academic skills. In M. Cole & The Distributed Literature Consortium (Eds.), *The fifth dimension: An after-school program built on diversity* (pp. 85-106). New York: Russell Sage Foundation.
- Bliss, J., Askew, M., & Macrae, S. (1996). Effective teaching and learning: Scaffolding revisited. *Oxford Review of Education*, 22(1), 37-61.
- Bonk, C.J., & Cunningham, D.J. (1998). Searching for Learner-Centred, Constructivist and Socio-Cultural Components of Collaborative Educational Learning Tools. In C.J. Bonk & K.S. King. (Eds.), *Electronic collaborators* (pp. 25-50). Mahwah, NJ: Lawrence Erlbaum Associates.
- Bonk, C.J., & Kim KA. (1998). Extending sociocultural theory to adult learning. In M.C. Smith & T. Pourchot (Eds.), *Adult learning and development: Perspectives from educational psychology* (pp 67-88). Mahwah, NJ: Lawrence Erlbaum Associates.

- Brown, A.L., & Campione, J.C. (1990). Communities of learning and thinking, or a context by any other name. In D. Kuhn (Ed.), *Developmental perspectives on teaching and learning thinking skills* (pp. 108-126). Basel: Karger.
- Brown, A.L., & Palincsar, A.S. (1989). Guided, cooperative learning and individual knowledge acquisition. In L.B. Resnick (Ed.) *Knowing, learning, and instruction* (pp.393-408). Hillsdale, N.J: Erlbaum.
- Bruner, J. (1997). Celebrating divergence: Piaget and Vygotsky. *Human Development, 40*(2), 63-73.
- Burns, T.C., & Ungerleider, C.S. (2003). Information and communication technologies in elementary and secondary education: State of the art review. *International Journal of Educational Policy, Research and Practice, 3*(4), 27-54.
- Chalkey, T.W., & Nicholas, D. (1997). Teacher's use of information technology: observations of primary school practice. *Aslib Proceedings, 49*(4), 97-107
- Chang K., Sung Y., & Chen S. (2001). Learning through computer-based concept mapping with scaffolding aid. *Journal of Computer Assisted Learning, 17*(1), 21-33.
- Christmann, E., Badgett, J., & Lucking R. (1997). Microcomputer-based computer-assisted learning within different subject areas: a statistical deduction. *Journal of Educational Computing Research, 16*(3), 281-296.
- Clements, D.H. (2000). From exercises and tasks to problems and projects – Unique contributions of computers to innovative mathematics education. *The Journal of Mathematical Behaviour, 19*(1), 9-47.
- Cohen, J.W. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

- Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). New York: Routledge.
- Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA and London: The Belknap Press of Harvard University Press.
- Collins, A., Brown, J.S., & Newman, S. (1989). Cognitive apprenticeship: teaching the crafts of reading, writing and mathematics. In L.B. Resnick (Ed.), *Knowing, learning and instruction: Essays in honor of Robert Glasser*, (pp 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Condie, R., & Munro, B. (2007). *The impact of ICT in schools – a landscape review*. Coventry: Becta.
- Cox, M. (2003). How do we know that ICT has an impact on children's learning? In G. Marshall & Y. Katz (Eds.), *Learning in school, home and community: ICT for early and elementary education*, (pp. 159-168). Boston: Kluwer.
- Cox, M., Abbott, C., Webb, M., Blakele, B., Beauchamp, T., & Rhodes, V. (2003). *ICT and attainment: A review of the research literature* (DfES Project Report ICT in School Research and Evaluation series 17, 1-51). London: Becta.
- Cox, M., & Nikolopoulou, K. (1997). What information handling skills are promoted by the use of data handling software? *Education and Information Technologies*, 2(2), 105-120.
- Creswell, J.W. (2008). *Educational research: planning, conducting and evaluating quantitative and qualitative research* (3rd edition). Upper Saddle River, NJ: Pearson.
- Daniels, H. (2001). *Vygotsky and pedagogy*. New York: Routledge.

