Science and Mathematics Education Centre

The Effectiveness of an Outreach Programme in Science and Mathematics for Disadvantaged Grade 12 Students in South Africa

Mogamat Shaheed Hartley

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

Signature:

Date: 24/9/02

ABSTRACT

This study was designed to evaluate the effectiveness of a computer-based outreach programme that addresses one aspect of a national strategic recommendation in South Africa. This outreach programme, which started in 1982, was in its twentieth year of existence in 2001 and provided support in mathematics and physical science to Grade 12 students and teachers from historically disadvantaged schools. This study examined the role that the outreach programmes played at two schools during 2001 and endeavoured to provide an analysis of the intended, implemented, perceived and achieved programmes for this year. Therefore, the purpose of this study was to investigate the effectiveness of this outreach programme in providing support to both teachers and students in the teaching and learning of mathematics and physical science.

The goals and objectives of the outreach programme *(the intended programme)* were identified from documentation of the Outreach Project and interviews with Outreach Project managers. In addressing the implementation of the outreach programme (*the implemented programme*), lessons at each of the two Mini-Computer Supported Education Centres (MICSECs) were observed over a period of four months. At one centre (Centre A), the lessons consisted of a formal (talk-and-chalk) presentation followed by an informal part when students worked on the computer in the same period. At the second centre (Centre B), the MICSEC was used as an adjunct to the normal classroom lesson, that is, students were taught in their normal classrooms and then, at least once a week, taken by their teacher to the MICSEC to do problem-solving on the computers.

The perceptions of students (*the perceived programme*) were examined by an actual and preferred version of the *Computer-Assisted Learning Environment Questionnaire* and by interviews conducted with both individual students and groups. At Centre A, the students preferred more involvement, more open-endedness, more organisation and more learning assessment opportunities in their computer-assisted classes but also less integration of computers in their every day classes whilst desiring investigation procedures in their classes to remain the same. At Centre B, students preferred to be more involved, to have more open-ended activities in their classes, have more learning assessment opportunities and a greater level of

integration of computers but a reduction in investigative activities. Findings from student interviews were summarised as reflecting three viewpoints with regard to the inclusion of computer-assistance in classes. Students holding one viewpoint considered the inclusion of computer-assisted learning as important to their learning and were convinced that their interaction with the computer, fellow-students and teacher, led to an improvement in their learning. Students holding the second viewpoint conveyed a message of insecurity in the use of computers for they were not sure whether their working with computers made any difference to their learning. Many students' views were somewhere between the first and the second viewpoints which left the impression that these students were not convinced that using the computers would guarantee them success in the final examination. The third viewpoint was strongly articulated by a group of three students at Centre A and to a lesser degree at Centre B (one student), who considered that the new computer-assisted classes played no role in their learning and that teacher-centred classes would produce better results.

The extent to which the outreach programme met its objectives (*the achieved programme*) included improved student performance on the matriculation examinations. Teachers and students were generally positive of the support that they received but indicated that more computer terminals were required to address students' individual needs. The mean achievement of students at both schools improved in both mathematics and physical science, but more so in physical science. The MICSECs mainly served as a resource to students at the school where the centres were based and provided limited computer skills to students from historically disadvantaged backgrounds.

The findings of this study provided insight into the implementation of computer-assisted classes in two disadvantaged schools and the results can serve as baseline data for conducting research into computer-assisted learning environments in other secondary school grades in South Africa. However, it should be noted that students at the Grade 12 level also wanted a continuation of, indeed more of, teacher-centred teaching, in addition to the computer-assisted classes because of the perceived competency of teachers in helping them perform well in the matriculation examination.

DEDICATED TO

Mogamat Kaashief, Tasneem and Thaakirah

my son and daughters who have endured a lot and complained little

Mujtaba and Fatima Hartley

my parents who have been my life-long fountain of inspiration

and finally

Ayesha

my wife, my companion, my friend

for all your love, patience, encouragement and support

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CHAPTER 1

RATIONALE FOR THE STUDY

1.1 Introduction

This study focuses on the effectiveness of a technology-based outreach programme in mathematics and physical science for disadvantaged Grade 12 students. This chapter provides a background to the South African education system since the first democratic elections in 1994 and the problems being faced by many students in historically disadvantaged schools. The post-apartheid status of teachers and students in mathematics and physical science are discussed together with the response of the National Education Department in trying to address the problems emanating from the past. The significance of this study is addressed and the research questions are stated within the conceptual framework developed for this investigation. A number of limitations of the study also are identified and an overview of this thesis is provided.

1.2 Background to the Study

The need to transform the South African education system has been a subject of intense debate and discussion dating back for many decades. The transformation of both its form and content evoked sharp debates in schools, universities, technikons, teachers' colleges, workshops and conferences. The most striking feature of education in South Africa was the legacy of the previous government's policy of differential development of education based on racial groups. Many studies and policy documents argued that the past provision of science education was of poor quality and was wasteful because the so-called African students, who were in the majority, were denied access to fully engage in the study of science (Department of Arts, Culture, Science and Technology (DACST), 1996; Department of Education, 2001; International Development Research Centre (IDRC) Mission Report, 1993; Mkhatshwa, 1999). The education policy of the apartheid government resulted in many schools designated for black students not having electricity, water, infra-structure, textbooks, and other teaching and learning resources, as well as having under-qualified teachers and teacher-student ratios sometimes exceeding 1:100 (especially in primary schools). Learners who were forced to face these harsh realities were mostly *black* but also *coloured* and *Indian* and are described in this study as the disadvantaged students.

The demise of apartheid and the change to a democratic dispensation in South Africa in 1994 provided the new government with the much-needed opportunity to bring the education system in line with principles of democracy, equality and justice. One of the first challenges in education that confronted the new government was the creation of a single education system comprising the National Education Department and nine provincial education departments, out of the 19 formerly racially divided education departments. This process did not only involve the housing of personnel from the former apartheid departments under one roof, but also meant the creation of a completely new organisation with its own identity, culture and ethos (Lehoko, 1998).

The new government also was faced with the unequal distribution of its human resources especially in Science, Engineering and Technology (SET). SET has critical implications for human resource development, education and training policy in general, and SET education in particular for South Africa (Lewin, 1995). The dilemma in SET participation created new challenges with regard to SET interventions that would empower and enable marginalised communities to make informed decisions about their future. The new government recognised the importance and the role of SET education in developing the country's human resource capacity (Department of Arts, Culture, Science and Technology, 1996). It was generally agreed that if South Africa was going to reduce poverty and unemployment, and all their negative side effects, it must become competitive in the global economy. Those in government responsible for education and training acknowledge the social significance of the need to develop a highly skilled labour force for the future economy.

Indeed, both the White Papers on Education and Training (Department of Education, 1994) and Science and Technology (Department of Arts, Culture, Science and

Technology, 1996) recognised the roles of their respective ministries in the government's growth and development strategy. The White Paper on Science and Technology (Department of Arts, Culture, Science and Technology, 1996) argued that government:

> has a responsibility to promote science culture, science education and literacy amongst both children and adults and influence the attainment of equity by providing incentives for disadvantaged groups to study mathematics and science and achieve computer literacy. (p. 41)

While the White Paper on Education and Training (Department of Education, 1994) stressed the need to:

> raise the workers' level of general education and skill, to support the introduction of more advanced technologies, to overcome the inheritance of racial and gender stratification in the workforce, and to achieve effective worker participation in decision making and quality improvement. (p. 63)

Such effective human resource development programmes in science, engineering and technology are vital to redress the racial and gender inequalities of the past which have excluded black men and women from the mainstream of South African society, in addition to improving the general quality of life and making South Africa globally competitive (Arnott, Kubeka, Rice & Hall, 1997).

The provision of extensive mathematics and science training would be an effective start in addressing the country's economic and social problem. Learners studying science subjects such as physical science, biology and mathematics at the secondary level are the likely students for tertiary education. Naidoo (1996) argues that although it is at the tertiary level that the human resource capacity is developed, it is the quality of teaching and learning at the secondary level in mathematics and science that determines the numbers of the students that are trained in the SET fields.

1.3 Status of Science and Mathematics in South African Schools

1.3.1 The state of mathematics and science teachers post 1994

Arnott, Kubeka, Rice and Hall (1997) compiled an extensive report for the Department of Education and Training and the Department of Arts, Culture, Science and Technology about the status of mathematics and science teachers in South Africa. They looked at the qualifications and experience profiles of mathematics and physical science teachers in schools, their utilisation and the type of training they received in colleges of education. In addition, these authors compared the output of teachers from colleges of education, technikons and universities in these subjects with the number of teachers needed in terms of projected student enrolment.

Arnott et al. (1997) found an insufficient supply of adequately trained mathematics and science teachers, both in terms of enrolment in these subjects as well as if access to these subjects were provided for the majority of secondary students. They estimated that if class sizes were improved to 40 students per teacher in these subjects, 2000 mathematics teachers and 2200 science teachers would be needed. If improved access was a goal with 85% of senior secondary students enrolled in mathematics and 75% in physical science then an additional 3000 mathematics teachers and 5000 science teachers would be needed. Purely in terms of numbers, whether qualified or not, there was an absolute shortage of teachers. The majority of secondary mathematics and science classes had a student/teacher ratio greater than 40 (Department of Education, 2000). The shortage of science teachers was greater than that of mathematics teachers. The number of students enrolled in science classes were, however, lower (20% less) than those enrolled in mathematics.

Another key finding of this report was that although most mathematics and science teachers have professional qualifications, less than half have accredited training in the subject they are teaching. Fewer than 50% of mathematics teachers and 42% of science teachers have at least one year of specialised training in either mathematics or science. Of these, the majority received training by means of a Secondary Teacher's Diploma. In addressing just the lack of subject knowledge in teachers, approximately 8000 mathematics teachers and 8200 science teachers would need to be targeted for in-service training.

Arnott et al. (1997) further found that a significant number of mathematics and science teachers at the secondary level were not being engaged effectively. Given the teacher shortage in these subjects, there were a surprisingly high number of mathematics and science teachers who spent less than 40% of their time teaching either mathematics or science. More than half of all science teachers were in this position.

A further disturbing finding was the low level of teaching experience among mathematics and science teachers. A sizeable majority of teachers in these subjects were newcomers in their field. Over a third of mathematics teachers, over 45% of general science and nearly 40% of physical science teachers had less than two years experience teaching their subject. These high numbers of newcomers were attributed to a high attrition rate of more experienced teachers in these fields.

According to Arnott et al. (1997) the quality of mathematics and science teaching at colleges of education varied considerably across institutions. The lack of importance given to mathematics and physical science in the curriculum as a consequence of Bantu Education (as education for black people were derogatively termed by the apartheid government) diminished their relative importance in the understanding of students and teachers alike and also assisted in mystifying these subjects (Rogan & Gray, 1999). None of the teachers' colleges made a serious attempt to bridge the gap between the language of instruction and cognitive development. Schools and colleges of education were seriously under-resourced in terms of teachers as well as laboratories, equipment, textbooks and libraries (Mkhatswa, 1999).

The lack of links with universities and the isolation of the African teacher education sector from the latest developments in mathematics and physical science education resulted, in part, in a lack of understanding on the part of teachers of the relevance of these subjects for their daily lives or environment. A further effect of isolation has been that teachers were not exposed to new developments in didactics. Consequently, teacher-centred approaches became entrenched and accepted as the norm. The lack of academic background had fostered a passive dependency on perceived higher authorities (Ogunniyi, 1998) and an unquestioning, uncritical attitude to the development of relevant curricula (Arnott et al., 1997).

1.3.2 The state of mathematics and science students post 1994

The Third International Mathematics and Science Study (TIMSS), coordinated in South Africa by the Human Resources Research Council (Howie, 1997), revealed the extent of the country's educational legacy. The Human Sciences Research Council conducted TIMSS, under the auspices of the International Association for the Evaluation of Educational Achievement, among 15 000 South African students from more than 400 primary and secondary schools during 1994/1995. Of the 63 countries that started the study, only 41 completed it. South Africa was the only country in Africa to do so. South African learners scored the lowest of all participating countries in both tests. South Africa's scores were based on a racially and geographically representative sample of 5031 Grade 7 students and 4491 Grade 8 students who took the tests at 114 and 137 schools, respectively. In the mathematics component, the South African Grade 8 students managed to answer only 24% correctly, as opposed to the world average of 55%. Virtually the same results were obtained in the science component; nor was there any appreciable difference between Grades 7 and 8 students.

In 1998, TIMSS was repeated (TIMSS-R), with tests and questionnaires administered in 38 countries. TIMSS-R was conducted in South Africa by researchers from the Human Sciences Research Council (Howie, 2001). More than 8000 Grade 8 students were assessed in 200 schools and more than 350 teachers and 190 principals of those schools participated. A total of 225 schools were selected at random from all nine provinces. One intact mathematics class per school was selected such that schools from all former departments of education were represented and both government and private schools were included in this sample. Ultimately, 194 schools and 8147 students were included in the international dataset for analysis. South Africa achieved an 85% response rate and the national sample was representative for the country.

South African students again performed poorly when compared to other participating countries (Howie, 2001). The average score of 275 out of 800 points was significantly below the average scores of all other participating countries, including the two other African countries, namely, Morocco and Tunisia as well as other developing or newly developed countries such as Malaysia, the Philippines, Indonesia and Chile. South African students who scored around the country's average score fell below the least proficient students from almost all other countries with the exception of Morocco, the Philippines, Chile and Indonesia. South African pupils' performance was relatively low in every mathematics topic (from 37% for algebra to 45% for data representation, analysis and probability). For South Africa, the average score of 356 points (out of 800 points) for data representation, analysis and probability was the highest achieved. However, this topic was not included in the intended curriculum at Grade 8 level. The lowest achievement was in the area of algebra with a score of 293 out of 800 points. Twenty-six countries in TIMSS-R also participated in the original TIMSS study, including South Africa. Less than 0.5% of pupils in South Africa reached the average score of the top 10% of pupils internationally. For science, South Africa's overall score decreased by 20 scale points which was deemed not to be statistically significant. This meant that although the difference seemed comparatively large, there was not enough evidence to conclude that there was a real difference in performance between the pupils in 1999 and those in 1995.

1.3.3 Strategic intervention for South African mathematics, science and technology

Arnott et al. (1997) painted a bleak picture in their report on the state of mathematics and science teachers in South Africa coupled with the dismal performance of South African learners in the 1995 and 1999 TIMMS tests, and a decline in the number of those achieving matriculation exemption in the Senior Certificate Examination. Also, the continued weak showing in the country's rankings in the World Competitiveness Report and further independent confirmation of the serious shortcomings in science and mathematics education found in the Presidential Education Initiative Research Report (Department of Education, 1999) prompted the President of South Africa to emphasise the urgent need for the improvement in school science and mathematics:

> Special attention will need to be given to the compelling evidence that the country has a critical shortage of mathematics, science and language teachers, and to the demands of the new information and communication technologies. (Excerpt from President Thabo Mbeki's parliamentary address in 1999, quoted in Department of Education, 2000)

This need in terms of mathematics, science and technology (SMT) education was given special attention by the Minister of Education and Minister of Arts, Culture, Science and Technology by calling a National Consultative Conference in September 2000 involving a wide range of role players and stakeholders. The task of the conference was to draft intervention strategies to address the identified need in SMT education. The author was invited to attend this strategic conference and participated in workshops that dealt with supporting teachers in their didactic task. One of the recommendations that is relevant to this study determined that provinces should give high priority to interventions in language, science, mathematics and technology in selected schools from Grades 10 to 12, and that such interventions should be "evaluated to establish their success to enhance the scientific, mathematical and technological cognitive core of learning" (Department of Education, 2000, p. 42). The role of non-governmental organisations and outreach programmes run by tertiary institutions were mooted as important examples. The evaluation study reported in this thesis was designed to examine how the need to support mathematics and science teachers had been implemented, a need that also was identified at this national strategic conference.

1.4. The University of the Western Cape's (UWC) Outreach Programme

The UWC computer-based outreach programme to schools was chosen for this evaluation study because it is probably one of the oldest, if indeed not the longest serving, outreach programme in South Africa. In the year 2001, it was in its twentieth year of existence. The outreach programme was one leg of an Outreach Project which was started in 1982 by the Teaching Centre of the University of the Western Cape (UWC). The development of instructional computing by UWC in 1982 had a single goal in view, namely, to use instructional technology to improve education at all levels.

The Outreach Project started with three programmes in 1982 to support the above goal, namely, the mathematics/sciences matriculation outreach programme, the instructional computing services dissemination programme, and the computer courseware evaluation / improvement programme (Sinclair & Kansky, 1989). This study evaluated the first programme, as the last two programmes had ended a number of years before this study was started.

The mathematics/sciences matriculation outreach programme was initially designed for a period of four and a half years (July 1982-December 1986) and aimed at improving instruction in secondary school mathematics and the sciences. This programme extended the development of a computer-based educational programme that was designed to provide instruction in Standards 9 and 10 (Grades 11 and 12) of the South African matriculation syllabi for biology, chemistry, mathematics and physics. The Programmed Logic for Automated Teaching Operation (PLATO)-based product was presented in both the Afrikaans and English languages. The intended users included secondary school students, teachers, prospective university students and adults involved in self-improvement in order to prepare them for better employment opportunities (Mehl & Sinclair, 1983)

The computer-based interaction served as bases for students' participation in the outreach programme. Programme officers teaching structured lessons to students in both mathematics and physical science augmented this activity. The physical science component included practical laboratory work prescribed by the syllabus but unfortunately this was not always implemented in schools due to a shortage of resources. A Mobile Computer Unit was added at a later stage to take computer-supported instruction to schools. The mobile unit is a fully equipped trailer that can accommodate up to 30 pupils at a time. The computer network has been duplicated from the campus installation, so that any software that is developed is applicable to both the mobile unit's network and the Outreach Project's on-campus centre. It was best suited for serving clusters of schools in outlying areas (Ogunniyi & Isaacs, 1998).

From August to October 1982, as a pilot run to prepare for full-scale operations in 1983, 120 Grade 12 students from neighbouring schools came to the campus every Saturday to work through computer-based courseware. During the same period, 130 Grade 12 students took turns to be bussed to the campus every afternoon during the week to work through computer-based physical science and mathematics lessons on the PLATO in preparation for the final examinations. The teachers concerned accompanied the students in order to be able to integrate the computer-based work into the classroom activities, and also to ensure that no knowledge gap developed between the students and the teachers. The year 1983 marked the beginning of a full-scale outreach programme to eight schools (four black and four coloured) covering the entire academic year with a student participation rate of more than 500. A separate programme was organised for the June/July winter vacation. Every one of the eight schools showed at least a 15% increase in its pass-rate in both mathematics and physical science as compared to the previous years (Sinclair & Kansky, 1989).