Department of Education. (2003). *National curriculum statement: Grades 10-12 (General): Mathematics*. Retrieved March 10, 2010, from <http://www.schoolnet.org.za/teach10/resources/eo/resources/curriculum/fet/Maths.pdf>

Department of Education. (2008). *National curriculum statement: Grades 10-12 (General): Subject assessment guidelines: Mathematics*. Retrieved March 10, 2010, from <http://www.education.gov.za/Curriculum/SAGs2008/SAG%20MATHEMATICS.pdf>

Department of Education. (2009). *Education statistics in South Africa: 2007*. Retrieved January 22, 2010, from <http://www.education.gov.za/emis/emisweb/07stats/Education%20Statistics%20in%20South%20Africa%202007.pdf>

Fisher, C., Dwyer, D.C., & Yocam K. (1996). *Education and technology: Reflections on computers in classrooms*. San Francisco: Jossey-Bass and Apple Press.

Forsythe, S. (2007). Learning geometry through dynamic geometry software. *Mathematics Teaching Incorporating Micromath*, 202, 31-35.

Gallimore, R., & Tharp, R. (1993). Teaching mind in society: Teaching, schooling and literate discourse. In L. Moll (Ed.), *Vygotsky and education: Instructional implications and applications of socio-historical psychology*. Cambridge: Cambridge University Press.

Griffin, P., & Cole, M. (1984). Current activity for the future. In B. Rogoff & J.V. Wertsch (Eds.), *Children's learning in the zone of proximal development*. San Francisco: Jossey-Bass.

Guile, D. (1998). *Information and communications technology and education*. London: University of London.

- Halliday, M.A.K. (1973). *Explorations in the functions of language*. New York: Elsevier.
- Halliday, M.A.K. (1978). *Language as social semiotic: The social interpretation of language and meaning*. London: Arnold.
- Halliday, M.A.K., & Hasan, R. (1989). *Language, context and text: Aspects of language in a social-semiotic perspective*. Oxford: oxford University Press.
- Hardman, J. (2005a). Activity Theory as a framework for understanding teachers' perceptions of computer usage at a primary school level in South Africa. *South African Journal of Education*, 25(4), 258-265.
- Hardman, J. (2005b). An exploratory case study of computer use in a primary school mathematics classroom: new technology, new pedagogy? *Perspectives in Education*, 23(4), 1-13.
- Hardman, J. (in press). Mind my Words: an investigation into whether semiotic mediation varies across computer-based and face-to-face mathematics lessons at the primary school level. *Education as Change*.
- Harrison, C., Comber, C., Fisher, T., Haw, K., Lewin, C., Lunzer, E. et al. (2002). *ImpaCT2: The impact of information and communication technologies on pupil learning and attainment*. Retrieved January 20, 2010, from http://partners.becta.org.uk/page_documents/research/ImpaCT2_strand1_report.pdf
- Harrison, C., Lunzer, E., Tymms, P., Fitz-Gibbon, C., & Restorick J. (2004). Use of ICT and its relationship with performance in examinations: A comparison of the ImpaCT2 project's research findings using pupil-level, school-level and multilevel modelling data. *Journal of Computer Assisted Learning*, 20(5), 319-337.

- Harrison, C. (2005). ICT and Classroom Pedagogies. In M. Leask & N. Pachler (Eds.), *Learning to teach using ICT in the secondary school* (2nd ed., pp 154-169). New York: Routledge.
- Hasan, R. (1992). Speech genre, semiotic mediation and the development of higher order mental functions. *Language Sciences*, 14(4), 489-528.
- Hasan, R. (2004). The concept of semiotic mediation: Perspectives from Bernstein's sociology. In J. Muller, B. Davies & A. Morais (Eds.). *Reading Bernstein, researching Bernstein* (pp. 30-43). London: Routledge Falmer.
- Hasan, R. (2005). *Semiotic mediation and mental development in pluralistic societies: Some implications for tomorrow's schooling*. Retrieved January 22, 2010, from <http://lchc.ucsd.edu/mca/paper/JuneJuly05/HasanSemMediation.pdf>
- Healy, J.M. (1998). *Failure to connect: How computers affect our children's minds and what we can do about it*. New York: Simon and Schuster.
- Hennessy, S. (2000). Graphing investigations using portable (palmtop) technology. *Journal of Computer Assisted Learning*, 16(3), 243-258.
- Hennessy, S., Deaney, R., & Ruthven, K. (2005). *Emerging teacher strategies for supporting subject teaching and learning with ICT*. Cambridge: University of Cambridge. Retrieved January 20, 2010, from <http://www.educ.cam.ac.uk/research/projects/istl/TiPS0521.pdf>
- Higgins, S. (2001). ICT and Teaching for Understanding. *Evaluation and research in Education*, 15(3), 164-171.
- Higgins, S. (2004). *Does ICT improve learning and teaching in schools?* Retrieved May 13, 2008, from <http://www.staff.ucsm.ac.uk/rpotter/ict/research/does-ict-improve-learning.pdf>

- Hinostroza, J.E., Guzman, A., & Isaacs, S. (2002). Innovative uses of ICT in Chilean schools. *Journal of Computer Assisted Learning*, 18(4), 459-469.
- Howell, C., & Lundell, P. (2000). *Computers in schools: A national survey of information communication technology in South African schools*. Cape Town: Education Policy Unit, University of Western Cape.
- Howie, S.J. (2001). *Mathematics and science performance in Grade 8 in South Africa 1998/99*. Pretoria: Human Sciences Research Council.
- Howie, S.J., Muller, A., & Paterson, A. (2005). *Information and communication technologies in South African secondary schools*. Cape Town: HSRC Press.
- Isaksal, M., & Askar, P. (2005). The effect of spreadsheet and dynamic geometry software on the achievement and self-efficacy of 7th grade students. *Educational Research*, 47(3), 333 – 350.
- Jonassen, D.H., & Reeves, T.C. (1996). Learning with technology: using computers as cognitive tools. In D.H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (Vol. 5, pp. 693-719). New York: Simon and Schuster.
- Karpov, Y.V., & Haywood, H.C. (1998). Two ways to elaborate Vygotsky's concept of mediation. *American Psychologist*, 53(1), 27-36.
- Kirkpatrick, H., & Cuban, L. (1998). Computer make kids smarter – right? *Technos*, 7(2), 26-31.
- Koedinger, K.R., Anderson, J.R., Hadley, W.H., & Mark., M.A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education*, 8(1), 30-43.

- Kozulin, A. (2003). Psychological tools and mediated learning. In A. Kozulin, B. Gindis, V.S. Ageyev & S.M. Miller (Eds.), *Vygotsky's educational theory in cultural context* (pp. 15-38). Cambridge: Cambridge University Press.
- Lajoie, S.P. (2005a). Extending the scaffolding metaphor. *Instructional Science*, 33(5-6), 541-557.
- Lajoie, S.P. (2005b). Cognitive tools for the mind: the promises of technology: cognitive amplifiers or bionic prosthetics? In R.J. Sternberg & D. Preiss (Eds.), *Intelligence and technology: Impact of tools on the nature and development of human skills* (Vol. 5, pp. 87-102). Mahwah, NJ: Erlbaum.
- Langer, J.A., & Applebee, A.N. (1986). Reading and writing instruction: Toward a theory of teaching and learning. In E.Z. Rothkopf (Ed.), *Review of research in education* (Vol. 13, pp. 171-194). Washington: American Educational Research Association.
- Louw, J., Muller, J., & Tredoux, C. (2008). Time-on-task, technology and mathematics achievement. *Evaluation and Progress Planning*, 31(1), 41-50.
- Maxwell, J.A. (1992). Understanding and Validity in Qualitative Research. *Harvard Educational Review*, 62(3), 279-300
- Mayer, R.E., Quilici, J.H., Moreno, R., Duran, R., Woodbridge, S., Simon, R., Sanchez, D., & Lavezzo, A. (1997). Cognitive consequences of participation in a 'Fifth Dimension' after-school computer club. *Journal of Educational Computing Research*, 16(4), 353-369.
- McClain, K., Cobb, P., Gravemeijer, K., & Estes, B. (1999). Developing mathematical reasoning within the context of measurement. In L. Stiff (Ed.), *Developing mathematical reasoning in Grades K-12. NCTM Yearbook 1999*. Reston, VA: National Council of Teachers of Mathematics.