In three separate articles of *The Cape Argus* (a local Cape Town newspaper) dated 26-04-1989, 09-05-1989 and 30-05-1989, respectively, the role that the outreach programme played in correcting "the disgraceful state of black education" (Sinclair & Kansky, 1989, p. 9) was lauded. Pupils and teachers were not only assisted in their co-operative learning endeavour, but "it is also shown that through the outreach programme UWC provides an environment which is conducive to learning away from the kind of almost unimaginable tensions which accompany the police presence in schools and communities" (p. 9).

The outreach programme has gone through various changes throughout its 20 years of existence in terms of format, target, structure, staff, and sponsors. In more recent years, outreach off-campus activities centred primarily around two contingencies, namely the traditional Mobile Computer Supported Education Centre (MOCSEC) and the Mini Computer Supported Education Centre (MICSEC).

MOCSEC, which was in use since the inception of the outreach project, became a semi-stationary unit that was placed in schools in the outer-laying areas of the Western Cape. It was used as a centre to serve a number of schools in its surroundings. This unit has, sadly, not been in use for the past two years since being vandalised and burgled when it was stationed at a school; a substantial amount of money would be required for the mobile unit to become operative again (Ogunniyi & Isaacs, 1998).

The placing of MICSECs in schools was decided upon because it had become too expensive to transport learners to the campus. To overcome this financial burden, satellite computer centres (MICSECs) were set up at schools to serve learners and teachers. In the year 2001, a total of nine MICSECs were installed to serve a total of 50 high schools in different parts of the Western Cape. Each centre consisted of approximately 15 computer terminals with a server. The computers were dedicated for the use of physical science and mathematics only because the intention with the establishment of each centre was to serve Grade 12 mathematics and physical science students and teachers. The University of the Western Cape developed the physical science software and the coursework was based on the Physical Science Syllabus for Grades 8 to 12. The mathematics component, the CAMI software, which formed the basis of the activity, was developed in South Africa around the core Mathematics Syllabus to prepare students for university entrance. The course was divided into modules in accordance with subject matter, making remedial and enriching work easier. The physical science and mathematics software made provision for the teacher to use different methods in the same class and, if needed, to teach different grades simultaneously. All MICSECs carry the same software on their networks (Ogunniyi & Isaacs, 1998).

It is against this background that this study was carried out to investigate the effectiveness of this outreach programme to serve the disadvantaged Grade 12 mathematics and physical science students in 2001, its twentieth year of existence.

[For the purpose of clarifying two terms that are used in this study: the *Outreach Project* is a university structure which has as one of its responsibilities the organisation and implementation of the *outreach programme* in mathematics and physical science to Grade 12 teachers and learners.]

1.5 The Research Problem

In South Africa, there was, and still is, a dire need to support teachers in mathematics and science in the secondary schools. This need was especially true in the historically disadvantaged schools where long-existing imbalances were still prevalent. In the context of the national strategy to bring members of the historically disadvantaged communities into mainstream science and technology fields, it was considered imperative to develop interventions that could adequately address this need.

The purpose of this study is to investigate the effectiveness of the University of the Westen Cape's outreach programme in providing support to both teachers and students in the teaching and learning of mathematics and physical science. This study looked at the role that the outreach programme played in two schools during 2001 and endeavoured to document a thick description (Guba & Lincoln, 1989) of the intended, implemented, perceived and achieved programmes for this year.

1.6 Research Questions

In addressing the purpose of this investigation, the following research questions are addressed:

1. What were the outreach programmes intended to achieve?
2. How were the computer-assisted lessons in the outreach programmes actually implemented, perceived and achieved?
3. How did students perceive their computer-assisted learning (CAL) classes?
4. What were the outcomes in mathematics and physical science as a result of the students' participation in the outreach programmes?

1.7 Significance of the Study

This investigation is significant for a number of reasons. Firstly, it will attempt to provide unique baseline data on the contribution of an outreach programme to the education of disadvantaged students in science and mathematics. Secondly, it will attempt to identify useful performance indicators with a view to developing a framework for good practice for outreach programmes throughout the country. Thirdly, it will attempt to identify the merits and limitations of the outreach programme and lessons to be learned on such projects.

1.8 Limitations

During the implementation of this study, the researcher identified a number of limitations that could have an impact on the outcomes of this study. One limitation that could influence this study was the small sample size at each school that participated in the project. This could affect the reliability of the results. Secondly, the computer-assisted learning questionnaire could not be trial-tested with a large sample, due to the limited number of schools involved in the project, limited access to these schools and the huge distances separating these schools. Thirdly, even though the language of instruction of the students at the two schools was English and therefore questionnaires were drafted in English, this language was not the students' mother tongue. More details on these aspects are provided in Section 6.5.

1.9 Structure of the Thesis

This thesis consists of six chapters.

Chapter 1: Rationale for the study

The first chapter deals with the rationale for this study by providing the background to education in South Africa since the first democratic election, the state of mathematics and science teachers and learners in the post-apartheid era, strategies developed to address problems emanating from the past and the role of the UWC outreach programme in addressing mathematics and physical science at the Grade 12 level in disadvantaged black schools. The research problem is stated and the research questions, significance of the study and limitations of the study also are identified.

Chapter 2: Literature review

This chapter considers the development of a conceptual framework to address the research problem stated in Chapter 1 and discusses the research questions that serve to elucidate the conceptual framework. A number of evaluation studies in South Africa are described and also studies where computers were employed in various contexts in school mathematics and science subjects are reviewed. Finally, a number of learning environment instruments used in computer-assisted classes are considered.

Chapter 3: Methodology

The review of the literature in Chapter 2 dealing with the development of a conceptual framework and elaborating on the research questions to address the research problem stated in Chapter 1, provide the guidelines for the methodology described in this chapter. The four research questions are used as headings and the particular methodology used to address each question is provided to inform the reader how the study was conducted. The research techniques used to collect the data were the *Computer-Assisted Learning Environment Questionnaire*, on-site observations, mining of outreach programme documents, and interviews with students, teachers, principals and Outreach Project managers.

Chapter 4: Research Findings

The methodology described in the previous chapter was used to collect the data that are reported in this chapter. The four research questions are held as headings under which the findings to address each research question are described. The research data gathered are presented as descriptions, tables and graphs.

Chapter 5: Discussion of Research Findings

The research findings for each of the four research questions that were described in Chapter 4 are interpreted and discussed in this chapter. The discussion of the findings takes place within the conceptual framework identified in Chapter 2 under the heading of each of the research questions.

Chapter 6: Summary and Conclusions.

This chapter concludes the thesis by addressing five important areas. The first section summarizes the study by providing a brief overview of its background, objectives and methodology. The second section considers the major findings of the study by briefly answering each of the research questions. The last three sections deal with the implications of this study, the limitations of the study, and suggestions for further research.

1.10 Conclusion

This chapter has presented the rationale for the study by highlighting the research problem through some background information on education in South Africa, illuminating the state of mathematics and science teachers and students after 1994, describing the history of the outreach programme run by the Outreach Project of the University of the Western Cape, and stating the research problem and the research questions used in this study. The significance and the limitations of the study also are identified.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the literature review by addressing five areas. Section 2.2 describes an outline of the theoretical framework for this study. Section 2.3 provides an overview of educational programme evaluation research within the proposed framework. Section 2.4 presents a brief review, using the framework developed in Section 2.2, of outreach support activities provided to mathematics and science students in South Africa. Section 2.5 provides a review of research literature on the use of computers in mathematics and science classrooms and Section 2.6 highlights some studies that used relevant computer learning environment instruments.

2.2 Towards a conceptual framework for this study

2.2.1 Introduction

A conceptual framework for educational evaluation originally conceptualised by Goodlad (1966), adopted by the International Association for the Evaluation of Education (Keeves, 1972; Rosier & Keeves, 1991) and further developed by Treagust (1987) and Van den Akker (1998), forms the basis of this study.

2.2.2 Investigating curriculum inquiry research

The development of the conceptual framework that is used in this study has its origin in curriculum inquiry research. Goodlad (1966), in his work towards conceptualising a curriculum, adapted Tyler's (1950) rationale by changing the prescriptive questions to guide descriptive research. More than a decade later, Goodlad (1979) indicated that the questions developed by Tyler, namely (1) What educational purposes does the educational institution seek to attain? (2) What educational experiences are provided to attain these purposes?, (3) How are these educational experiences organised?, and (4) How is the attainment of these purposes or the value of these experiences being evaluated? (p.19), identified the major elements of curriculum. It is these elements about which curriculum makers must make decisions, on which researchers must focus, and to which theorists must pay attention in formulating their theories and conceptions. Goodlad (1979, 1994) provided a conceptualisation that revealed five major domains or representations of curriculum decision-making where these three elements are addressed. These domains are ideological, societal, institutional, instructional, and experiential.

The *ideological* curriculum emerges from idealistic planning processes whereby the contents of ideological curricula are determined by examining textbooks, workbooks, teachers' guides and other related documentation. Goodlad (1979) pointed out that it is rare for the elements of some ideal curriculum to be carried through to students in their original form. Even if the content remains reasonably intact, the methodology may be distorted through the pedagogy employed. In short, those who draw up the ideal curriculum are not the ones who implement it.

The *societal* or *formal* curricula are those that gain official approval by state and local school boards. For such approval to be secured, there must necessarily be some sort of written documentation, which could include curriculum guides, state or local syllabi, adopted texts, and units of study by a curriculum committee. The formal curriculum could be a collection of ideal curricula, simply approved and passed along without modifications. The important consideration here is that it is official and has been sanctioned (Goodlad, 1979).

The *institutional* or *perceived* curricula according to Goodlad (1979) were "curricula of the mind" (p. 61). What has been officially approved for teaching and learning is not necessarily what various interested people perceive in their minds to be the curriculum. Parents differ greatly on what they think their school should teach their children and even more widely in their reactions to what they perceive the curriculum to be. The important issue is that these perceptions generate changes and frequently are taken into account in curriculum revision. However, the most significant perceptions are usually those of teachers because they are in the best positions to effect adjustments; for example, if teachers perceive that the time spent by students on computers to be minimal, they can make the necessary changes by increasing the time available in their lessons for computer use.

The *instructional* or *operational* curriculum is what goes on hour after hour, and day after day in the school and classroom. What teachers perceive the curriculum of their classrooms to be and what they are actually teaching may be quite different. Consequently, the operational curriculum too is a perceived curriculum, existing in the eye of the beholder (Goodlad, 1979).

The *experiential* curriculum refers to what students experience in the classroom. Goodlad (1979) indicated that watching children reveals very little and, on the other hand, asking them about their perceptions raises questions of validity.

Van den Akker (1998) distinguished between various curriculum interpretations which included: the *ideal* curriculum referring to the original vision underlying a curriculum (basic philosophy, rationale or mission); the *formal* curriculum providing the vision elaborated in a curriculum document (with either a prescribed/obligatory or exemplary/voluntary status); the *perceived* curriculum indicating the curriculum as interpreted by its users (especially teachers); the *operational* curriculum as the actual instruction process in the classroom, as guided by previous representations (also often referred to as the curriculum-in-action or the enacted curriculum); the *experiential* curriculum being the actual learning experiences of the students; and the *attained* curriculum describing the resulting learning outcomes of the students. This typology of curriculum representations was found to be particularly instructive for analysing the roots and fruits of numerous curriculum innovation efforts in science education over a number of decades (van den Akker, 1998).

Treagust (1987) used four curriculum presentations to develop a framework to witness the teaching practices of two Biology teachers, one in a government school, and the other in a private Catholic school. He used the framework in order to identify teaching practices, which could be considered exemplary and worthy of attention for and analysis by other teachers and teacher educators. The investigation addressed specific aspects of the *intended* curriculum, described briefly in terms of the syllabus, the textbooks, teaching foci and the nature of the academic work described by teachers; the *implemented* curriculum based on the qualitative and quantitative data from classroom observations; the *perceived* curriculum described in terms of student responses to learning environment questionnaires and to interview questions; and the *achieved* curriculum obtained from teacher records of student progress and from interviews with teachers and students.

2.2.3 Summary

In the above research in curriculum inquiry, the various curriculum representations have been described by different terms that essentially refer to the same aspect of the curriculum, as summarised in Table 2.01. Subsequently, in order to investigate the effectiveness of the outreach programme for mathematics and physical science students, those representations described by Treagust (1987) were used to form the framework of this study distinguishing between the intended, implemented, perceived and achieved programmes. The intended programme included the ideological and societal (or formal) curricula identified by Goodlad (1979) as well as the ideal and formal curriculum representations by van den Akker (1998). The implemented programme reflected Goodlad's instructional (or operational) curriculum and van den Akker's operational curriculum. The perceived programme encompassed the institutional (or perceived) and experiential curricula identified by Goodlad and the perceived curriculum identified by van den Akker. The achieved programme was synonymous with van den Akker's attained and experiential curricula.

In brief, the four aspects of the theoretical framework used as a template for this investigation are defined as the *Intended Programme* describing the original vision underlying the programme, in the form of the stated objectives or programme theory; the *Implemented Programme* including the actual instructional process as implemented; the *Perceived Programme* referring to the actual learning experiences as perceived and/or experienced by the learners; and the *Achieved Programme* highlighting the resulting learning outcomes of the learners after participating in the outreach programme.

Table 2.01
Summary of curriculum representations leading to the development of a theoretical framework for this study

Goodlad's curriculum representation	Van den Akker's curriculum representation	Treagust's curriculum representation	Programme representation in this study
Ideological Societal or formal curricula	Ideal Formal curricula	Intended curriculum	Intended programme
Instructional or operational curriculum	Operational curriculum	Implemented curriculum	Implemented programme
Perceived or institutional Experiential curricula	Perceived curriculum	Perceived curriculum	Perceived programme
	Attained Experiential curricula	Achieved curriculum	Achieved programme

As outlined in Section 3.2, four research questions were identified to investigate the role of the outreach programmes at two disadvantaged South African schools. Each research question specifically addresses one of the four representations. The following section describes the important aspects of each of the programme representations identified above.

2.3 An overview of programme evaluation research

2.3.1 Definition of programme evaluation

Programme evaluation is the use of research procedures to investigate the effectiveness of an intervention programme that was developed in accordance with a need identified in society and implemented to address that need (Rossi, Freeman & Lipsey, 1999, p. 20). In the case of this study, the outreach programme was developed to address the needs of mathematics and physical science teachers and students in disadvantaged schools; the implementation of the outreach programme in 2001 was evaluated for its effectiveness in terms of its stated objectives.

2.3.2 Addressing intention in programme evaluation

The goals of programme evaluation

The extent to which an educational programme, like the outreach programme in this study, meets its goals and objectives is the central question in programme evaluation. According to Rossi et al. (1999), the distinction between goals and objectives is critical. Goals are typically stated by programmes in broad and rather abstract terms. For evaluation purposes, such broad goals must be translated into concrete statements that specify the condition to be dealt with together with one or more measurable criteria of success. Evaluators generally refer to these more specific statements of measurable attainments as objectives.

Kirschner (1975) developed four helpful techniques for the writing of useful objectives. The first deals with the use of strong verbs. A strong verb is an action-oriented verb that describes an observable or measurable behaviour that will occur. For example, 'to increase the use of computers at each centre' is an action-oriented statement or behaviour that can be observed. In contrast, 'to promote greater use of computers at each centre' is a weaker and less specific statement. The term promote is subject to many interpretations. A second useful suggestion for writing a clear objective is to state only a single aim or purpose. Most programmes will, of course, have multiple objectives, but within each objective a single purpose should be delineated. An objective that states two or more purposes or desired outcomes may well require different implementation and assessment strategies, making achievement of the objective difficult.

A third technique contributing to a useful objective is to specify a single end-product or result. A clearly written objective must have both a single aim and a single end-product or result. Kirschner (1975) maintained that those involved in writing and evaluating objectives need to keep two questions in mind. Firstly, is the objective clear and unambiguous? Secondly, what visible, measurable, or tangible results are present as evidence that the objective has been met? In the final instance, it is useful to specify a deadline for expected achievement of the objective.

Many programme evaluators stress the importance of inclusiveness of all stakeholders in the evaluation process (Chelimsky, 1998; Mertens, 1998; Stanfield, 1998; Weiss, 1998). For example, Mertens (1998) argued that inclusive evaluations have the potential for stronger objectivity and increased rigor because all stakeholders have been consulted in the process. Therefore, to conduct an inclusive evaluation it is necessary to both know the diversity within the community that is impacted by the evaluation, and appropriate ways for gathering data from diverse sub-groups. Programme managers, programme officers, sponsors, school principals, teachers, parents, community members and students who participated and are participating in the outreach programme are considered as stakeholders in this investigation.

An important task for the evaluator, therefore, is to collaborate with programme managers and other stakeholders to identify the programme goals and transform overly broad, ambiguous, or idealistic representations of goals into clear, explicit, concrete statements of objectives. The more closely the objectives describe situations that can be directly and reliably observed, the more likely it is that a meaningful evaluation will result. It is important that the evaluator and stakeholders agree on programme objectives that will be used to measure the success of the programme. For example, one of the broad goals of the outreach programme was to improve the learning and teaching of mathematics and physical science (see Section 4.2). After consultation with the outreach programme manager, this goal was subsequently broken into six objectives that were more measurable, for instance, one of these objectives was 'to improve the achievements of students in mathematics and physical science in the external matriculation examination'. In addition, in this study a programme theory (described in Section 4.2) was proposed to illustrate the philosophy behind the formation of the outreach programme, developed as one facet of the Outreach Project in 1982 but which was still relevant in South Africa in 2001.

Programme theory

Educational evaluation is about assessing how an educational programme is performing, whether at some macro-level or with regard to specific functions and aspects. Most evaluation questions are, therefore, variations of the theme of 'Is what's supposed to be happening actually happening?' For example, 'Are the intended target participants being reached?', 'Are the services adequately delivered' or 'Are the goals being met?'. A useful analysis of a programme for purposes of identifying relevant and important evaluation questions is to delineate in some detail what is supposed to be happening in a programme. The evaluator can construct a representation or a conceptual model of how the programme is expected to work and the connections presumed between its various activities and functions and the social benefits it is intended to produce. This representation of the programme assumptions and expectations can then be used to identify those aspects of the programme most essential to effective performance. This representation is referred to as programme theory (Rossi et al., 1999).