- McClain, K., & Cobb P. (2001). Supporting students' ability to reason about data. *Educational Studies in Mathematics*, 45(1-3),103-129.
- Moll, L.C. (1990). Introduction. In L.C. Moll (Ed.), *Vygotsky and education* (pp 1-30). Cambridge: Cambridge University Press.
- Noss, R., & Pachler, N. (1999). The challenge of new technologies: Doing old things in a new way, or doing new things? In P. Mortimore (Ed.), *Understanding pedagogy and its impact on learning* (pp. 195-211). SAGE: London.
- Olusi, F.I. (2008). Using computers to solve mathematics by junior secondary students in Edo State, Nigeria. *College Student Journal*, 42(3), 748-755.
- Pachler, N. (2005). Theories of Learning and ICT. In M. Leask & N. Pachler (Eds.), *Learning to teach using ICT in the secondary school* (2nd ed., pp. 187-208). New York: Routledge.
- Pallant, J. (2007). *SPSS survival manual*. Maidenhead, UK: Open University Press.
- Passey, D., & Rogers, C. (2004). *The motivational effect of ICT on pupils*. (Research Report RR523). Retrieved January 22, 2010, from <http://www.dfes.gov.uk/research/data/uploadfiles/RR523new.pdf>
- Pea, R.D. (1985). Beyond amplification: Using the computer to reorganise mental functioning. *Educational Psychologist*, 20(4), 167-182.
- Pittard, V., Bannister, P., & Dunn, J. (2003). *The big pICTure: The impact of ICT on attainment, motivation and learning*. Retrieved January 22, 2010, from <http://ww.dfes.gov.uk/research/data/uploadfiles/ThebigpICTure.pdf>
- Raghavan, K., Sartoris, M.L., & Glaser, R. (1997). The impact of model-centred instruction on student learning: The area and volume units. *Journal of Computers in Mathematics and Science Teaching*, 16(2), 363-404.

- Reddy, V. (2006). *Mathematics and science achievement at South African schools in TIMMS 2003*. Cape Town: Human Sciences Research Council.
- Reynolds, D., Treharne, D., & Tripp, H. (2003). ICT – the hopes and the reality. *British Journal of Educational Technology*, 34(2), 151-167.
- Rogoff, B. (1995). Observing socio-cultural activity on three planes: participatory appropriation, guided participation and apprenticeship. In J. Wertsch, P. Del Rio, & A. Alvarez (Eds.), *Socio-cultural studies of mind* (pp. 139-164). New York: Cambridge University Press.
- Roshelle, J.M., Pea, R.D., Hoadley, C.M., Gordin, D.N., & Means, B.M. (2000). Changing how and what children learn in school with computer-based technologies. *Children and Computer Technology*, 10(2), 76-101.
- Saljo, R. (1999). Learning as the use of tools: A Socio-cultural perspective on the human technology link. In K. Littleton & P. Light (Eds.), *Learning with computers: Analysing productive interaction* (pp. 144-161). London: Routledge.
- Salomon, G. (1988). AI in reverse: Computer tools that turn cognitive. *Journal of Educational Computing Research*, 4(2), 123-139.
- Seo, Y-J., & Bryant, D.P. (2009). Analysis of studies of computer-assisted instruction on the mathematics performance of students with learning difficulties. *Computers and Education*, 53(3), 913 – 928.
- Shaw, N., Jean, B., & Peck, R. (1997). A statistical analysis on the effectiveness of using a computer algebra system in a developmental algebra course. *The Journal of Mathematical Behaviour*, 16(2), 175-180.
- Sinclair, J.M., & Couthard, R.M. (1975). *Towards an analysis of discourse*. Oxford: Oxford University Press.
- Somekh, B. (2007). *Pedagogy and learning with ICT*. London: Routledge.

- South African Ministry of Education. (2007). Statement by Naledi Pandor, Minister of Education, on 28 December 2007. Retrieved January 22, 2010, from <http://www.info.gov.za/speeches/2007/07122810151001.htm>
- Smith, P., Rudd, P., & Coghlan, M. (2008). *Harnessing technology: Schools survey 2008 report 1: Analysis*. Retrieved Jan 18, 2009, from http://schools.becta.org.uk/upload-dir/downloads/page_documents/research/ht_schools_survey08_data.pdf
- Stephens, L.J., & Konvalina, J. (1999). The use of computer algebra software in teaching intermediate and college algebra. *International Journal of Mathematical Education in Science and Technology*, 30 (4), 483-488.
- Stoll, C. (1995). *Silicon snake oil: Second thoughts on the information highway*. New York: Doubleday.
- Struwig, F.W., & Stead, G.B. (2001). *Planning, designing and reporting research*. Cape Town: Pearson Education.
- Taylor, N., Muller, J., and Vinjevoold, P. (2003). *Getting schools working: Research and systematic school reform in South Africa*. Pearson Education : Cape Town.
- Tharp, R. (1993). Institutional and social context of educational reform: Practice and reform. In E.A. Forman, N. Minick & C.A. Stone (Eds.), *Contexts for learning: Sociocultural dynamics in children's development* (pp 269-282). New York: Oxford University Press.
- Tharp, R., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning and schooling in a social context*. Cambridge, MA: Cambridge University Press.