Several studies reported that those engaged in evaluation research often fail to make explicit, before evaluating a programme, the theoretical underpinnings of the programme and the problem it is designed to address (Chen & Rossi, 1983; Cole, 1999; Patton, 1986, 1987; Torvatn, 1999). In response to this recommendation, a number of researchers have proposed the need to conduct theory-based evaluation because theory plays a major role in guiding programme design and evaluation (Chen, 1990; Fitz-Gibbon & Morris, 1996; Weiss, 1996). The concern in programme evaluation has been shifting from demonstrating the causal connection between the programme and the intended outcomes (that is, determining that the programme works) to examining the processes underlying the programme effects. The processes explain how the programme exerts its influence on the anticipated effects and identify what makes a programme work (Chen, 1990; Cook, 1993; Lipsey, 1993). The emphasis on understanding how a programme works and what makes it work, in addition to knowing whether or not it works, led to the development of the theory-driven approach to programme evaluation (Sidani & Sechrest, 1999).

Chen (1990) defined programme theory as "a specification of what must be done to achieve the desired goals, what other important impacts also may be anticipated, and how these goals and impacts would be generated" (p. 43). This definition implies that this theory consists of two parts. The first part dealt with what the structure of a programme should be, including such things as treatments, outcomes, and implementation processes that are related to the values of the programme. The second part deals with what are the underlying causal mechanisms that link the relationships among programme treatment, implementation processes, and outcomes. Chen (1990) argued that any social or intervention programme is the purposive and organised effort to intervene in an ongoing social process of solving a problem or providing a service. The question of how to structure the organised efforts appropriately and why the organised efforts lead to the desired outcomes implies that the programme operated under some theory. Although this theory is frequently implicit or unsystematic, it provides general guidance for the formation of the programme and explained how the programme is supposed to work.

According to advocates of this approach, if a programme's theory of action (McLaughlin & Jordan, 1999) was not carefully explicated and examined in the normal course of an evaluation, a number of difficulties could arise. For example, without knowing the preconceived relationship between a programme's delivery and its effects, it is difficult to determine whether the programme was delivered as planned and whether or not it produced the intended effects (Chen, 1990; Chen & Rossi, 1983; McLaughlin & Jordan, 1999; Weiss, 1996). Furthermore, when there is no explicit link between the activities of the programme and their intended effects on the problem targeted by the programme, the information generated by the evaluation is of little value in improving the programme (Fitz-Gibbon & Morris, 1996; McLaughlin & Jordan, 1999). Likewise, when successes or failures cannot be attributed to individual programme components, it is almost impossible to project the results of the evaluation to other programme efforts or to know which parts made a difference and which parts did not (Chen, 1990; Weiss, 1996). This last point is particularly important if one wants to enhance aspects of the outreach programme described in this thesis that work and/or improve or eliminate components that do not work.

Cole (1999) pointed out another important reason (previously identified by Provus, 1971) to examine programme theory, namely, that if a programme is successful others will want to copy it. In this thesis, therefore, it is important to know the exact processes of the outreach programme activities so that they could be reproduced. In brief, without the benefit of a clearly articulated theory about how a programme is supposed to work, one cannot ascertain whether it did work, and why it did or did not produce the intended benefits.

2.3.3 Addressing implementation in evaluation

Implementation, which essentially is an evaluation of the intended processes involved, verifies what the programme is and whether or not it is delivered as intended to the targeted recipients (Scheirer, 1994). Implementation does not attempt to assess the effects of the programme on the recipients, which is the domain of outcomes evaluation. Evaluation specialists typically conduct implementation evaluation as a separate project that may involve programme personnel but it is not integrated into their daily routine. When completed and, while underway, process evaluation generally provides the information about the programme performance to programme managers and other stakeholders.

Trochim (1984) argued that a major problem in documenting programme implementation involves determining what type of specific instruction students received. Any attempt to document the type of instruction students received is likely to improve the quality of evaluation, although it may pose political and managerial difficulties. Also, the setting in which students receive the instruction has important implications for analysis and should therefore be documented where possible. The nature of the subject matter introduced during a programme makes a difference and should be accounted for because this has further implication for the evaluation report. In support of this, Trochim (1984) indicated that the skills needed for a programme that introduce, for example, reading as opposed to mathematics are different, and that this difference should be recorded. The evaluator also should consider other programmes that are operating in tandem with the one being evaluated. Goals and objectives that may have an overlapping effect will influence the validity and reliability of the evaluation outcomes.

A combination of methods can be employed during site-visits to carry out implementation evaluation. These procedures normally include observations, video- and audio-taping, drawing up of field notes and in-depth interviews of key participants (Rossi et al., 1999).

2.3.4 Addressing recipient perceptions in evaluation

It is important for programme managers to obtain feedback from participants in their programmes in order to adapt the implementation procedures in accordance with the needs of participants. In the same way, this study made use of a questionnaire and interviews to obtain students' perception of the outreach programme. In addition, the communication that arises naturally from such evaluation is a vital source of information to programme organisers in order to become more aware of the participants' needs, views, problems and expectations. Therefore, collecting data about programme performance directly from the participants themselves is extremely valuable for a number of reasons, including the distinctive perspective that participants often have on a programme. Securing participant data may be necessary for programme organisers to know what is important to recipients, including their satisfaction with and understanding of the intervention. In addition, it may be the only way of finding out what was actually delivered (Harris & Bell, 1994).

Papineau and Kiely (1996) pointed out that in many programmes the intended programme is not always identical with the implemented programme. Thus it may be critical to interview participants to determine their perception of the implemented programme. For complex interventions, it also may be necessary to ascertain participants' understanding of the interventions and the programme's operating rules. In short, it is important to establish not only that designated services have been delivered but also that they were received, used, and understood as intended. There are times when participants' satisfaction with a programme is a key indicator in monitoring programme implementation.

According to Trochim (2000), many of the problems related to measuring a programme are involved with the seemingly mundane task of determining who actually received the service. These problems may include difficulties such as determining who received the service as opposed to who should have received it. Sometimes teachers may simply have too many students and not all students are accommodated in the implementation of the programme. Also, as was reported in Section 4.4 of this study, students who enter the school during the school year would have different perceptions than those were part of the programme from the beginning. Equally difficult to determine are those persons who did not receive the programme or those, for one or other reason, simply did not participate in the programme.

Data for determining the perception of participants can be obtained by interviews and questionnaires on an individual level, and through surveys and group discussions on a systemic level (Rossi et al., 1999).

2.3.5 Addressing outcomes in evaluation

An outcome evaluation or impact assessment gauges the extent to which a programme produces the intended improvements in the social conditions it addresses (Rossi et al., 1999; Trochim, 2000). The evaluation questions around which outcome evaluation is organised relate to such matters as whether the desired programme outcomes were attained, whether the programme was effective in producing change in the social conditions targeted, and whether programme impact included unintended side effects. These questions assume a set of operationally defined objectives and criteria of success. The objectives may be social-behavioural ones, such as increasing the students' interaction with mathematics and physical science software on computers; or they may be physical, such as increasing the number of computers available in each centre. Outcome evaluations are essential when there is an interest in determining if a programme is effective in its efforts to address a target problem, to compare the effectiveness of different programmes, or to test the utility of new efforts to address a particular community problem (Mohr, 1995).

To conduct an outcomes evaluation, the evaluator needs a plan for collecting data that will allow a persuasive demonstration that the observed changes are a function of the intervention and cannot readily be accounted for in other ways. This procedure requires a careful specification of the outcome variables on which programme effects may occur, development of measures for those variables, and a research design that not only establishes the status of programme recipients on those measures but also estimates what their status would be had they not received the intervention. This status, known as the counterfactual, contributes greatly to the complexity of outcomes evaluation because it describes a condition contrary to what actually happened to programme recipients (Rossi, 1997; Trochim, 2000). In the case of this study, the counterfactual would refer to the status of students in the absence of the Mini-Computer Supported Education Centres.

Specific outcomes evaluation designs differ considerably. It is possible to use classic experimental designs with control and experimental groups randomly constituted, each receiving different interventions. It is sometimes more practical to use quantitative approaches to isolate programme effects rather than true experiments. Therefore, non-randomised, quasi-experiment and other non-experimental methods are commonly used in outcomes evaluation. According to Trochim (1984), such non-experimental designs may provide reasonable estimates of effects.

Outcomes evaluation is often combined with implementation evaluation so that a linkage can be established between the implementation of the programme and the observed outcomes (Rossi et al., 1999). When implementation evaluation is disregarded during the outcomes evaluation exercise, it is often referred to as black box evaluation. This term is used because the evaluator may learn what the programme effects are but does not know anything about the processes that produces the effects (Trochim, 1984).

Ascertaining when an outcomes evaluation is appropriate, and what evaluation design to use, can sometimes pose a challenge to evaluators (Trochim, 2000). It is generally appropriate only when there is an important purpose to be served by learning about programme effects. This purpose may be because the programme concept is innovative and promising or in circumstances where identifiable decision-makers have a likelihood of actually using evidence about programme outcomes as a basis for significant action.

If the need for outcome information is sufficient to justify the effort of an outcome evaluation, there is still the question of whether the programme circumstances are suitable for such an assessment. It makes little sense, for instance, to establish the impact of a programme that is not well structured or cannot be adequately addressed. Even if positive effects are found under such circumstances, ambiguity remains about what programme features caused them or how they would be replicated elsewhere. Outcome evaluation, therefore, is most appropriate for mature, stable programmes with a well-defined programme model and a clear use for the results that justifies the effort required to conduct this form of evaluation. The most useful impact assessment results are for well-structured, well-documented programmes believed to have valuable effects that must be determined to support important decisions about the programme or the programme model (Rossi, 1997; Trochim, 2000).

2.3.6 Summary

The above four programme representations used to outline the evaluation of programmes, or in the case of this study an outreach programme for mathematics and physical science, provide a detailed description of what each representation entails. A summary of the four programme representations as it applies to this study is provided in Table 2.02.

Table 2.02
Summary of programme representations

Intended programme	Implemented programme	Perceived programme	Achieved programme
Goals, objectives and programme theory	Implementation of the MICSECs in lessons	Student perception of CAL classes	Teaching and learning outcomes
Programme documents and interviews with principals and programme managers	Observations of lessons during on-site visits	CALEQ and student interviews	Matriculation examination results and teacher interviews
What must be measured?	How did implementation take place?	How did students experience the implemented programme?	Did the outreach programme have the desired effect?

Note: The questions above are simplified versions of the research questions in Section 1.6.

2.4 Evaluation research of mathematics and science outreach programmes in South Africa

2.4.1 Introduction

Although many programmes are implemented in South Africa to support learners, especially in mathematics and science, little research is reported in the South African education literature that evaluates the effectiveness of these programmes. The author examined the proceedings of the last three years of the most comprehensive science, mathematics and technology conference in Southern Africa and, in this section, provides a brief review of the outreach support activities for mathematics and science students that were reported. The theoretical framework developed in section 2.2 is used to analyse these evaluation studies.

2.4.2 Selected studies of outreach programmes

The following studies reported in the South African literature are used to examine the applicability of the theoretical framework to evaluate the effectiveness of outreach programmes in mathematics and science at schools.

The impact of a technology project on the self-esteem of learners was investigated by Sookdin, Mahlomaholo, Nkoane and Khabanyane (2000). The study was directed at evaluating the impact of the Bloemfontein Technology Project on the attitudes of students towards science, mathematics and technology as school subjects with the view to increasing the number of students from disadvantaged communities in science, engineering and technology careers (*intended programme*). One group consisting of eight students was exposed to the technology project run by Vista University in Bloemfontein; another group of eight students who did not take part in the project served as control. In this project, students were supported by having additional classes in mathematics, technology and science taught by experienced educators in these fields. The students also were exposed to career possibilities through contact with industry (*implemented programme*). Students' perceptions were elicited through open-ended in-depth interviews (*perceived programme*). The authors found that students in the experimental group exhibited greater motivation, could make clear choices of career, and developed a general positive attitude towards mathematics, science and technology as school subjects. The control group was found to consider a pass mark in each of these subjects as sufficient whereas the experimental group wanted to achieve better in order to be eligible to enter tertiary institutions and/or to follow the careers of their choice (*achieved programme*).

Hartley (2000) investigated the efficacy of Open Days as interventions to raise the engineering awareness of Grade 9 students (*intended programme*). A sample of 40 students from a disadvantaged school were specifically invited to the university to assist them in their subject choices, especially with regard to mathematics and physical science, for future career purposes. Exhibitions were held at the engineering faculty and students were observed as they interacted with exhibitions and the members of staff who were on hand to explain careers and requirements for study (*implemented programme*). Students' perceptions were measured with open-ended questionnaires, where students were allowed to write in their perceptions, used as pre- and posttests and the accompanying teacher was interviewed for his impressions (*perceived programme*). Analysis of the pre- and posttests results revealed that the level of engineering awareness of students increased. Post-posttest results indicated that the awareness was sustained over a three-month period and that all but five out of the 40 students chose mathematics and physical science as subjects for Grade 10. The remaining five students chose commerce *(achieved programme)*.

In another study, Hartley (2001) investigated the science related-attitudes of a group of Grade 11 students' in response to a science, engineering and technology (SET) focus-week (*intended programme*). Students were allowed to visit exhibitions that were held for a week at a central venue and engage with the many interactive exhibits as well as with the people from tertiary institutions and industry who were presenting their respective fields (*implemented programme*). The *Test for Science-Related Attitudes Questionnaire* (TOSRA) was used as pre-, post- and delayed posttests to determine student attitudes (*perceived programme*). The study found that students' science-related attitudes increased from pretest (two weeks before the SET focus-week) to posttest (two weeks after SET focus-week). The delayed posttest (after two months) indicated that students' science-related attitudes dropped back to pretest levels. The author concluded that more research is needed to identify SET programmes that would have a sustained effect on students' attitudes (*achieved programme*).

Table 2.03
A comparison of four South African studies using the theoretical framework

	Intended	Implemented	Perceived	Achieved
Sookdin et al. (2000)	Improving student attitudes towards science, mathematics and technology (SMT)	Bloemfontein technology project involving additional classes in SMT	Open-ended in-depth interviews of 8 students as experiment and 8 students as control	Students in the experimental group had more positive attitudes towards SMT as school subjects
Hartley (2000)	Efficacy of open days to improve engineering awareness	Exhibitions at Open Day	Open-ended questionnaires as pre-, post and delayed posttests in Grade 9 students	Experimental group had an increased awareness, sustained over 3 months
Hartley (2001)	Effect of science focus-week on students' science-related attitudes	Exhibitions, interactions and activities at an organised science focus-week in the Western Cape	Test for science-related attitudes (TOSRA) of Grade 11 students as pre-, post- and delayed posttests	Students in experimental group had increased science-related attitudes after two weeks but dropped back to pretest levels after two months
Mahapa (2000)	Effect of a science centre exhibit on student attitudes and their conception of pressure	Student interaction with science centre exhibit	Students completed a visitor attitude scale as pre- and posttest, and a worksheet on the exhibit	Student had more positive attitudes towards science after their visit but did not change their prior conception of pressure.

In an investigation to determine how science centre exhibits affected the attitude of learners and whether the learners experienced any changes of scientific concepts after interacting with exhibits (*intended programme*), Mahapa (2000) engaged a sample of 100 high school students who visited the science centre and interacted with the science exhibits. The interaction of students with one exhibit (squeezing water bottles) in particular was chosen for closer scrutiny (*implemented programme*). Before the visit, students were requested to complete a pretest questionnaire consisting of Likert-type questions and which was used to assess students' attitudes towards science and technology, their interest in science and technology careers and the type of school subjects they liked. The questionnaire also was administered as a posttest. In addition, students were requested to complete a worksheet about the glass and plastic water bottles while interacting with the exhibit and their interactions were observed and recorded (*perceived programme*). The questionnaire results reflected a more positive attitude towards science and technology from pretest to posttest. Students maintained their prior conception of pressure in the two bottles and used different reasoning to keep their conception. The author concluded that more opportunities must be made available to challenge students' alternative conceptions (*achieved programme*).

2.4.3 Summary

The four studies reported dealt with the provision of additional opportunities to students to increase the participation of historically disadvantaged students in science, engineering and technology careers. A summary of the studies in accordance with the research framework developed for this study is presented in Table 2.03.

2.5 Research into the use of computers in mathematics and science classrooms

2.5.1 Introduction

This section outlines the various ways in which computers have been employed in the teaching and learning of mathematics and physical science; physical science in the South African school context consists of both chemistry and physics.

2.5.2 Application of computers in the teaching and learning process

With the increasing inclusion of new technologies in classrooms, teachers are challenged to adjust their existing modes of teaching into ones that give more autonomy and initiative to their students. The mathematics and science curricula are beginning to relate not only to content, but also to learning and teaching styles.

While the initial role of the computer as a tool has a part to play in the classroom, teachers also are challenged to use different strategies such as computer-assisted learning (CAL) and computer-assisted instruction (CAI) to help students with their learning. Although the computer is able to provide new opportunities for the teaching of mathematics and science, the onus is on teachers and educators to overcome the difficulties of using these activities (Cornu, 1995).

Computer-assisted instruction and computer-assisted learning refer to the use of computers in the teaching and learning process. For almost two decades, researchers have claimed that appropriate courseware could help teachers provide better instruction to their students (Bangerdrowns, Kulik & Kulik, 1985) by introducing new materials, allowing practice of new skills and providing review and remediation. Indeed, studies by Johnson (1995), McCoy (1991) and Sasser (1990) showed that the use of computers in the instructional process does produce significantly greater achievement in science and mathematics. However, extensive research and planning are needed to guide the educational system in its transitions to the use of new technology, including revision of curricula in schools, so as to integrate computer use as part of the educational activity (Duchateau, 1995).

Bear (1984) considered the attributes of the courseware in the use of CAI as critical to its success. While many variables influence the success of CAI, it is safe to assume that the type of CAI used, as well as the subject matter of investigation, will affect the outcomes of the CAI research (Hodgson, 1995). In looking specifically at studies in which CAI has been used in chemistry education, some research showed that CAI served to enhance achievement (Geban, Askar & Ozkan, 1992; Prey, 1996).

Interactive multimedia in combination with computer graphical user interfaces provide a learning environment that, in many instances, meets the need of teachers and learners of physical science. Loss, Zadnik and Treagust (1994) explored these possibilities and developed an interactive multimedia physics instruction programme. A major outcome of their research was that the most commonly used interactive multimedia programmes have limited applicability in teaching and learning physical science due to the abstract and counter-intuitive nature of many (even elementary) physical science concepts. The authors concluded that the limitations of these multimedia design bases were unlikely to be resolved by the application of more advanced hardware or software tools. Rather, these authors recommended that significant research be directed into instructional designs appropriate to the physical sciences and to the development of effective learning interactions. This finding also was supported by a study into the limitations of interactive multimedia by Nash and Alexander (1995).