- Thorpe, R., & Roberts-Young, D. (2001). Portable computers: A catalyst for collaboration? A study of how the use of multi-media portable computers in primary schools can affect teacher and pupil collaboration. *Journal of Information Technology for Teacher Education*, 10(3), 203-223.
- Tienken, C., & Wilson, J. (2007). The impact of computer assisted instruction on seventh grade students' mathematics achievement. *Planning and Changing*, 38(3&4), 181-190.
- Van Wyk, K. (2002). Khanya: Technology in education: Business plan. Retrieved March 10, 2010, from <http://www.khanya.co.za/projectinfo/?catid=22>
- Verenekina, I. (2003, October). *Understanding scaffolding and the ZPD in educational research*. Paper presented at the Australian Association of Educational Research Conference, Newcastle, Australia. Retrieved January 22, 2010, from <http://www.aare.edu.au/03pap/ver03682.pdf>
- Vygotsky, L.S. (1978). *Mind in society: Development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, E. Souberman, Eds.). Cambridge, MA: Harvard University Press.
- Vygotsky, L.S. (1981). 'The genesis of higher mental functions', in Wertsch, J.V. (Ed.), *The concept of activity in Soviet psychology*, pp. 144-188. Armonk, NY: Sharpe.
- Vygotsky, L.S. (1986). *Thought and Language* (A. Kozulin, Ed.). Cambridge, MA: MIT Press.
- Vygotsky, L.S. (1987). Thinking and Speech. In R.W. Rieber & A.S. Carton (Eds.), *The Collected Works of L.S. Vygotsky, Volume 1: Problems of General Psychology*. New York: Plenum.

- Walker, S., & Senger, E. (2007). Using technology to teach developmental African-American algebra students. *Journal of Computers in Mathematics and Science Teaching*, 26(3), 217-231.
- Wang, P., & Chan, P.S. (1995). Advantages, disadvantages, facilitators and inhibitors of computer-aided instruction in Singapore's schools. *Computers and Education*, 25(3), 151 - 162
- Watson, D (Ed.). (1993). *ImpaCT – an evaluation of the impact of Information Technology on childrens' achievements in primary and secondary school*. London: King's College.
- Waxman, H.C., Connell, M.L., & Gray, J. (2002). *A quantitative synthesis of recent research on the effects of teaching and learning with technology on student outcomes*. Retrieved January 22, 2010, from <http://www.coe.ufl.edu/Courses/eme5054/Foundations/Articles/waxman.pdf>
- Wegerif, R. (1996). Collaborative learning and directive software. *Journal of Computer Assisted Learning*, 12(1), 22-32.
- Wegerif, R. (2004). The role of educational software as a support for teaching and learning conversations. *Computers and Education*, 43(1), 179-191.
- Wells, G. (1994, September). *Learning and teaching "scientific concepts": Vygotsky's ideas revisited*. Paper presented at the conference on Vygotsky and the Human Sciences, Moscow. Retrieved January 30, 2009, from http://people.ucsc.edu/~gwells/Files/Papers_Folder/ScientificConcepts.pdf
- Wells, G. (1999). *Dialogic enquiry: Towards a socio-cultural practice and theory of education*. New York: Cambridge University Press.
- Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics*. Retrieved January 22, 2010, from <http://www.ets.org/Media/Research/pdf/PICTECHNOLOG.pdf>

- Wertheimer, R. (1990). The geometry proof tutor: An 'intelligent' computer-based tutor in the classroom. *Mathematics Teacher*, 83(4), 308-317.
- Wertsch, J.V. (1985). *Vygotsky and the social formation of mind*. Cambridge, MA: Harvard University Press.
- Wertsch, J.V. (1991). *Voices of the Mind: a socio-cultural approach to mediated action*. Cambridge, MA: Harvard University Press.
- Williams, L.P. (2000). *The effects of drill and practice software on multiplication skills*. Retrieved January 22, 2010, from http://eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/16/59/ef.pdf
- Wong, M., & Evans, D. (2007). Improving basic multiplication fact recall for primary school students. *Mathematics Education Research Journal*, 19(1), 89 – 106.
- Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, 17(2), 89-100.
- Wood, D., Underwood, J., & Avis P. (1999). Integrated Learning Systems in the classroom. *Computers and Education*, 33(2-3), 91-108.
- Wood, D., & Wood, H. (1996a). Commentary: Contingency in tutoring and learning, *Learning and Instruction*, 6(4), 391-7.
- Wood, D., & Wood, H. (1996b). Vygotsky, tutoring and learning, *Oxford Review of Education*, 22(1), 5-16.
- Wood, D.J. (1998). *How children think and learn: The social contexts of cognitive development*. Oxford: Blackwell.