Yalcinalp, Geban and Ozkan (1995) investigated the effect of CAI when used as a supplement to classroom instruction for the purpose of improving secondary-school students' understanding of chemical formulas and mole-related problems. In addition, the effect of CAI on students' attitudes to chemistry as a school subject and to CAI itself was investigated. These authors found that the CAI approach enhanced students' problem solving skills as well as enhanced attitudes towards chemistry as a school subject. The computer programme allowed students to process information actively to comprehend it, which was consistent with Ausubel's (1960) theory that learning is an active process, and resulted in improved students' attitudes toward computerised instruction. Yalcinalp et al. (1995) concluded that CAI could be used to assist in the teaching and learning process and eliminate the time that teachers have traditionally spent solving problems on the chalkboard. Furthermore, they suggested that CAI material should conform to the curriculum if it is to enhance achievement and students' ability to conceptualise science concepts.

In a review on the use of computers in mathematics education, Bennett (1992) indicated that some of these findings suggested that computer-assisted lessons should require students to work co-operatively rather than competitively or individually and that students who used computers are probably more self-assured, confident and independent. Some studies cautioned that the gap between advantaged and disadvantaged students might widen and that the computer will not overcome the effect of the teacher. Studies stressed that computers should be used as tools to improve students' problem solving skills and that it would be the combination of a positive teacher and a computer that would produce the better result. A number of studies concluded that students who were taught with computers developed very positive attitudes towards the computer and to mathematics as a school subject.

During the 1970s and 1980s, educators were often unabatedly enthusiastic about the possibilities for learning with computers (Barman, 1993; Roth, Woszczyna & Smith, 1996). Now, a much more reflective attitude questions the possibilities for content and skill learning as a direct function of software content and interface (Jackson, Edwards & Berger, 1993; Salinger, 1991). Research suggests that computer displays based on diagrams current in scientific theory talk (such as vector or ray diagrams) facilitate learning, especially when they serve as a backdrop and referent for students' conversations, and when they serve to coordinate students' verbal and non-verbal communicative acts (Bendall, Galili & Goldberg, 1993; Johnson, 1995; Roschelle, 1992). Roth et al. (1996) argued that past research has neglected the setting effects of computers and software in the knowing and learning of students; in other words, very little is known about how computers, as a setting of cognition, hinder or support this cognition (Jackson et al., 1993). Overall, Roth et al. (1996) maintained that little educational research has dealt with the function of computers and their displays on the collaborative cognition of students, their conversations, and the structure of their interactions.

To address this void, Roth et al. (1996) designed a study that investigated how computers and a modelling software programme contributed to students' interactions and learning in an 11-week unit on mechanics and kinematics as part of an introductory Canadian high school physics course for 46 Grade 11 students. The course was premised on the assumption that learning means to achieve a certain level of competence in talking physics. The teacher planned activities that provided students with opportunities to engage each other in science conversations. The opportunities existed in the context of three types of activities, namely, (a) open investigations of motion phenomena of the students' choice, (b) computer-based micro-world explorations, and (c) collaborative concept mapping with the main concept labels of the unit.

Roth et al. (1996) found that the computer display afforded students the possibility for constructing a coherent conversation. Because it is often difficult to make sure that all participants talk about the same thing as they converse about conceptual issues in real time, the physical presence of the object of talk provided students with a means for coordinating just what they are talking about. The immediacy of the display allowed the students to point to specific objects, and the animation afforded a replay of motion by means of gesture. Through this immediacy, the interface became an object of conversation immediately available. Thus, the conversations were about something actually present rather than about some objects removed from the students' experiences. Students coordinated their conversation directly over and about the display which provided an anchor for the conversational topic (Erickson, 1982; Johnson, 1995), by testing their understanding and repairing possible mishearing in the presence of the object of the conversation. Roth et al. (1996) also found that the computer environment was sometimes not user-friendly so that students spent more time learning the software rather than physics, and limited the interactions within groups of more than two students. It was concluded that while computer environments have some potential as learning tools, they also limit interactions in significant ways, rendering them less than ideal for everyday classroom use.

The extent to which a computerised learning environment could facilitate students' development of higher-level thinking skills associated with scientific inquiry was investigated by Maor and Taylor (1995). In two classes, students' interactions with a scientific database were closely monitored, and the mediating roles of the seven high school teachers' epistemologies were examined. The results of their study indicated that although the use of the computers in inquiry-based science classrooms offered the potential to facilitate students' higher-level learning, the teachers' epistemologies continued to perform a central role in mediating the quality of student learning. The authors concluded that teachers who adopted constructivist pedagogies which promoted both the personal and social processes of knowledge construction were more likely to enable students to better exploit the potential of computerised data bases for developing the higher-level thinking skills associated with scientific inquiry.

A computer-assisted instructional package, based on a conceptual change model to challenge misconceptions of chemical equilibrium held by Year 12 students from the Maldives, was used by Hameed, Hackling and Garnett (1993). The research also examined the extent to which misconceptions of chemical equilibrium changed by working through the CAI programme based on a conceptual change model.

Significant changes in student conceptions did take place and were likely to be the result of the intervention. The delayed post-test showed that the conceptual change achieved was stable over a period of one month. The authors concluded that computers are suitable for conceptual change instruction by providing for individualised instruction that allows students to work at their own rate and receive individualised feedback.

Using computer-supported predict-observe-explain (POE) tasks presented as abstract computer simulations to investigate conceptual change, Tao and Gunstone (1999) required students from a Grade 10 science class to predict what would happen if certain changes were made in their Force and Motion microworld. A conceptual test was administered as a pre-, post-, and delayed posttest to determine students' conceptual change. Students worked in pairs on the programmes carrying out predict-observe-explain tasks according to worksheets while their conversations were recorded during this process. A range of data was collected at various junctures during instruction. All the conceptual snapshots collected at different junctures together provided a delineation of the students' conceptual development. The authors found that students alternated between alternative and scientific conceptions from one context to another during instruction, that is, their conceptual change was context-dependent and unstable. The few students who achieved context-independent and stable conceptual change appeared to be able to perceive what was common and general about scientific conceptions across contexts.

Goldberg and Bendall (1996) reported on a computer simulation programme used for facilitating learning in geometrical optics. In this programme, students were presented with a situation where they needed to make a prediction about certain optics problems. They then observed what happened on the computer simulation, evaluated their observation and compared it with their prediction. Overall, students who had the computer-videodisc instruction drew diagrams that were more accurate than those drawn by students who did not have the opportunity to work with the computer-videodiscs.

In an investigation to determine how students and teachers perceived the use of POE within a computer environment, Kearney, Treagust, Yeo and Zadnik (2001) used sixteen POE tasks illustrating projectile motion. Students and their teacher from two science classes, one Year 10 and the other a Year 11 class, participated in the research. The authors found that the use of the computer environment to present the POE tasks had a noticeable impact on the whole classroom environment. Students manipulated the demonstrations in small groups instead of in a whole class situation, which gave students more control of the POE tasks and the pace of each POE task. This approach also gave students the time and confidence to thoroughly discuss predictions, reasons, observations and explanations. This result supported the findings of Hameed et al. (1983) described above. In a separate part of this study, Kearney & Treagust (2000) endeavoured to analyse students' conversations and written responses, investigating the use of the computer-mediated POE tasks to elicit student conceptions and encourage reflections on these ideas. The authors found that the programme mediated meaningful discussions about students' ideas and common alternative conceptions about force and motion were elicited.

Atwater and Wiggins (1995) reported that although a majority of urban African-American students held favourable attitudes towards science careers, only a small percentage held favourable attitudes toward classroom science. Haberman (1991) argued that urban teachers have tremendous constraints on their teaching, including large class sizes, inadequate preparation time, lower levels of training, inadequate classroom space, and outdated materials, and that often these constraints resulted in what he called a pedagogy of poverty. This pedagogy was characterised by teacher-controlled activities. A national study conducted by Becker (2000) documented that students in low-income areas often used computers for repetitive activities, whereas students in high-income areas often used technology for higher-order thinking, problem solving, and other intellectually challenging activities. Similarly, teachers in low socio-economic status schools were more likely to use technology for repetitive practices, whereas teachers in high socio-economic status schools were more likely to use technology to foster creativity or problem solving.

In an investigation to examine the implementation of a technology-rich inquiry weather programme in 19 urban American classrooms, Songer, Lee and Kam (2002) reported that their study provided evidence that a systemic programme for fostering inquiry including the accompanying professional development activities could overcome many of the norms and practices associated with the pedagogy of poverty, including norms of how science is taught and how technology is used for learning. Although significant learning results were found in classrooms, a number of barriers persisted. These barriers, for example, inadequate space and materials, low content knowledge of teachers or large class sizes, were unfortunately outside the control of the researchers. These barriers also are commonplace in many South African schools including the two schools involved in this study.

A cross cultural study of Zimbabwean teachers' and students' views on the application of computers in science classes found that teachers were hesitant to discuss the incorporation of computers in their classes (Mushayikwa, 2000). The author accounted for this hesitation to the teachers' limited exposure to computers. Nevertheless, students were quite positive and receptive towards using computers in science classes and were less guarded than their teachers and more optimistic of the benefits. In a survey to determine the extent to which computers were used by mathematics teachers in Zimbabwe Tsvigu and Maswera (2001) concluded that most mathematics teachers were yet to realise the effectiveness of computers in mathematics education in schools.

2.5.3 Summary

From the science and mathematics education literature, it appears that computers are used in various contexts to improve learning, to understand learning and to investigate learning strategies. Despite the fact that many of the earlier studies reported the potential of introducing computers to improve student learning, many contemporary researchers have cautioned that more research is needed into issues like appropriate software programmes, the teaching strategies used with computers, and student perceptions of computer-assisted learning.

2.6 Computer learning environments

2.6.1 Introduction

In reviewing the direction and extent of research on learning environments in schools, Ellett (1986) urged investigators to improve on the small number of studies of computers and their impact on student learning. Lancy (1987) noted that very little is known about the effect of computers on the learning environment and stated that to study an ongoing computer learning environment unobtrusively may require tradition to have been established. This may take some years to evaluate and certainly holds true for South Africa today. An important issue facing those who implement the computer-assisted instruction (CAI) model is the question of scale. The extent to which computers are available, periods for which computers can be used (i.e. demand by different subjects) and the incorporation of the available computers in large classes are some of the issues facing teachers who contemplate using CAI. Since the mid 1980s a number of studies have been conducted with CAI and its effect on the learning environment. Some of these studies are reported in the next section.

2.6.2 Computer classroom environment instruments

One of the first published studies that used an instrument for assessing a computer-based classroom was by Maor and Fraser (1993). They examined the perceptions held by 120 students and seven teachers of the learning environment in their inquiry-based computer classrooms by administering the *Computer Classroom Environment Inventory* (CCEI). This inventory measured the classroom environment on five scales — Investigation, Open-Endedness, Organisation, Material Environment and Satisfaction — had six items in each scale, and the responses were on a five point Likert scale: Never, Seldom, Sometimes, Often and Very Often. Both student and instructor forms of the questionnaire were designed. Within the inquiry-based computer classroom, the authors found an increase in student-perceived investigation and open-endedness, indicating a supportive learning environment for the development of inquiry learning and also the promotion of higher-level thinking skills, which was corroborated by the interpretive part of their study. Although teachers' and students' perceptions showed a similar trend, teachers' perceptions were more positive than those of the students in terms of open-endedness, organisation and material environment. Maor and Fraser reported a change in the teacher's role from lecturer and conclusion-drawer to initiator and facilitator while using the computer to teach science; similar findings were reported by Ryba and Anderson (1990). Two of the scales used in this instrument were found applicable to the two South African schools in this study. These two scales — Investigation and Open-Endedness (see Section 3.6.3) — were consequently drafted into the *Computer-Assisted Learning Environment Questionnaire* (CALEQ) that was used to identify student perceptions of their learning environment in each of the two computer centres.

During the same period, Teh and Fraser (1993) studied the learning environment associated with the use of computer-assisted learning in school geography classes in Singapore. This study was different from traditional studies in learning environments in that firstly, the use of CAL in geography education has been sparse relative to other disciplines, secondly, research on CAL in geography education in Singapore hitherto has been non-existent, and thirdly, only a very small amount of classroom environment research has previously been undertaken in Singapore. The main purposes of this study was to (1) develop and validate a new instrument for assessing the unique learning environment of computer-assisted learning classrooms; (2) to evaluate an innovation in computer-assisted learning for teaching the topic of decision-making in geography in Singapore schools, in terms of impact on student achievement, student attitude and the classroom environment; and (3) to investigate associations between students' cognitive and affective outcomes and the nature of the learning in computer-assisted settings.

One of the major contributions of this study was that a new classroom environment instrument, namely, the *Geography Classroom Environment Inventory* (GCEI), was developed and validated specifically for the unique setting of computer-assisted learning. The four scales in this instrument — Gender Equity, Investigation, Innovation and Resource Adequacy — were found to display adequate factorial validity, internal consistency reliability, discriminant validity and predictive validity (in terms of being significantly related to student outcome scores). Also each scale differentiated significantly between perceptions of students in different classrooms. Another important finding was that, in contrast to previous research, the use of CAL in this study led to a high impact in terms of achievement, attitudes and classroom environment. The authors concluded that there was considerable scope to make use of the new instrument (GCEI) for computer-assisted learning environments in replicating the evaluation study of innovations in CAL as well as their investigation into the effects of CAL classroom environments on student learning outcomes. Two scales — Investigation and Resource Adequacy (see Chapter 3.6.3) — of this instrument was incorporated in the *Computer-Assisted Learning Environment Questionnaire* (CALEQ) that was used in this investigation to elicit student perception of their CAL environment.

Focusing on five computer centres in Singapore, Khoo and Fraser (1997) assessed the perception of 250 adult learners regarding their participations in those learning environments. The authors used a modified version of the *What Is Happening In This Class* (WIHIC) questionnaire (Fraser, Fisher & McRobbie, 1996), the final version of which was called the *Computer Classroom Environment Personal Form* (CCEPF) which had five scales — Teacher Support, Involvement, Autonomy, Task Orientation and Equity. This study was distinctive in that it evaluated a computer application course, and it involved adult learners. The authors found that students had positive perceptions of their computer learning particularly in the areas of teacher support, task orientation and equity. The courses appeared less successful in autonomy and involvement. Differentiation with gender as the focus found that males perceived much greater involvement and females perceived higher levels of equity in the environment.

In a study of computer laboratory environments, Zandvliet and Fraser (1998) looked at three aspects, namely the physical environment, the psychosocial environment and the information technology environment. For the psychosocial environment, they developed an instrument called the *Computerised Classroom Ergonomic Inventory* (CCEI), which had five physical variables measured by the researcher. These variables were grouped into the domains of workspace, computer, visual and spatial environments, together with a measure of overall air quality. The psychosocial environment was measured by using five scales of the *What Is Happening In This Class* questionnaire (Fraser et al., 1996). These are Student Cohesiveness, Involvement, Autonomy, Task Orientation and Cooperation. The questionnaire was administered to 1404 secondary school students in 81 classes, and the classrooms were assessed by one of the researchers using the CCEI. The results showed that there were significant correlations between the visual environment and both student cohesiveness and task orientation. There also were correlations between all psychosocial environment variables and student satisfaction, with regression analysis showing 36% of the variance in satisfaction may be accounted for by Task Orientation and Autonomy; a similar result was obtained by Khoo and Fraser (1997).

2.6.3 Summary

This section has reviewed a number of studies using computer classroom learning environment instruments to investigate the effect of computer-assisted instruction on the learning environment. Some of the scales of the instruments indicated in this section were used to compile the *Computer-Assisted Learning Environment Questionnaire* (CALEQ), the instrument that was employed in this study to examine students' perceptions of their computer-assisted classes.

2.7 Conclusion

This literature review explored the origin of the conceptual framework used in this study from its beginnings in curriculum research and also highlighted important aspects of each of the four programme representations. An analysis of evaluation studies in the South African context illustrated how the framework could be used in this study. The review then considered studies in the literature where computers were used in a variety of contexts in order to draw parallels between the findings from the outcomes in the reviewed literature and that of the present study. Learning environment research in computer-assisted classes, with special emphasis on those studies using instruments that contained scales that were included in the CALEQ, was reported in the final section of this review. The following chapter reports on the methods and data collection procedures.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter outlines the research questions, the research framework, the research design and method, and the instruments employed for the two case studies reported in this thesis. The chapter is divided along six broad sections starting with the research questions and the conceptual framework used to answer the research questions is explained. The second section explains the choice of case studies, narrative inquiry, and interviews as techniques used for data collection. The third section examines the sites for data collection and the background of the schools and centres. The fourth section describes in detail the process by which data were collected and the instruments used and developed to answer the research questions. The fifth section is concerned with data collection and sixth section considers issues related to quality and evaluation of research.

3.2 Research Questions

As outlined in section 2.2, the conceptual framework for the evaluation of the outreach programme that is used in this study had its roots in curriculum inquiry. The framework was initiated by the International Association for the Evaluation of Education (Keeves, 1972; Rosier & Keeves, 1991) and further developed by Treagust (1987) and Van den Akker (1998). The framework was adapted to suit the evaluation of the outreach programme within the context of programme evaluation. This reworked framework distinguishes between the intended, implemented, perceived and achieved programmes. According to Mills and Treagust (2002), the four aspects of the framework can be defined as follows:

The intended programme is the original vision underlying the programme in the form of the stated objectives or programme theory.

The implemented programme is the actual instructional process as implemented.

The perceived programme is the actual learning experiences as perceived and/or experienced by the learners.

The achieved programme is the resulting learning outcomes of the learners.

(Mills & Treagust, 2002, p. 7)

Consequently, the purpose of this study is to investigate the effectiveness of this outreach programme at two Mini-Computer Supported Education Centres using the above framework in terms of providing support to both teachers and students in the teaching and learning of mathematics and physical science. Thus, in line with the above conceptual framework, the following research questions, also introduced in Chapter 1, are addressed:

1. What were the outreach programmes intended to achieve?
2. How were the computer-assisted lessons in the outreach programmes actually implemented, perceived and achieved?
3. How did students perceive their computer-assisted learning (CAL) classes?
4. What were the outcomes in mathematics and physical science as a result of the students' participation in the outreach programmes?

3.3 Research Techniques and Approaches used in this Study

3.3.1 The case study approach

The nature of case studies

Case studies have become one of the most common ways to do qualitative inquiry (Stake, 2000). According to Merriam (1988), case study is not necessarily a methodological choice but a choice of what is to be studied. It offers a means of investigating complex social units consisting of multiple variables of potential importance in understanding the phenomenon and has proved "particularly useful for evaluating programs" (Merriam, 1988, p. 33).

Cohen, Manion and Morrison (2000) maintained that case studies provide a unique example of real people in real situations, enabling readers to understand the events more clearly than simply presenting them with abstract theories or principles. In addition, case studies can penetrate situations in ways that are not always susceptible to numerical analysis. Further, case studies can establish cause and effect; indeed one of their strengths is that they observe effects in real contexts, recognizing that context is a powerful determinant of both causes and effects (Cohen et al., 2000).