Wood, T. (1994). Patterns of interaction and the culture of mathematics classrooms. In S. Lerman (Ed.), *Cultural perspectives on the mathematics classroom*. Dordrecht: Kluwer.

Zolkower, B., & Shreyar, S. (2007). A teacher's mediation of a thinking-aloud discussion in a 6th grade mathematics classroom. *Educational Studies in Mathematics*, 65(2), 177-202.

University Of Cape Town

APPENDICES

Appendix 1: Questions for Teacher Interviews

1. What is your gender and age?
2. How many years of teaching experience do you have? How many of those years included teaching Maths at a high school level?
3. What other teaching subjects do you have?
4. What academic and professional qualifications do you have?
5. What do you feel is your Comfort/Competency level in using ICT for teaching Mathematics (rate from 1 – 10)?
6. How much training have you had in using ICT for teaching?
7. How often do you use computers to teach Maths? Is it a regular slot(s)?
8. How is the amount of time you use computers to teach Maths likely to change in the future? Why?
9. Which topics do you select to teach on the computer? Why? (Do some topics lend themselves better to the computer than others? Do you use computers to teach new sections or for revision, or both?)
10. What resources did you use before you had the computer?
11. Why do you use the computer?
12. Would you describe the lessons I have observed as fairly typical maths lessons?
13. Do you think the availability of the computer has changed the way you teach? How?
14. In what ways do you think the computer helps children to learn maths? How?
15. In what ways, if at all, has the use of computers assisted in your own maths teaching?
16. Do you think the computer programme you use to teach Maths is useful? Why?

17. Does it have any drawbacks? Please elucidate.
18. Have you used any other Maths learning software? If so, how do they compare?
19. Are you aware of any differences in the way you teach Maths in face-to-face compared to computer lab lessons?
20. Do you think children learn better in a classroom without computers or with computers? If yes, how?
21. Can you give an example of how the students have been assisted by using the computer software?
22. Do you think that using computer software will help students in
 - improving grades
 - Motivation
 - Collaboration?
23. Have you noticed an improvement in grades after you have used computers?
24. If you could select whatever resources you liked for teaching, would you yourself select the computer? That is: is it worth the effort / time / money to use IT in education?
25. What is the role of the students in computer-based lessons?
26. What is the role of the teacher in computer based lesson?
27. Do the roles in computer based lessons differ to the roles in face to face lessons?
28. Does the computer impact on pace, sequence and selection of content in the lesson? How?

Appendix 2: Khanya Permission E Mail

----- Original Message -----

From: Garth Spencer-Smith

To: garf@webafrica.org.za

Sent: Monday, July 28, 2008 8:59 AM

Subject: FW: Research

From: Charles Pearce [mailto:cpearce@pgwc.gov.za]

Sent: Fri 7/25/2008 3:45 PM

To: Garth Spencer-Smith

Subject: Research

Dear Garth

I have finally got an answer for you. Kobus is quite happy for you to visit Khanya schools as long as we get a copy of your research when it is complete. Would that be in order?

Regards
Charles

"All views or opinions expressed in this electronic message and its attachments are the view of the sender and do not necessarily reflect the views and opinions of the Provincial Government of the Western Cape ('the PGWC').

No employee of the PGWC is entitled to conclude a binding contract on behalf of the PGWC unless he/she is an accounting officer of the PGWC, or his or her authorised representative.

The information contained in this message and its attachments may be confidential or privileged and is for the use of the named recipient only, except where the sender specifically states otherwise.

If you are not the intended recipient you may not copy or deliver this message to anyone."

No virus found in this incoming message.

Checked by AVG - <http://www.avg.com>

Version: 8.0.138 / Virus Database: 270.5.6/1577 - Release Date: 7/28/2008 6:55 AM

Appendix 3: Participant Consent Form

Participant Consent Form for Research Study

Project: Investigating how computers are used to teach mathematics

Researcher: Garth Spencer-Smith, M.Phil student at the University of Cape Town

The purpose of this research is to determine how computers are used to teach mathematics. Results of the study will give researchers an opportunity to develop and test computer-assisted learning in similar demographic areas and ultimately help to impact on our understanding of optimal teaching practices with computers.

The researcher would like to obtain your consent to participate in this research. There is no risk, injury, discomfort or cost involved with participation in this study. There is no financial reward for participation.

This study will benefit teachers directly by providing information to the researcher (which will be fed back to the schools) regarding the effects of computer technology on teaching. It is hoped that by learning more about the influence of the computer on teaching we will be able to develop deeper understandings regarding the nature and impact of technology, ultimately leading to educational interventions aimed at enhancing computer-based teaching.

All information shared with the researcher will be kept strictly confidential. You will not be identified in any reports on this study. The records will be kept confidential to the extent provided by law. One copy of this document will be kept together with the researcher's records of this study. Codes, but not names, will be assigned to each participant for research purposes. Only the researcher and his supervisor (Dr J. Hardman) will analyse the data provided.

If significant new knowledge is obtained during the course of this research, which may relate to your willingness to continue participation, you will be informed of this knowledge. Also, you may contact Garth Spencer-Smith at telephone numbers 021

790 2310 or 084 624 9803 for answers to further questions about this research or anything you may feel is related to the study.

Participant Declaration:

I have read and understood the information given above. I hereby give my consent to participate in this study.

Name

Consenting Signature

Date

University Of Cape Town

Appendix 4: Raw Data on Teacher Talk

Table 33: Summary of Tallies: Computer Lab Lessons (number of interactions, class by class)

TEACHER		Mr Mhorah								Mrs Cupido			
GRADE CLASS		Gr 11N		Gr10T		Gr11N		Gr10T		Gr12L		Gr12M	
		CLASS	INDIVID	CLASS	INDIVID	CLASS	INDIVID	CLASS	INDIVID	CLASS	INDIVID	CLASS	INDIVID
feedback	praise / encouragement	1	2	0	0	0	0	0	2	1	5	0	1
	criticism	0	0	0	0	0	3	1	1	2	2	0	2
	correction of error	7	5	2	2	1	5	0	3	0	5	0	1
statements	information	18	2	16	3	12	0	13	8	14	9	6	0
instructions	deportment	7	1	5	10	5	4	15	11	6	4	2	1
	academic - Maths	5	8	8	7	7	4	2	10	4	9	0	0
	academic - IT	12	19	18	38	7	35	13	20	9	8	16	5
questions	IT related	5	1	9	20	2	19	12	7	3	5	3	2
	Maths factual	44	26	12	17	1	13	0	33	0	16	0	3
	Math assistance	2	2	1	3	0	1	0	15	0	4	0	0
	other	19	12	9	23	6	18	12	0	17	16	1	6
explanations	Maths statement	77	51	32	18	8	35	0	53	0	38	0	2
	rationale	2	3	1	2	0	1	0	1	0	8	0	0
	IT usage	8	9	20	8	1	7	0	12	6	6	0	3
TOTALS		207	141	133	151	50	145	68	176	62	135	28	26

Table 34: Summary of Tallies: Traditional Classroom Lessons (number of interactions, class by class)

	TEACHER	Mr Mhorah				Mrs Cupido			
	GRADE CLASS	Gr10S		Gr11N		Gr12M		Gr12L	
		CLASS	INDIVID	CLASS	INDIVID	CLASS	INDIVID	CLASS	INDIVID
feedback	Praise / encouragement	0	2	0	0	2	0	0	2
	criticism	0	2	0	1	2	0	0	0
	correction of error	0	13	1	0	2	0	1	3
statement	information	23	0	21	0	25	0	22	0
instruction	deportment	12	6	8	2	2	0	2	0
	academic - Maths	14	17	17	0	13	0	8	6
question	Maths factual	39	16	67	0	39	0	13	14
	Math assistance	4	0	1	0	9	0	1	1
	other	144	8	26	1	15	0	6	2
explanation	Maths statement	104	24	171	4	67	0	111	24
	rationale	5	0	0	0	25	0	9	1
	TOTALS	389	110	390	9	214	0	182	54