Nisbet and Watt (1984) pointed out that a case study is a specific instance that is frequently designed to illustrate a more general principle and, according to Adelman, Kemmis and Jenkins (1980), it is the study of an instance in action. A case study is a holistic research method that uses multiple sources of evidence to analyse or evaluate a specific phenomenon or instance. Most case study research is interpretive and seeks to bring to life a case. 'It often, but not exclusively, occurs in a natural setting and it may employ qualitative and/or quantitative methods and measures' (Anderson, 1998, p. 152). Stake (2000) emphasised that a case study, like research of all kinds, should have a conceptual structure, being usually organised around a small number of research questions. Sturman (1999) argued that a distinguishing feature of case studies is that human systems have a wholeness or integrity to them rather than being a loose connection of traits, necessitating in-depth investigation. In addition, contexts are unique and dynamic; hence case studies investigate and report the complex dynamic and unfolding interactions of events, human relationships and other factors in a unique instance.

Yin (1984) defined a case study as an "empirical inquiry investigating a contemporary happening within real-life context and these boundaries are not clear [where] multiple sources of evidence are used" (p. 23). He further described a case study as being appropriate when 'how' or 'why' questions are asked about a contemporary set of events over which the investigator has little or no control. Yin (1984) asserted that case studies have four possible applications, namely (a) to explain the causal links in real-life situations; (b) to explore situations in which intervention has no clear or single set of outcomes; (c) to describe real-life contexts; and (d) to evaluate using a descriptive mode. These applications may be interrelated. Yin (1984) further pointed out that a case study is concerned with a rich and vivid description of events relevant to the case and that it should provide a chronological narrative of events relevant to the case. It should blend a description of events with the analysis of them while focussing on individual actors or groups of actors, and seeks to understand their perceptions of events. Specific events that are relevant to the case must be highlighted while the researcher remains integrally involved in the case. An attempt should be made to portray the richness of the case in writing up the report. Hitchcock and Hughes (1995) suggested that case studies are distinguished less by the methodologies that they employ than by the subjects/objects of their inquiry.

Strengths and weaknesses of the case study approach

Case studies have several claimed strengths and weaknesses. In identifying some of the strengths, Nisbet and Watt (1984) noted that the results of case studies are more easily understood by a wider audience (including non-academics) as they are frequently written in everyday, non-professional language. The reports are immediately intelligible, they speak for themselves and catch unique features that may otherwise be lost in larger scale data (e.g. surveys); these unique features might hold the key to understanding the situation. Case studies are strong on reality and provide insights into other similar situations and cases, thereby assisting the interpretation of other similar cases. A single researcher can undertake case studies without needing a full research team and can embrace and build in unanticipated events and uncontrolled variables.

Nisbet and Watt (1984) also identified a number of weaknesses pointing out that the result of case studies may not be generalizable except where other readers/researchers see their application. Case studies are not easily open to crosschecking; hence they may be selective, biased, personal and subjective and they also are prone to problems of observer's bias, despite attempts made to address flexibility.

Case study research in science education

The case study approach has been used with great success by a number of authors reporting on curriculum change. Treagust (1987) used case studies as an approach to examine the teaching practices of two Biology teachers at different schools. By observing the classes of the two teachers as a form of data collection he identified those practices that were considered as exemplary. Braithwaite (1993) used a comparative case study to determine the extent to which a group of schools were able to meet the needs of their students following a mandated curriculum change requiring them to become academically selective schools. In Braithwaite's (1993) study, interviews, document reviews and surveys were carried out as part of the data collection process. Rennie and Treagust (1994) used a multi-site case study to determine the important factors involved in implementing a new technology curriculum into schools in Western Australia, collecting data in a similar fashion to Braithwaite – viewing documents, teacher questionnaires and interviewing of teachers, coordinators and parents. Johnston (1992) also used a case study as the basis for her investigation into how teachers developed and implemented a school-based curriculum change.

Application of the case study approach in this research

The case study approach was used in this investigation to evaluate the effectiveness of an outreach programme (Merriam, 1988) in mathematics and physical science and was structured around only four research questions (Stake, 2000) that addressed specific aspects of the outreach programme that would illuminate its effectiveness. This study employed both quantitative and qualitative measures (Anderson, 1998). In answering the research questions, the author developed and used the *Computer-Assisted Learning Environment Questionnaire* to identify student perceptions of the impact of the Mini-Computer Supported Education Centre, on their learning as well as qualitative strategies that included observations of the CAL lessons, interviews with students, teachers, principals and outreach programme managers, and analysed the outreach programme documents to describe the interactions at these centres. Through on-site visits over a period of four months, the author was presented with the opportunity to provide a thick description of the daily activities of students and teachers at the two centres (Cohen et al., 2000) and to highlight the human element

(Sturman, 1999) involved when students interact with the computer, their fellow-students and teachers. Specific lessons and interactions in these lessons were described in the context of the setting of the school (Nisbet & Watt, 1984; Adelman, Kemmis and Jenkins, 1980).

In addressing the characteristics of a case study outlined by Yin (1984) and Hitchcock and Hughes (1995), it is important to note that both centres were situated in schools and used as an integral part of the daily teaching of the teachers concerned. The events at the centres were recorded during the onsite visits through field-notes and video-recordings of the interactions witnessed at each centre. Students were monitored individually and in groups, and there was a continuous interaction between students and the researcher in trying to elicit their perceptions of their computer-assisted classes. Students were interviewed after lessons in April/May 2001 as well as at the end of the on-site visits in August/September 2001.

3.3.2 The narrative as a research technique

The nature of the narrative

The results of a qualitative study are most effectively presented by means of a narrative, rich in detail, often referred to as rich (thick) description (Wallen & Fraenkel, 2001). A qualitative report should therefore provide the reader with enough information so that he or she can determine whether the findings of the study apply to other people or situations. It is the reader of the qualitative study, not the researcher conducting the study, who determines the study's generalizability, if such seems appropriate (Wallen & Fraenkel, 2001). Carter (1993, p. 6) described the narrative description of a story as a "mode of knowing" that "captures the richness and nuances of meaning in human affairs" while at the same time accommodating "ambiguity and dilemma as central figures or themes". Teacher stories that are framed within the context of a teacher's life and the central themes that emerge are often moral and philosophical, revealing more about his or her purposes, feelings, aspirations and personal meaning, than teaching methods or curriculum structures (Constas, 1998).

Polkinghorne (1995) divided narratives into two broad categories depending on the origin of the data. The first category is called narrative analysis and involves the construction of narratives or stories from the raw data. Polkinghorne described how data elements could be configured into a story in the process of narrative analysis. In the narrative analysis the configuration of the story often begins with the final outcome and events and actions that produced the story and are reconstructed to show "how and why this outcome has occurred" (p.18). According to Connelly and Clandinin (1986), this process of taking personal histories of participants "embedded within the social history of schools and schooling" and developing them into "storied accounts" was described as narrative unity as it gives some meaning to their personal and professional experiences (p. 297).

Polkinghorne's second narrative category is that of analysis of narrative, which used a paradigmatic analysis (a classifying or categorising approach to bring order to experiences) of stories or narratives to create categories or themes. He further divided this category into two groups, those where concepts are derived from previous theory (using pre-existing categories), and those that use inductive analysis, where categories are derived from the data (Polkinghorne, 1995). This inductive approach, also known as the grounded theory, was first espoused by Glaser and Strauss (1967) and has, as a key feature of the approach, a general method of comparative analysis. Grounded theory, described by Strauss and Corbin (1994), is a general methodology for developing a theory that is grounded in data systematically gathered and analysed. Merriam (1990) considered grounded theory as building a theory based on descriptive data grounded in real-life situations.

Application of the narrative approach in this research

The narrative inquiry to the analysis of data was used in this study to provide a detailed description of each case study. Events that took place during the implementation of the MICSECs in the teaching and learning of mathematics and physical science at each of the two centres and the interactions in these classes, lent themselves to narrative description. Participants in the outreach programme brought with them their own personal histories (Connelly & Clandinin, 1986). The schools where the centres were based each had their own traditions and culture and the narrative is used to bring about the detailed stories of the student interactions (Wallen & Fraenkel, 2001).

One of the strengths of the narrative as a technique is that it can improve communication between people because story telling is an essentially human activity (Carter, 1993). The very idea of evaluating a programme of this nature in the South African context is to bridge the gap between research as a purely academic exercise to one where the outcomes, good or bad, could inform others wishing to follow similar projects. It is important that the academic rhetoric be communicable to those involved in the project. This study endeavours to use the narrative to inform readers about the effectiveness of the outreach programme by providing thick descriptions of the activities at each of the two centres and to allow interested parties to draw their own parallels to these settings. It is not the intention of this study to draw a generalised conclusion.

3.3.3 Interviews

The nature of interviews

Different types of interviews are put forward in the literature. Wallen and Fraenkel (2001) distinguished between four kinds of interviews, namely, structured, semi-structured, informal and retrospective which consider structured interviews and semi-structured interviews as verbal questionnaires. These consist of a series of questions designed to elicit specific answers on the parts of the respondents and are often used to obtain information that can later be compared and contrasted. Informal interviews tend to resemble casual conversations, pursuing the interest of both the researcher and the respondent in turn. They do not involve any specific type of sequence of questions or any particular form of questioning. The primary intent of the informal interview is to find out what people think and how the views of one individual compare with those of others. With retrospective interviews, a researcher tries to get a respondent to recall and then reconstruct from memory something that happened in the past (Wallen & Fraenkel, 2001).

Cohen et al. (2000) distinguished between structured, unstructured, non-directive and focused interviews. The structured interview is one where the content and procedures are organised in advance. The unstructured interview is an open situation having greater flexibility and freedom. The non-directive interview as a research technique has its striking feature that the interviewer exerts minimum control or direction during the interview and allows the interviewee to express her subjective feeling as fully and spontaneously as possible. The distinctive feature of the focused interview, according to Cohen et al. (2000), is that it focuses on the respondents' subjective responses to a known situation and which has been analysed by the interviewer prior to the interview.

Advantages and disadvantages of structured and semi-structured interviews

Smith (1995) considered the advantages and disadvantages of structured and semi-structured interviews. The 'alleged' advantages (p. 2) of the structured interview format are control, reliability and speed, that is, the investigator has maximum control over what takes place in the interview. It is also argued that the interview will be reliable in the sense that the same format is being used with each respondent, and that the identity of the interviewer should have minimal impact on the responses obtained. Smith maintained that the disadvantages of the structured interview arise from constraints put on the respondent and the situation because it deliberately limits what the respondent can talk about – this having been decided in advance by the investigator. Thus the interview may well miss out on a novel aspect of the subject for discussion, an area considered important by the respondent but not predicted, or prioritised, by the investigator. The structured interview also can become stilted because of the need to ask questions in exactly the same way and sequence to each participant.

Smith (1995) pointed out that with semi-structured interviews, the investigator will have a set of questions on an interview schedule but the interview will be guided by the schedule rather than be dictated by it. Semi-structured interviews allow the respondent to be perceived as the expert on the subject and should therefore be allowed maximum opportunity to tell his or her own story. Smith (1995) suggested that with semi-structured interviews there is an attempt to establish rapport with the respondent, the ordering of questions is less important, the interviewer is freer to probe interesting areas that arise, and the interview can follow the respondent's interests or concerns.

Application of interviews in this research

In this study, semi-structured interviews were used to interview both students and teachers as it provided the opportunity to probe answers of respondents. In the case of students, group interviews (2-5 students) were conducted for, as Lewis (1992) argued, group interviews generate a wider range of responses than do individual interviews. Indeed in some instances, the author found that students were more eager to participate in discussions when they were interviewed in groups. A number of informal interviews/discussions were held with students and teachers during the initial on-site visits in April 2001, which assisted in the construction of two scales of the CALEQ and the format for the semi-structured interviews with students and teachers (see Appendices A and B, respectively).

3.4 Data Sources

As described in Chapter 1, nine Mini-Computer Supported Education Centres (MICSECs) set up around the Western Cape by the end of the year 2000 were located at disadvantaged schools, namely, the so-called *black* and *coloured* schools. These schools have been specifically identified on the basis of their low attainment in Grade 12 mathematics and science results achieved in previous final matriculation examinations. This investigation involved case studies of two of these centres located in specific schools to which the author, as the investigator, was allowed full access. The study also provided two different settings because Centre A is in a rural area and Centre B is in a peri-urban area.

3.4.1 Centre A

The school at which Centre A was placed (see Appendix C for photographs) was established in 1978 as a secondary school for people designated as *coloured* by the then apartheid government. Before 1978, the premises were used for a primary school and no secondary school existed in the area. African (*black*) students wishing to attend a secondary school had to go to areas designated as homelands for African people. The nearest homeland for students at Centre A was an area called Transkei which was approximately 1000 kilometres away. However, as the numbers of black people increased in the area, more students entered the school. Eventually, additional secondary schools for *coloured* students were built and the school where Centre A is located became a designated school for *black* students.

The school of Centre A is situated in a rural area and is surrounded by small brick houses as well as informal settlements commonly known as squatter camps. Some of the surrounding houses have access to electricity and water, but in the informal settlements infra-structural problems in terms of lack of electricity, water and roads persist.

The UWC outreach project established a MICSEC at this school towards the end of the year 2000. Twelve computer terminals and a server were housed in a classroom that could be extended to a second classroom should additional computer terminals become available. Physical science and mathematics software was preloaded on the computers. Additional classes were held on Saturdays for students, including those from three surrounding schools. For the year 2001, the school had 32 teachers including a principal, two deputies and four heads of departments. There were three classes in Grade 12, three classes followed mathematics and two classes physical science. In total there were 64 mathematics students and 38 physical science students in Grade 12. There were also 11 students registered as private students for the Senior Certificate Examination. The same teacher (we will refer to him as Mr. R) taught both mathematics and physical science to the Grade 12 students.

3.4.2 Centre B

The secondary school where Centre B was located (see Appendix C for photographs) stemmed from a school that was first situated in an area 30 kilometres from its current location being located behind the University of the Western Cape premises from where the Outreach Project operated. Centre B was housed for a period of approximately five years (1995-1999) in a training college premises that were formerly used for telecommunication students. The original school with 2200 learners and 70 teachers teaching Grades 8 to 12 had easy access to the Goldfields Resource Centre where the Outreach Project was located. In October 1999, this school was moved and divided into two separate schools, one of which formed the school at which Centre B is based. The staff complement was also divided between the two schools.

The new school where Centre B was located was situated in a peri-urban area on the outskirts of Cape Town that was developed by the apartheid government for people of African (*black*) origin. Very few resources (in terms of libraries, sport, entertainment) and infra-structure (electricity, water, roads) were available to students in this area because the area consists mainly of informal housing - a so-called squatter area. The school of Centre B stood out amongst its surroundings as it had the structure of a modern school. Bus and taxis to the school from the surrounding informal settlement areas transported a large number of the students to and from this school.

In 2001, the school of Centre B had 1329 students with 37 teachers. In total, 80 students followed mathematics and 60 students followed physical science in Grade 12. The Mini Computer Supported Education Centre at Centre B was established in August 2000 and became fully operational from January 2001. The centre houses 15 computers and a server; mathematics and physical science software is loaded on the computers. The centre is located in a large secure room that is big enough to fit an additional 30 computers. Three teachers made use of the centre, two of whom taught Grade 12 mathematics (we will refer to them as Mr. U and Mr. A) while the other teacher (Mr. M) taught Physical Science.

3.5 Data Collection

The following is a description of the methodologies employed during the investigation to answer each of the research questions indicated.

3.5.1 What were the outreach programmes intended to achieve?

The objectives of the outreach programme were compiled from documents and interviews. Documents comprised for example brochures, pamphlets, guides, funding applications and annual reports (see Appendix D) with regard to the activities of the outreach programme were scrutinised for the aims and objectives that it wanted to achieve.

The Outreach Project manager responsible for the outreach programme in 2001 was interviewed in March 2002. In May 2002 the Outreach Project manager who initiated the project in 1982 and guided it through its first ten years of operation also was interviewed. At Centre A, the principal of the school and, at Centre B, the deputy principal who took the responsibility for the implementation of the MICSEC were interviewed. Interviews were of an open-ended nature and took place in the principal's and deputy principal's office. The teacher who also was responsible for teaching both Grade 12 mathematics and physical science at Centre A as well as the three teachers involved in the incorporation of the Centre B in the teaching of Grade 12 mathematics and physical science were interviewed. Interviews with the teachers were of a semi-structured nature (see Appendix B).

3.5.2 How were the computer-assisted lessons in the outreach programmes actually implemented, perceived and achieved?

The implementation of the programme was observed through on-site visits to both Centres A and B. Sites were visited during two cycles of two months; the first took place during April-May 2001 and the second round during July-August 2001. The researcher spent a total of two weeks at each centre during each round. At Centre A, a total of 12 lessons — 6 lessons for physical science and 6 lessons for mathematics — were observed and recorded. All lessons observed took place inside the MICSEC which was used daily for both mathematics and physical science lessons. At Centre B, the 12 computer-assisted lessons were observed and recorded, three for each teacher. Because the MICSECs were not used by teachers on a daily basis, one of the observed lessons of each teacher took place in the normal classrooms outside the MICSEC.

Follow-up visits also were made during October 2001 and February 2002. A narrative report of on-site visits was used to describe the application and actual implementation of the Mini-Computer Supported Education Centres at schools in the daily lessons by teachers. The data collection for the above research question involved observations of lessons, drawing up of field notes and videotaping the use of the MICSECs in both mathematics and physical science lessons. The lessons were recorded and coded for cross-reference purposes. The codes are explained in Section 3.6 as part of analysis of data.

3.5.3 How did students perceive their computer-assisted learning classes?

The perception of learners of the contribution of the outreach programme was established through interviews and an instrument called the *Computer-Assisted Learning Environment Questionnaire* (CALEQ), which had both an actual and preferred version. Students at both centres were asked for volunteers for interviewing purposes and were given the option to be interviewed individually or in groups. At Centre A, seven students were interviewed individually as well as five groups of two to four students. At Centre B, nine individuals and five groups consisting of two to five students were interviewed. Responses provided in the questionnaire were used as a basis to guide the interviews. The interviews were coded for cross-reference purposes. The codes are explained in Section 3.6.

Development of the Computer-Assisted Learning Environment Questionnaire (CALEQ)

The development of an instrument called the *Computer-Assisted Learning Environment Questionnaire* (see Appendix E for scale classification according to Moos's scheme) was initiated by a search for an instrument that would firstly, adequately encompass circumstances unique to the two disadvantaged schools in South Africa engaged as cases for this study and secondly, focus on inviting students' perceptions of their own learning in computer-assisted mathematics and science classes. Guidance in identifying scales was obtained from scales contained in existing validated and reliable classroom environment instruments, which included both computer and non-computer settings (Fraser, 1998; Fraser, McRobbie & Fisher, 1996; Maor & Fraser, 1993; Teh & Fraser, 1993).

The instrument also was constructed in a way that would require a relatively short time to complete and hand score. It was important that the instrument be as brief as possible because the students involved were in Grade 12 and as little incursion on their time as possible was encouraged by all concerned. Thus the questionnaire included a fairly small number of scales (6), each containing a relatively small number of items (8). Finally, in order to ensure that the CALEQ's scales and items were considered salient by both teachers and students, a meeting was conducted with the teachers involved at each centre and two science and mathematics teachers from neighbouring schools, as well as five students from neighbouring schools of each centre. The teachers and students were asked to comment on the preliminary versions of the instrument for face validity, clarity of language and suitability for issues such as culture. As a result of this validation exercise, modifications to the language of some items were done. An issue with regard to students' experience of the MICSECs and how it can be improved was raised in the meeting and discussed. This resulted in two versions of the CALEQ, namely one actual (see Appendix F) and one preferred (Appendix G). The actual format referred to how students actually perceived their CAL classes whilst the preferred referred to how students would want these classes to be. For example, an item in the open-endedness scale would be as follows: 'The teacher decided the best way for me to proceed' for the actual version and for the preferred version it read 'The teacher would decide the best way for me to proceed'.

CALEQ scales included adaptations to the Involvement scale from the *What Is Happening In this Class* (WIHIC) questionnaire (Fraser, McRobbie and Fisher, 1996), the Open-Endedness scale from the *Science Laboratory Environment Inventory* (SLEI) (Fraser, McRobbie and Giddings, 1993), the Investigation scale from the *Individualised Classroom Environment Questionnaire* (ICQE) (Fraser, 1990). The Resource Adequacy scale from the *Geography Classroom Environment Inventory* (GCEI) (Teh & Fraser, 1993) and Organization scale from *Computer Classroom Environment Inventory* (CCEI) (Maor & Fraser, 1993) were modified and items amalgamated to form one scale called the Material Organization scale. The last two scales, namely the Learning Assessment scale and Integration scale were developed by the researcher in order to address specific questions around, in the first instance, students evaluating their own learning in CAL classes, and in the case of the latter, obtaining student perceptions around the application and inclusion of MICSECs in the teaching and learning environment. The CALEQ consisted of the above-mentioned six scales, each scale defined by eight items (see Appendix H). Table 3.1 clarifies each of the meaning of each of the six scales and provides scale descriptions and sample items with information of scoring.

Table 3.01
Descriptive information for the CALEQ scales

Scale Name	Description	Sample item
Involvement	Extent to which students have attentive interest, participate in discussions, perform additional work, and experience the CAL classes	I am asked to explain how I solve problems (+)
Open-endedness	Extent to which an open ended approach is adopted in the CAL classes	I must answer questions in a prescribed way (-)
Investigation	Extent to which student is encouraged to engage in the learning process	I find out answers to questions by doing investigations (+)
Material Organization	Extent to which CAL classes are organized and computer hardware and software are adequate	The computer programs are hard to use (-)
Learning assessment	Extent to which the learner can assess his understanding of subject content	I have improved my ability to solve problems by using the computer (+)
Integration	Extent to which the computer is included as a tool in daily teaching of mathematics and physical science	The computer work is integrated with the regular science and mathematics class work. (+)

Note: Items designated (+) are scored 1, 2, 3, 4 and 5, respectively, for the responses Almost Never, Seldom, Sometimes, Often, Very Often. Items designated (-) are scored in the reverse manner. Omitted or invalid responses are scored 3. The same scoring procedures apply to both actual and preferred formats of the CALEQ.

3.5.4 What were the outcomes in mathematics and physical science as a result of students' participation in the outreach programmes?

The learning outcomes were obtained from the results of students in examinations that were compared to examination results prior to implementation of the outreach programme. Outcomes also were measured in terms of the extent to which the outreach programme addressed its goals and objectives that were identified in Section 4.2 and discussed in Section 5.2. The physical science and mathematics teachers involved in the application of the MICSECs in their daily teaching were interviewed for their views on the role that the outreach programme played in the learning outcomes of the students.

3.5.5 In summary

How the research framework, the research questions, the research methodology and the data sources are related is shown in Table 3.02.

Table 3.02
Summary of data collection procedures

Research framework	Methodology	Data source
Intended programme		
What were the outreach programmes intended to achieve?	Analysing documents	Brochures, pamphlets, guides, funding proposals, annual reports
	Interviews	Outreach Project managers, teachers and principals
Implemented programme		
How were the lessons in the outreach programmes actually implemented, perceived and achieved?	Observations and field notes, videotaping of computer-assisted learning sessions.	Two sites where Mini-Computer Supported Education Centres (MICSECs) were installed
Perceived programme		
How did students perceive their computer-assisted learning (CAL) classes?	Instrument (CALEQ, actual and preferred) and interviews	Students' responses
Achieved programme		
What were the outcomes in mathematics and physical science as a result of the students' participation in the outreach programmes?	Analysing students marks in mathematics and physical science Observation of classes Interviews	1999-2001 Matriculation examinations Two sites where the MICSECs were installed Teachers

3.6 Data Analysis

The three approaches to analysis of data, as suggested by Gall, Borg and Gall (1996) were used in the two case studies. These approaches, namely, interpretational analysis, structural analysis and reflective analysis were used in a combined manner to identify themes or patterns emerging from the data. The interpretational analysis examines data for themes and patterns within the teaching and learning environment. In analysing the interview transcripts, the author examined the data for themes that could be linked to student responses, for example, after analysing transcripts of the students' interviews, three views, discussed in Section 5.4, became evident about the students' perception of the computer-assisted classes. In structural analysis, the focus is on the identification of patterns in the discourse, text, events and other phenomena, for example, in this study, two distinct ways of implementing the MICSECs were witnessed at the two centres. Reflective analysis depends on intuition and judgement; for example, the responses of a group of three students interviewed at Centre A appeared, to the author, to have been discussed before the interview. The author followed up their views with the teacher to get more clarity on the students' backgrounds.

Spradley's (1980) approach to analysing ethnographic studies also was used to clarify data. This approach starts with a systemic view of the case in question, breaks it down into parts, determines the interrelationship of the parts, and the relationship of the parts with the whole. Each of the computer-assisted classes was considered within its setting, how it related to the normal activities of the school and the interactions within each class.

According to Cohen et al. (2000), coding is a process that helps in defining categories and organising them into some form of order or structure. Analyses of these categories should involve screening for similarities and differences. Creswell (1998) suggested three modes of coding. The first, called open coding, entails the initial categorisation of data. The second mode of coding is called axial coding and this involves the researcher assembling the data in a different manner after the initial categorisation. The third type of coding, called selective coding, is where the researcher identifies an excerpt from data and writes a story that will result in the integration of the categories in the axial coding. In this study, the initial categorisation followed the process along which the data was collected, for example, during the April/May on-site visits data were collected about the background of the centres through the interviews with the principals of each school and on-site observation of lessons in the form of field-notes and video-taping took place. The data categories that were used followed the particular stages along which the data were collected during each visit (open coding). These data were later reorganised in terms of the research framework and addressing the research questions, for example, field notes of observation and videotaping formed an implementation category while student interviews and CALEQ data formed a student perception category (axial coding). Within each representation of the research framework, particular events were identified which clarified aspects of another representation; for instance, interviews to obtain student perceptions about computer-assisted classes informed the author about the particular implementation procedures at the each centre (selective coding).

For the purposes of identifying and cross-referencing data from sources like transcripts and lesson from field-notes and video material, different codes were used. In the context of this study, the codes took on particular formats. For example, the lessons observed in the computer-assisted classroom were recorded by field-notes as well as transcripts of video-taped material. In order to identify a lesson for referencing purposes, a format was used represented by the code A/R/L03/0513. The first letter represented the centre (Centre A), the second identified the teacher (Mr. R), the third part referred to the number of the lesson that was observed (lesson no. 3), and the fourth the date of the lesson (13th May 2001).

In the same manner, reference is made to transcripts of interviews. In the code A/Gi5/0513, A refers to Centre A, Gi5 refers to Group interview number 5 and 0513 is the date that the interview was conducted (13th May 2001). The middle part of the code (Gi5) is changed to, for example, I2 if an individual interview with student number 2 was held. In the interviews of teachers, the second part changes to the letter referring to the teacher in question, for example an interview conducted with Mr. R on the 13th May would be represented by A/R/0513.

3.7 Quality Criteria and Research Evaluation

It has been argued by Denzin and Lincoln (1998) that there is no single interpretive truth and that criteria that are used for evaluation purposes should stress the "situated, relational, and textural structures of the ethnographic experience" (p. 30). Constructivists have argued that traditional and positivist or post-positivist research paradigms requiring validity and reliability checks are not relevant for an interpretive study (Denzin & Lincoln, 1998; Guba & Lincoln, 1989). Where positivism concerns itself with validity, reliability and objectivity, the constructivist paradigm replaces these issues with credibility, dependability and confirmability respectively (Guba & Lincoln, 1989). Thus, in order to satisfy questions of rigour in this research, these terms are expounded upon.

3.7.1 Internal Validity or Credibility

Cohen et al. (2000) contended that "internal validity seeks to demonstrate that the explanation of a particular event, issue or set of data can actually be sustained by the data" (p. 107). In other words, the findings must accurately describe the phenomena being researched. Merriam (1990) suggested that there were six basic strategies that could be used to ensure internal validity, namely, (a) triangulation which includes using multiple data sources or multiple methods to confirm emerging findings; (b) member checks, that is, taking data and interpretations back to the people from whom they were derived and asking them if results are plausible; (c) long-term observation at the research site or repeated observation of the same phenomena; (d) peer examination which implies asking colleagues to comment on the findings as they emerge; (e) participatory modes of research involving participants in all phases of research; and (f) researcher's biases which can be addressed by clarifying the researcher's assumptions, worldview and theoretical orientations at the outset of the study. These six criteria are in agreement with those proposed by Guba and Lincoln (1989) — prolonged engagement at the site of inquiry, triangulation, persistent observation, peer debriefing, negative case analysis and member checking.

In this investigation, credibility was addressed in a way consistent with both Merriam's (1990) and Guba and Lincoln's (1989) constructivist strategies. In terms of triangulation, this study used a number of data sources and methods, which include observations of computer-assisted learning classes, interviews with students and teachers, and scrutinising documents from the Outreach Project. Peer examination took place through discussion with fellow doctoral students on a regular basis, as well as with the associate supervisor and supervisor. This study involved sustained observation of the two sites over a period of four months. This study also included member checks through continued interaction with teachers and students by regular site visits that resulted in the participation of those involved in the research.

3.7.2 External validity or transferability

Cohen et al. (2000) referred to external validity as the degree to which the results can be generalized to a wider population, cases or situations. The term transferability was preferred by Lincoln and Guba (1985) and by Guba and Lincoln (1989) as they contended that generalizability is relative. These authors argued that in naturalistic research the researcher's task was not to provide an index of transferability; rather, they suggested researchers should provide sufficiently rich data for the readers and users of research to determine whether or not transferability is possible. In this regard, transferability requires a thick description. In the description of case studies in this research, the author attempted to provide a thick description of the settings of the two centres and the interactions at these centres. There are nine of these Mini-Computer Supported Education Centres located at schools in the Western Cape where similar activities are taking place. A number of similar interventions may be in operation or being contemplated in other provinces in South Africa. The author provides the outcomes of this research for the evaluation studies of other outreach programmes to comment on similarities and differences.

3.7.3 Reliability or Dependability

Reliability is concerned with the stability of the data over time or the extent to which findings may be replicated (Merriam, 1990). Quantitative research assumes the possibility of replication. With the emergent nature of qualitative research or case study, the traditional meaning of reliability becomes somewhat strained when using a constructivist approach to teaching and learning. Merriam (1990) described Guba and Lincoln's (1989) concept of dependability as outsiders concurring that given the data collected, the results make sense – they are consistent and dependable. Merriam (1990) further suggested three techniques to ensure dependable results: (a) stating the investigator's position, assumptions and theory behind the study; (b) triangulating data and method as indicated above concerning internal validity; and (c) providing an audit trail.

The author has outlined his position, assumptions and theory behind this study in Chapter 1 and triangulation was discussed above under internal validity. An audit trail, according to Guba and Lincoln (1989), is a process that is established, trackable and documentable so that the analysis of the collected data can be confirmed. This study's audit trail has been described in detail under Section 3.6 such that the data collection procedures can be followed by other researchers to carry out a similar study.

3.7.4 Objectivity or Confirmability

Guba and Lincoln (1989) proposed the concept of confirmability as a parallel notion for objectivity, which is concerned with "assuring that the data, interpretations and outcomes of inquiries are rooted in contexts and persons apart from the evaluator" (p. 243). To confirm the existence of the data, this study has shown how the data were converted into findings such that the findings are not simply part of the researcher's imagination. Consequently, this chapter on research methodology and the following chapters on results attempt to establish both the confirmability and dependability audit so that the processes and assumptions used are clear and explicit.

3.8 Conclusion

This chapter dealt with the research methodology and justified it using the specified research techniques to answer each of the research questions. The chapter also has highlighted the location of each school in order to provide the context in which the data were collected. The following chapter is devoted to the findings obtained after the implementation of the methodology explained above. The findings are presented in terms of each of the four research questions described in Section 1.6.

CHAPTER 4

RESEARCH FINDINGS

4.1 Introduction

The previous chapter was primarily devoted to the methodology employed to answer the research questions. The instruments used to collect data, namely, observations, questionnaires, interviews and protocols for analysing documents, within the context of the four research question, were described.

The purpose of this chapter is to report on the findings as a result of the data analyses. Reporting in this chapter is divided into four parts with each part corresponding to the four research questions indicated below:

1. What were the outreach programmes intended to achieve?

With this question, the analysis of the intentions, goals, objectives, underlying philosophy and programme theory were elucidated.

2. How were the lessons in the outreach programmes actually implemented, perceived and achieved?

The response to this question is in the form of case studies of the two schools where the implementation of the outreach programme was observed.

3. How did students perceive their computer-assisted learning (CAL) classes?

Student perceptions obtained through the *Computer-Assisted Learning Environment Questionnaire* and student interviews were evaluated and reported upon.

4. What were the outcomes in mathematics and physical science as a result of the students' participation in the outreach programmes?

The outcomes were measured through student examination results and interviews with teachers.

4.2 What were the outreach programmes intended to achieve?

It is important to note that the investigation of the intended programme of the Outreach Project used documentation like brochures (wherein most of the programme intentions/goals were indicated), annual reports and funding applications (see Appendix D) as well as interviews with a former and the current Outreach Project manager to establish the intended goals. This procedure is in line with Chen (1990) who suggested that programme goals are "usually formally documented in publications such as annual reports, programme pamphlets, or brochures, which makes them easily accessible" (p. 169).

The initial documentation developed for the onset of the Outreach Project in 1982 stated as its overall goal to "To use instructional technology to improve education at all levels" (Sinclair & Kansky, 1987, p. 10). This goal was further refined specifically for the school outreach programme by the following statement: "To improve instruction in secondary school mathematics and the sciences" (Mehl & Sinclair, 1983, p. 15).

In an interview with the Outreach Project manager, who started the project in 1982 and carried it through for the first ten years, he maintained that the initial goal was to support Grade 12 mathematics and physical science teachers and students during the difficult days of apartheid. The establishment of the outreach project was the University's response to this dire need in the community and was also an attempt by the University to increase its intake of students in the science and technology fields. The above goals were specified in broad terms, but as the Outreach Project manager put it, "there would be future developments to allow for adaptations" (OMM/0502). These possible changes would have their effects in additional or modified objectives that would still serve the overall objective of the programme. The initial ideas around the establishment of the outreach programme was to assist the many under-qualified teachers as well as their students in black and coloured schools by bringing them to the computer centre established on the University premises. Requests to be included in the outreach programme came from all over the Western Cape because teachers and their students wanted to be involved in a programme that supported them in the teaching and learning processes. The specific objective that the outreach programme adopted at the stage was indicated by the following statement: "To support teachers and students in disadvantaged schools in the teaching and learning of mathematics and physical science to Grade 12 students" (Mehl & Rhodes, 1993, p. 4)

In the year 2001, the basic philosophy behind the outreach programme remained unchanged. As the current Outreach Project manager reported in the year 2000 brochure, "The programme originally had a life expectancy of only four years but its success coupled with community demand ensured its continued existence" (Ogunniyi & Isaacs, 2000, p. 2).

In brief, the outreach programme was designed to assist and support students and teachers from disadvantaged communities by being located in their schools for ease of access. In 2001, the outreach programme was dedicated to establishing Mini-Computer Supported Education Centres to selected schools that were identified as a result of low matriculation examination results. Subsequently, the measure of success of a school's overall Grade 12 results would determine whether or not the outreach programme would support it. According to the Outreach Project manager, the outreach programme supports schools that scored in the bottom half of the outcomes in the Senior Certificate Examination. The following two broad goals for 2001 were identified, namely:

> To use technology in support of teachers and students at disadvantaged schools in mathematics and physical science.
>
> To increase the University of the Western Cape's intake of disadvantaged students with the necessary background in mathematics and physical science in the science and technology fields.
>
> (Ogunniyi & Isaacs, 2000)

Specific objectives were obtained from analysing the Outreach Project documentation (Mehl & Sinclair, 1983; Sinclair & Kansky, 1987; Mehl & Rhodes, 1993; Ogunniyi & Isaacs, 1998; Ogunniyi & Isaacs, 2000) and by specific probing questions during the interview with the project manager (OMI/0424). The author compiled the objectives after discussions with the Outreach Project manager and the teachers involved at each of the two MICSECs included in this study. These objectives are represented by six composite statements as follows:

1. To assist teachers to incorporate computers as a tool in their daily task of teaching science and mathematics.
2. To improve the learning of science and mathematics by Grade 12 students.
3. To improve the achievements of students in mathematics and physical science in the external matriculation examination.
4. To serve as a resource centre that students can use in their own time.
5. To expose students to computers and their operation.
6. To provide skills to those sections of the South African population who through historical circumstances have been denied full access or chances of acquiring these skills.

As indicated in Section 2.3.2, for the evaluation of a programme it is important to identify the programme theory. Chen (1990) defined programme theory as "a specification of what must be done to achieve the desired goals, what other important impacts may also be anticipated, and how these goals and impacts would be generated" (p. 43). The philosophy behind the implementation of a project of this nature in the South African context and the development of a subsequent programme theory should be understood from whence it came and what it endeavours to overcome. According to the Director of the School of Mathematics and Science Education, who was ultimately responsible for the Outreach Project, the year 2001 saw the University of the Western Cape well into its three year rolling plan and a five year strategic academic plan. These plans formed a "response to the rapid changes in the higher education environment as a result of current globalisation and the concomitant need for quality control, systemic restructuring, rationalization and sustainability" (Ogunniyi & Isaacs, 2000, p.1). In these circumstances, the Outreach Project was pursuing a cost saving plan of bringing remedial outreach programmes in mathematics and physical science to the doorsteps of Grade 12 students. Many of the students who would be involved in the outreach programme were struggling to cope with mathematics and physical science due to circumstances beyond their immediate control. Since its inception in 1982, the Outreach Project was focussed on redressing the ills of the past by providing virile academic outreach programmes in mathematics and physical science to Grade 12 students from disadvantaged communities (Ogunniyi & Isaacs, 2000; Sinclair & Kansky, 1987).

In response to this situation, the Outreach Project embarked on an aggressive strategy of developing Mini-Computer Supported Education Centres in different parts of the Western Cape. These centres reduced the cost of transporting students by buses to the University and provided for the development of a critical mass of key mathematics and physical science teachers who could share their newly acquired knowledge and skills with their colleagues in neighbouring schools. The intended ripple effects were (1) the development of practical, technical and emancipatory capacities amongst teachers, and (2) the widening of opportunities for learners to pursue their study in mathematics and physical science in a more-enriched environment (Ogunniyi & Isaacs, 2000; Ulster, 1998).

The intended aim of this endeavour was therefore to break the readily "recognizable cycle of mediocrity which perpetuated ill-qualified educators to produce poorly qualified students who were themselves ill-prepared for either the job market or tertiary education" (Ogunniyi & Isaacs, 2000, p. 1). This cycle appeared to be the "malaise of the continuing crisis in education" in mathematics and physical science at poorly resourced schools where inappropriately qualified teachers tended to conglomerate (Ogunniyi & Isaacs, 2000, p. 1). The need to address teacher and student empowerment in mathematics and physical science has therefore become undisputed and imperative (Department of Education, 2000).

The planned modus operandi of the outreach programme was to start out with the training of teachers of schools where the Mini-Computer Supported Education Centres were to be placed. It was imperative to identify at least one teacher at a school who could share, with fellow teachers, the training that involved an introduction to the mathematics and physical science content of programmes on the computer. This experience was followed by an explanation of computer-assisted learning and how teachers could employ the computers as a tool in their daily teaching. The Computer-Aided Mathematics Instruction (CAMI) suppliers also provided their own trainers who would go out to the schools and train teachers on how to use the programme; school visits by outreach staff were planned to provide additional support. Personal contact with principals and educators was maintained through these visits in order to ascertain the problems experienced by each school, both of a general and a unique nature. Continued interactions with these educators resulted in the development and modification of the modus operandi. The manner in which the computer centres were to be included in the everyday teaching of mathematics and physical science was left to each school to decide.

In response to Research Question 1, the objectives indicated above and the motivation behind the implementation of the outreach programmes serve to illuminate the intended programme. The following section looks at the way that the programme was actually implemented at the two schools that served as case studies for this investigation.

4.3 How were the Computer-Assisted Lessons in the Outreach Programme actually Implemented, Perceived and Achieved?

4.3.1 Introduction

As pointed out in Chapter 3, the implementation of the outreach programme was observed through on-site visits to both Centres A and B. Sites were visited during two cycles of two months, the first took place during April-May 2001 and the second round during July-August 2001. Follow-up visits also were made during October 2001 and April 2002 for each centre, respectively. The data collection for the second research question involved observations, drawing up of field notes and video-taping of the implementation of the Mini-Computer Supported Education Centres (MICSECs) in the teaching and learning of mathematics and physical science at each of the two centres. In order to provide an account of the implementation process, detailed observations of lessons in each of Centres A and B are described. At Centre A, physical science lessons are described; at Centre B, the use of the centre as part of a mathematics test is outlined. In addition, general observations of the implementation of the Mini-Computer Supported Education Centres and of the schools are provided to make the setting comprehensible to the reader.

4.3.2 Implementation at Centre A

Context

The author's first journey to the school where Centre A was based took place in April 2001. The author met previously with the teacher (Mr. R) responsible for the MICSEC at the Outreach Project Management Centre at the University of the Western Cape earlier during the year. Through a telephonic discussion with the principal of the school, which was arranged by Mr. R, permission was granted for visits to the school and attendance of classes as part of this research study. Following the directions given, the author drove through the town, through an industrial area and then through a stretch of open field that looked like a no-man's land border area (see Appendix C for photograph). This observation was later identified by the teachers to be the case because this piece of land separated the black township from the rest of the white-owned industry and residential areas. This land also was used by the police to isolate the *troubles* of the black township during the uprising against apartheid during the 1970's and 1980's. The school was situated at the back of the township and was reached by driving through an informal settlement area. The school was surrounded by a high fence with an electronically operated gate guarding the entrance. The Mini-Computer Supported Education Centre was located in a large classroom which could be extended should additional computers become available. As indicated in section 3.5.1, there were 12 computer terminals available to students. The computers were supported by a server from which the CAMI mathematics programme and the University-developed physical science software operated. The classroom was a prefabricated building (demountable) that had bars on the windows and a security gate in front.

Mr. R, who was responsible for the teaching of both mathematics and physical science to Grade 12 students, held a BSc degree and a teacher's diploma (HDE) and had 10 years experience in teaching mathematics and physical science. There were three classes in Grade 12, all three classes followed mathematics and two classes followed physical science. In total, there were 64 mathematics students and 38 physical science students in Grade 12. The remaining mathematics class followed the economics stream. There were also 11 students registered as private students for the Senior Certificate Examination who did not attend classes on a regular basis. In my first two weeks of observation, Mr. R made use of the computer room (as the MICSEC was called).

The following is a description of the author's observations of lessons by Mr. R in teaching the section on momentum in the physical science syllabus.

General observation

Mr. R's lesson took place in the computer room. He was in his classroom at 7-45 am to prepare for the day's work; after switching on the server, he activated the 12 computer terminals one by one, a process that normally took about 10 minutes. A number of chairs were placed in front of each terminal because there were not enough terminals for individual students. The computer room had long tabletops along the side of each of three walls upon which the computer terminals were mounted; five terminals were placed against one wall, four against a second wall, and three computers were against a third wall that also had windows. The fourth wall, that was the front of the class, had a mounted blackboard with a bookrack and a cupboard where Mr. R's resources, such as textbooks, videocassettes, and administration files, were placed. Two walls had different posters that included the periodic table and an astronomy chart. The windows had vertical blinds that protected the room from the glare of the sun (see Appendix C for photographs).

School started at 8-00 am and by this time a large number of students were standing outside their classrooms waiting for their teachers to appear. By 8-30 am most students were in their rooms. When Mr. R opened the door of the computer room at 7-55 am students who were standing outside started to wander in. A number of quick scuffles took place between students as they tried to gain a good spot in front of a computer. As more students entered into the room, students started moving chairs from one terminal to another as they settled in. There were not enough chairs in the computer room so a few boys were quickly dispatched to fetch chairs from the library opposite the computer room. Some private students made up the extra numbers. In total there were 27 students in the class with groups of two to four per computer terminal.

Lesson 1 (A/R/L03/0423)

Intended lesson (1)

Mr. R introduced the topic of the lesson as momentum, writing it on the blackboard. He pointed out that the four lessons that followed dealt with the concept of momentum and that the concept also was covered by the physical science component on the computer. He indicated to students that they would be using the work on the computer as part of the lessons. The objective of the first lesson dealt with understanding what momentum entails.

Implemented lesson (1)

Mr. R introduced momentum as a concept which Newton derived and which he called 'quantity of motion'. The students were told that one could not speak of momentum without considering the following:

a) mass of the object concerned.

b) how fast it is travelling.

The collision of two cars was used as an example to explain how the above two factors played a role in the momentum of the cars. Students were asked to relate their experiences in this regard. Although one student showed his scars after an accident, very little interaction took place so the teacher decided to take the lead and explained about the roles of mass and velocity in colliding cars.

Following this explanation, the definition of momentum was written on the black board as follows:

Momentum is defined as the product of the mass of the object and its velocity.

Momentum = mass x velocity; $p = m \times v$

Since velocity is a vector, momentum is also a vector in the same direction as the velocity

[In the lessons described in this section, schoolwork that the teacher wrote on the black board is presented in italics.]

The information above was written on the blackboard for students to copy in their notebooks. Two examples involving the above formula were calculated on the blackboard from which students copied. Students were then directed to the programme on the computer dealing with momentum and to the first section where they were exposed to an elementary explanation of momentum with animation of rolling objects that collided (see Appendix I). After the explanation, a number of problems were stated that students had to work through.

Students got together in their groups and sat around the terminals. No notes were made during the explanation of momentum on the computer. In each group, at least one individual got out a book and took down the problems that were stated. These individuals then proceeded to answer the questions while everyone around contributed their own viewpoint and some discussion occurred. Mr. R emphasised that students should share their ideas of how to work out problems with each other in order to create, what he called, an atmosphere of social learning. Mr. R helped out where he thought students needed assistance or when he was called for assistance. He spent more time with students when he thought their understanding was weaker than that of others.

Perceived lesson (1)

One group consisting of four boys was going through the momentum session on the computer. During an interview, when asked whether the work on the computer made their understanding of momentum easier, they replied:

S_1: It is just a .... repetition of what ..... the teacher did on the board.

S_2: .....it helps me because we can also do problems.

S_3: Yes, it ..... just repeat what ..... teacher say.

S_4: (shrugs his shoulders and points to the other boys that he agrees with all)

(A/R/L03/Gi01/S_1-S_4/0423)

In response to my question: Do they like working on the computer as part of the class?, a second group consisting of three girls replied:

> It's OK. (I asked why?) Because ...... it helps (how?) I don't know, ... it gives more explanation and the teacher also gives more explanation. (What do

you mean?) We can .... ask the teacher to explain because Mr. R comes and helps with the problems. We also help each other. (A/R/L03/Gi02/S_2/0423)

The other students in the different groups provided similar responses. Some of them considered the additional computer explanation as unnecessary, while others regarded it as supporting. It appeared that switching from the formal lesson presented by the teacher to working on the computer provided students with an alternative forum where they could participate in the learning more freely. They discussed the problems with their friends and asked the teacher to assist whenever they were unsure of their work. Students were very enthusiastic in their groups, participating readily and speaking also in their mother tongue (Xhosa). However, when they conversed with the teacher it was always in English with the discussions directed at the problem at hand upon which the students were focussed in resolving. One of the recurring points made by students was the fact that they could proceed on their own. Many of them indicated that when they came back during a free session or after school, they could work individually and test themselves. Students considered it important to get exercise in answering questions on their own.

Achieved lesson (1)

For this lesson, the teacher explained the concept of momentum and the factors that determined the momentum of objects. Mr. R provided students with examples that he worked out on the blackboard as a guide to students on how to work out problems on momentum. Students were provided with a textbook definition of momentum, they took down the notes from the blackboard and were also drawn into a discussion of their experiences of momentum, even though very little interaction in this regard took place. When students were directed to the computer, they were provided with a second explanation of momentum. In contrast to their interaction in the classroom, students were actively engaged in answering questions through discussions with their classmates and with Mr. R. These questions were promptly written in their notebooks along with details of the calculation that led to the answers that was accepted by the computer.

Lesson 2 (A/R/L04/0424)

Intended lesson (2)

Mr. R introduced the conservation of momentum by writing on the blackboard:

The Principle of Conservation of Linear Momentum.

Special objectives that students needed to take cognisance of were highlighted such as the definition of the Principle of Conservation of Momentum, calculations involving this principle, types of collision, and kinetic energy involved in collisions. The teacher pointed out that this was a double period (120 minutes) and students were expected to make use of the problems dealing with this topic on the physical science component on the computers.

Implemented lesson (2)

The teacher explained that momentum, like energy, remained conserved and that conservation occurs under certain conditions. He wrote the following definition on the blackboard:

The total linear momentum of an isolated system remains constant in both magnitude and direction.

Alternatively, in an isolated system the total momentum before a collision equals the total momentum after the collision.

The teacher explained that two types of collision were identified as elastic and inelastic, and that momentum is conserved in any collision but kinetic energy only is conserved in elastic collisions. He used the example of a collision of cars and used a pendulum with iron balls on his table to explain the two types of collision.

He then wrote on the board:

Therefore, to determine the type of collision, the kinetic energy before and after collisions must be determined.

After this explanation, the teacher wrote the following on the board:

Momentum before collision equals momentum after collision.

$$mu_A + mu_B = mv_A + mv_B$$

Mr. R explained the conservation principle again and worked out two examples on the board and explained the above formula by referring to the examples. The point of calculating total collision of all participating objects before and after collision separately was emphasised. The teacher also stressed that the students must make a note in their books that if momentum before and after is equal, then, subtracting one from the other gives an answer that must be zero. After a short explanation of the above, students were referred to the physical science component on the computer. (see Appendix I). The students worked through the introductory lesson of the Principle of Conservation of Linear Momentum, and then proceeded to answers the questions that followed. Each student wrote down the questions, calculated the answers and entered his or her answer in the computer. These calculations involved all of the students in the groups who referred back to their notes, revisited the computer's introductory lesson and/or called the teacher for clarification. Mr. R continued to interact with students, encouraging them to explain to each other what they were doing when they were working out problems in groups. Mr. R made a point of telling students that it was important that they learned from one another and that this kind of interaction was beneficial to both the students who were explaining as well as those students who were listening. Where there were disputes about a step that needed clarification, he intervened and assisted. More time was spent with some of the academically weaker students in the class who needed additional explanations.

Towards the end of the second period, a worksheet with a number of exercises was handed out as part of homework for the next day.

Perceived lesson (2)

When the researcher asked students about the role that computers played in their lesson as they tried to resolve problems, the following are some answers that were provided:

> I guess .... computers have a place but .... still the teacher is more needed.
>
> (A/R/L04/Gi01/S_1/0424)
>
> I ask my teacher, ... I can't ask the computer to help.
>
> (A/R/L04/Gi01/S_2/0424)

The computer is useful and my friends help because we talk about where we don't know answers. It must be part of our lesson because we learn more and better. (A/R/L04/Gi01/S_3/0424)

Yes, it is good to have computers as part of the lesson, our teachers become boring. (A/R/L04/Gi02/S_1/0424)

The involvement of computers are good, especially for mathematics and physics, because... it helps me go through the work and understand it. If I don't understand, I can ask my friend ...or my teacher. We must get programmes for accounting and English also. (A/R/L04/Gi02/S_2/0424)

Yes, computers used in the class are good. We, in our group, each get a turn to answer, ...and the others will help if you get stuck. Yes...we also work out on our own and compare to each other. Then we punch the answer in the computer. If we get it wrong, we are all wrong. If we get it right, we are all right. We are not scared to answer questions. (A/R/L04/Gi02/S_3/0424)

Many students (Group 1, Students 1 & 2; Group 2, Student 2) expressed the central role that the teacher played in the use of the computer centre even though one student (Group 1, Student 3) preferred the computer sometimes in place of the teacher. The students claimed that their interaction with one another was important, and when prompted, they accepted that they actually learned from each other during these interactions (Group 2, Students 2 & 3)

Achieved lesson (2)

Students listened attentively to Mr. R and took down the notes on the Principle of Conservation of Linear Momentum, elastic and inelastic collisions, and kinetic energy as the teacher explained. When they were allowed to go to the computers, they formed similar groups as for the previous lesson and followed the introductory lessons on momentum and the Principle of Conservation of Linear Momentum provided by the physical science programme on the computers. Students used the computer to work out problems based on momentum and the related topics, as required by the physical science syllabus. Each student had a pen and a notepad upon which he or she worked out answers with the aid of calculators. Because the questions required more thought than those during the first lesson, animated discussions took place amongst the students. As the problems were worked through, these were followed by additional exercises with a higher degree of difficulty. This procedure allowed only for more discussion and arguments amongst students as they thought the problems through. Students from one group were called to assist students from another group. Mr. R moved between the different groups and answered questions on how to resolve problems and kept referring students to his own notes and encouraged them to think in terms of the principle he explained on the board.

An additional outcome of this lesson was that many students expressed the view that computers were important and an integral part of their learning. The point expressed by student 3 (A/R/L04/Gi02/S_3/0424) indicated above, emphasised their interaction with their fellow-students while continuing to refer back to the computer screen. This process kept students involved as they discussed the learning material. This situation was deemed as very favourable by teachers and the principal, considering the many distractions that students at this school faced around and outside the school.

4.3.3 Implementation at Centre B

Context

The author's first contact with Centre B occurred in March 2001 when he travelled to the school to meet the Deputy Principal who had been instrumental in getting the Mini-Computer Supported Education Centre installed at this school. He was one of the senior mathematics teachers at the school and also arranged the approval for this research study to be conducted at the school. Following the directions from the Outreach Project management, the author entered the township where the school was situated. On the way to the school, one drove through a number of informal settlements on the outskirts of Cape Town in between which the school was located. The history of the school was explained in Section 3.5.2. The school was surrounded by a high fence with an electronically operated gate guarding the entrance. The entire school was an enclosed structure with all classrooms opening toward the inside of the school and was under one roof. A court yard (also under the roof) was situated in the middle of the school with the computer centre next to it (see Appendix C for photographs). This courtyard appeared like a flea-market during lunch-breaks as members of the community sold their food and beverages here. The Mini-Computer

Supported Education Centre was located in a large room almost like a hall. As indicated in Section 3.5.1, there were 15 computer terminals spaced along three walls available for students which, like all the Mini-Computer Supported Education Centres of the outreach programme, were supported by a server from which the CAMI mathematics programme and the University-developed physical science software operated. There was more than enough space in this centre to add an additional 30 computer terminals.

Three teachers taught mathematics and physical science at Grade 12 level. Two teachers were responsible for the teaching of mathematics and one teacher for physical science. The one mathematics teacher (Mr. U), who was the head of the mathematics and physical science department, held a BSc degree and a teacher's diploma (HDE). The other mathematics teacher held a BA degree and a diploma for Adult Basic Education and Training (ABET). The physical science teacher held a BSc with a Further Diploma in Education (FDE). All three teachers had between 10 and 15 years experience in teaching. There were three classes in Grade 12; all three classes followed mathematics and two classes followed physical science. In total there were 80 mathematics students and 60 physical science students in Grade 12. As in Centre A, the remaining mathematics class followed the economics stream.

The following is a description of the author's observation of a session that Mr. U used to prepare students for the mathematics examination.

General observation

Mr. U's lessons took place in the Computer Centre (as it is called at this school). He was in the centre before the class started so that he could prime the computer terminals — the server needed to be switched on — followed by the individual terminals. Mr. U described the process as being time-consuming because there was little time available when the computer centre was shared between the three Grade 12 mathematics and physical science teachers. Only ten of the terminals could be used for mathematics as the centre only had one licence for the CAMI programme. Each licence allowed a maximum of ten computers to be linked to the server. No such restrictions were placed on the physical science component.

Lesson at Centre B (B/U/L05/0508)

Intended lesson

Mr. U had a double period session with one of his Grade 12 mathematics classes. He indicated that the purpose of this lesson was to use the computers to give the learners a test, starting out with factorisation in the first part and using the quadratic formula for the second part (see Appendix J). The mark that students obtained would go towards their yearly mark. Mr. U was able to monitor each student's progress on the CAMI programme as each student logged in under his or her own name. The computer flashed after a few minutes if students took too long to answer a particular item (question). Each student was given a maximum of five items to complete.

Implemented lesson

As students came into the centre, they were allowed to sit at the entrance. Mr. U reminded the students that they were warned of the test well in advance and that he expected them to be prepared for the test. The first ten students were then each seated at a terminal and were told to log in. They were directed to the relevant section and were told to start. Each student carried with them a pen and paper and started by reading the problem on the computer and answering the items, for example one item under the factorisation test (at the first difficulty level) required students to factorise the following quadratic equation: $x^2 + 5x + 6 = 0$. The computer provided two sets of brackets and students had to complete the contents, in this items being $(x + 6)(x - 1)$. Students were then required to give the values for x, which for this item were $x = -6$ or $x = 1$. In the next item, the difficulty level was increased with, for example, the addition of a co-efficient to the first term of the equation.

The students were allowed a certain amount of time at a terminal to complete an item before the computer flashed. When the computer flashed, they were told to continue to the next item. When students completed answering an item, they automatically moved on to the next one. Students who completed their five items were replaced by the students waiting who were frantically going through their notes. At the end of the first period, students were again lined up to start the next session on the computer where they had to answer problems by using the quadratic formula. The same process was followed as for the first set of five items. An example of an item in this test required students to use the formula to factorise the equation $3x^2 + 5x - 7 = 3$. When the test session ended, students were allowed to work on the computers in groups and discussion ensued on the sections dealing with factorisation and using the formula, and the missed chances for successful solutions.

Perceived lesson

Students indicated that they enjoyed the sessions when they got to use the computers to see if they understood what was taught in class. The following were some feedback obtained from students who were interviewed after the test:

> Using the computer is important to test how quickly you can answer. It is almost like an examination when you are under pressure.
> (B/U/L05/S_1/0508)
>
> The testing with computer is not so nice. [But] I like using the computer to work on my own and at my own time. (B/U/L05/S_2/0508)
>
> I cannot think so fast, especially when Mr. U is looking over my shoulder.
> (B/U/L05/S_3/0508)
>
> I have no problem with using the computer, even in a test. We will have to learn to use the computer anyway, so now is a good time.
> (B/U/L05/S_4/0508)
>
> The computer is just used to test if we know our work. Mr. U explains the work well, and we can always ask him. He is always in the computer centre during intervals. (B/U/L05/S_5/0508)
>
> Testing with the computer helps us know where we don't understand. For if I struggle, I will try and try until I get it right. Then I know it and can answer it again. This is how computer is a help. (B/U/L05/S_6/0508)

On the whole, students expressed their satisfaction with using the computer to write a test. They saw the computer as integral to their learning as pointed out by students 4 and 6 above. Some students considered the pressure that they are put under as good (Student 1) because this represented the pressure that they would experience under examination conditions; other students saw the combined pressure of working on the computer and the teacher monitoring their progress as limiting or inhibiting (Student

3). The role that teachers played still remained central to the classroom environment as expressed by Student 5, who regarded the teacher as the interactive resource that could be approached should they require additional assistance. Student 2 expressed the view that working on the computer individually still suited some students.

Achieved lesson

The key outcome of this lesson was that students were tested for their understanding of factorisation and using the quadratic formula by completing a test on the computer. Students showed a great willingness and acceptance for a test of this nature. Because it was a test, no interaction took place between students but they generally agreed to the test being a measure of their ability in factorisation and the application of the quadratic formula. The lesson also led to some students examining their own abilities in the two selected topics which resulted in many of them going back to these sections on the computer. The test also placed Mr. U in the position of determining which students still had problems with the tested areas, and the kind of remedial work or revision programme that needed to be structured. The outcomes of the test were used towards the year mark of students which eventually contributed to their achievement in the final examination.

4.3.4 General comments on the implementation, perception and achievement of lessons at the two centres

The inclusion of the Mini-Computer Supported Education Centre in the daily teaching followed the different approaches for the two centres, even though the use of the computers are similar.

At Centre A, one teacher taught both mathematics and physical science and could therefore use the centre on a daily basis. The teacher used the physical science and mathematics programmes as part of his teaching and would teach a particular topic including the introductory lessons on the programmes as part of his lesson after which students would work out problems on the computer. The teacher would also draw up his own worksheet of problems that students had to do as part of homework assignments.

At Centre B, there were three teachers for Grade 12 mathematics and physical science, which potentially caused a clash of time-tables should all three teachers decide to use the computer centre for all of their lessons. To solve this problem the three teachers planned their annual timetable to allow for double periods during which time the centre could be used and so they took turns to use the computer centre. The computer programmes were mostly used for reinforcement for what was already taught in the class. These sessions would also be planned around a particular topic that would provide students with the opportunity to hone their ability to work quickly and accurately. The centre was therefore not used as a classroom in the strict sense of the word, but as an additional resource centre. The physical science teacher at Centre B suggested that the physical science programme be revised to remove the introductory lesson so that students could go straight to problems based on the work that was already completed in class. At present the programme is designed to allow students to first go through lessons that illuminate the topic concerned.

Both centres used the mathematics programme in a similar way by tracking the progress of students for each topic. This tracking, they claimed, allowed teachers to select their revision programmes in order to address problem areas. At both centres, the author found that students would come during intervals, when they had a free opportunity and after school, to work on the computers. Unfortunately, during vacation periods, at Centre B computers have to be removed from the centre and locked up in their strongroom (safe) because it was too risky to allow computers to be in the computer centre. At Centre A, additional classes were held during the vacation period; students attended these classes under the supervision of Mr. R.

In both centres, teachers encouraged students in groups to interact with one another and that they should show one another how they went about solving problems related to the syllabus. Teachers intervened in groups when there was no consensus about the approach to a problem or when students were not clear about how to proceed between different steps when answering a problem. Teachers also used their time to assist the academically weaker students.

The general student perception and achievement of the computer-assisted lessons are discussed as part of Sections 4.4 and 4.5 below.

4.3.5 Summary

The above results of the implementation, perception and achievement of the computer-assisted lessons in the outreach programmes were obtained by observation through on-site visits at the two centres and interviews with teachers and students. The following section investigates student perception of their computer-assisted classes.

4.4 How did students perceive their computer-assisted learning (CAL) classes?

4.4.1 Introduction

As pointed out in Chapter 3, data collection procedures to address this research question involved the application of the *Computer-Assisted Learning Environment Questionnaire* (CALEQ), both in an actual and preferred format. The collection of the quantitative data was done in conjunction with interviews that were conducted with students individually and in groups.

4.4.2 Perceptions of students using the Computer-Assisted Learning Environment Questionnaire (CALEQ)

Limitations to the study

It is important to note that the application of the CALEQ was not trial tested with a large sample. This is identified upfront as a limitation to this study. In 2001 there were only nine schools where the Mini-Computer Supported Education Centres were placed. In the Western Cape, few schools from the disadvantaged areas had access to computers that could be employed in their daily teaching; while one or two computers might be available at schools, these were mainly used for administrative purposes. The schools that were involved in the Outreach Project were spread throughout the Western Cape making travelling to them extremely costly. The total numbers of Grade 12 students at each school that participated in the computer-assisted classes for both mathematics and physical science ranged from 30 to 60, and, given that there were only nine centres, this made the numbers too small for an effective trial of the CALEQ. In planning this investigation, the author tried to include an additional two centres that were in reasonable proximity of the two selected as cases for this study, but this was unsuccessful. The one school was not amenable to have a researcher included as part of their daily activities. The second school's principal chose not to reply to the author's repeated requests.

Findings related to the combined scores of the two schools (n = 89)

As pointed out in the previous chapter, the CALEQ has six scales, namely Involvement (IVO), Open-Endedness (OE), Investigation (IVE), Material Organisation (MO), Learning Assessment (LA) and Integration (ITG). Each scale was represented by eight items (see Appendix H). The scale's means range from 1 to 5, with 1 for the most negative perception that represents almost never, 2 represents seldom, 3 represents sometimes, 4 represents often and 5 for the most positive perception, which represents very often.

Table 4.01.
Cronbach alpha reliability of scales for the actual and preferred versions of CALEQ (n = 89)

No.	Scale	Alpha Reliability	
		Actual	Preferred
1	Involvement (IVO)	.64	.79
2	Open-Endedness (OE)	.51	.59
3	Investigation (IVE)	.61	.53
4	Material Organisation (MO)	.64	.64
5	Learning Assessment (LA)	.54	.63
6	Integration (ITG)	.65	.70

Following the data entry and re-scoring for the reverse items, a manual validation of all items was done to ensure accuracy of the data. This was followed by the measurement of Cronbach alpha reliability and inter-scale correlations using SPSS software to determine the internal consistency (Table 4.01) and discriminant validity for the actual (Table 4.02) and preferred (Table 4.03) versions of the instrument. The discriminant validity results (mean correlation of a scale with other scales) for the six scales of the CALEQ ranged from 0.18 to 0.36 for the actual form (Table 4.02) and between 0.21 and 0.47 for the preferred form (Table 4.03). The data suggest that the raw scores on the CALEQ assess distinct (on the actual form) but somewhat overlapping (on the preferred form) aspects of the computer-assisted learning environment. Unfortunately factor analysis to determine the validity of the structure of the instrument for assessing the students' perception of the computer-assisted learning environment could not be done as the sample size was not sufficient to perform a reliable factor analysis.

Table 4.02
Item-scale correlation coefficients of the actual version of CALEQ (n = 89)

Scale	IVO	OE	IVE	MO	LA	ITG
Involvement (IVO)	1.00					
Open-Endedness (OE)	0.38**	1.00				
Investigation (IVE)	0.44**	0.50**	1.00			
Material Organisation (MO)	0.13	0.33**	0.45**	1.00		
Learning Assessment (LA)	0.24*	0.12	0.07	0.09	1.00	
Integration (ITG)	0.20	0.02	0.34**	0.18	0.39**	1.00
Mean correlation with other scales	0.28	0.27	0.36	0.24	0.18	0.23

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

Table 4.03
Item-scale correlation coefficients of the preferred version of CALEQ (n = 89)

Scale	IVO	OE	IVE	MO	LA	ITG
Involvement (IVO)	1.00					
Open-Endedness (OE)	0.75**	1.00				
Investigation (IVE)	0.72**	0.72**	1.00			
Material Organisation (MO)	0.39**	0.36**	0.48**	1.00		
Learning Assessment (LA)	0.17	0.04	0.05	0.18	1.00	
Integration (ITG)	0.27**	0.26*	0.38**	0.39**	0.60**	1.00
Mean correlation with other scales	0.46	0.43	0.47	0.36	0.21	0.38

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level

The Cronbach alpha reliability test was used to determine the internal consistency of the instrument. The Cronbach alpha reliability scores for both the actual and preferred versions of the CALEQ for all the scales was greater than the 0.5 threshold proposed by Nunnally (1978). The Open-Endedness and Learning Assessment scales of the CALEQ (actual) instrument had Cronbach reliabilities of 0.51 and 0.54 which only just exceeded the threshold of 0.5. The coefficient for these two scales improved in the preferred format to 0.59 and 0.63, respectively. The other four scales in the actual version, Involvement, Investigation, Material Organisation and Integration all had Cronbach reliabilities of greater than 0.6.

The reliability coefficient scores for three of these four scales in the actual instrument improved in the preferred format of the instrument, except for the Investigation scale for which the Cronbach reliability decreased from 0.61 to 0.53. Items 2 and 44 of the Open-Endedness scale and items 22 and 46 of the Material Organisation scale had extremely low values for the reliability coefficient and it was suspected that students might not have understood the language used in these items. The reason for such misunderstanding was that in all South African schools in historically black areas, the language of instruction at the secondary level is English. In these two schools, the mother tongue of the students is Xhosa; English would be a second and sometimes a third language. For example, the word 'prescribed' in item 44 'I must answer questions in a prescribed way' was not understood by all students. Similarly, item 46 'The computer programmes are hard to use' the word 'programmes' were not understood by all students and the word 'hard' were not understood in the context of the statement; 'difficult' would have been a better word to use. These misunderstandings were revealed in the interviews that were held after the questionnaires were administered. Students perceived the items 2 and 44 on the Open-Endedness scale and items 22 and 46 on the Material Organisation scale opposite to what was intended. The reversal of the items of the two scales improved the reliability coefficient scores of the Open-Endedness scale from 0.08 to 0.51 and the Material Organisation scale from 0.44 to 0.64 – both on the actual version of the CALEQ.

In total, 89 students completed the CALEQ at the two centres, 40 at Centre A and 49 at Centre B. In the case of the preferred version of the CALEQ, one student at Centre

A did not complete her questionnaire due to illness. The mean scores and standard deviation of each scale for the actual version of the CALEQ of the two centres combined are presented in Table 4.04. The mean scores of all the scales were above 3 which indicated a positive perception of the computer-assisted learning environment by the students; the scores indicated that student perceptions ranged between sometimes (3) and often (4).

Table 4.04
Scale means and standard deviations for the actual and preferred versions of the CALEQ for the combination of Centres A and B (n = 89)

Scale	No. of items	Form	Average Item Mean	Scale Mean	Scale Std. Dev.
Involvement (IVO)	8	Actual	3.39	28.09	4.70
		Preferred	3.60	28.77	5.95
Open-Endedness (OE)	8	Actual	3.23	25.83	4.59
		Preferred	3.31	26.51	4.55
Investigation (IVE)	8	Actual	3.36	26.90	4.62
		Preferred	3.30	26.35	4.16
Material Organisation (MO)	8	Actual	3.40	27.17	5.83
		Preferred	3.40	27.01	5.56
Learning Assessment (LA)	8	Actual	3.44	27.52	4.80
		Preferred	3.80	30.21	4.98
Integration (ITG)	8	Actual	3.60	28.81	5.31
		Preferred	3.60	28.75	5.83

When comparing the mean scores of the six scales for the actual format of the instrument, as indicated by Figure 4.01, the Integration scale had the highest item mean (3.60) which pointed to a positive integration of computer lessons within the daily teaching and learning activities of teachers and students. This mean was followed by the Learning Assessment scale with an item mean score of 3.44; this result was indicative of a positive perception by students that they were able to monitor their learning through the use of the computer. The Material Organisation scale followed closely with an item mean score of 3.40 indicating a positive perception of the organisation maintained by the teacher in the computer supported classes and the adequacy of the computer programmes that were in use. The positive perception of the Involvement scale (item mean score of 3.39) represented the extent to which students participated in the computer-assisted classes. The item mean score of 3.36 of the Investigation scale reflected a positive perception by students of the degree to which they were encouraged to engage in the learning process. The Open-Endedness scale had the lowest item mean score (3.23) but which still pointed to a positive perception on the side of the students. This would be representative of the degree to which students perceived the teacher adopting an open-ended approach in the computer-assisted classes.

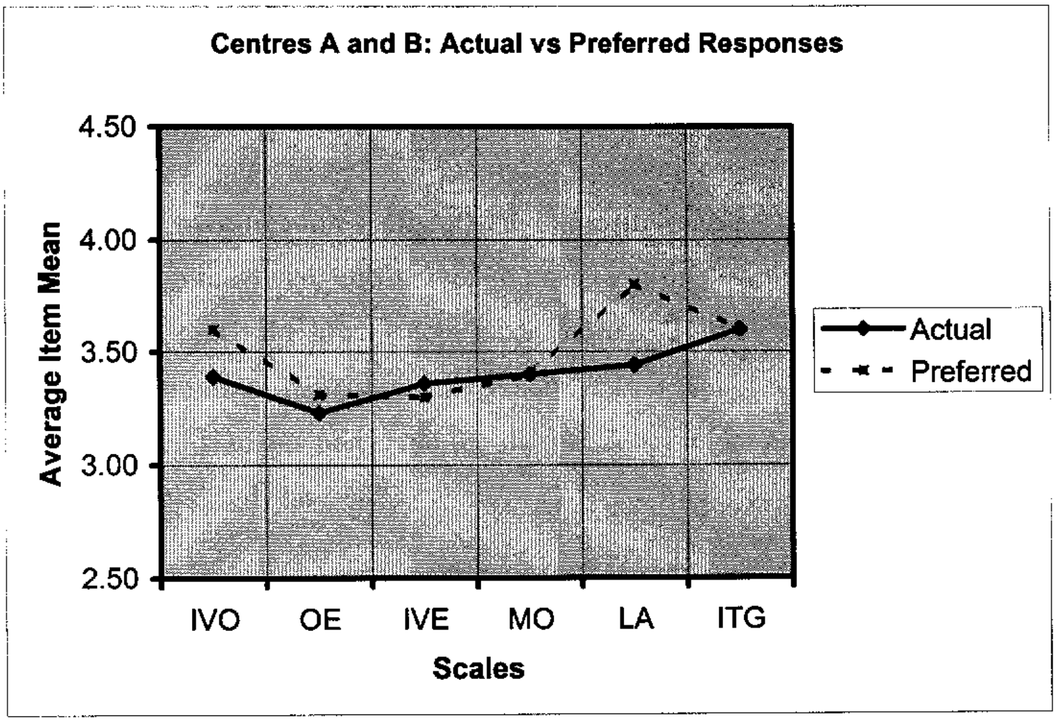

Figure 4.01
A comparison of average item means of scales in the actual and preferred versions of the CALEQ for the combination of Centre A and B (n = 89)

Scale means for the actual format ranged from 25.83 for the Open-Endedness scale to 28.81 for the Integration scale. The standard deviation scores for the six scales ranged from 4.59 to 5.83. In addition, large standard deviations scores for the Material Organisation scale (5.83) in particular, and the Integration scale (5.31) indicated that these two scales had a larger variation of responses compared with the other four scales. The smaller standard deviation scores for Open-Endedness (4.59) and Investigation (4.62) meant that these two scales had a smaller range of responses compared with the other four. The variations reflected by the latter two scales were, however, not much different to the Learning Assessment scale (4.80) and the Involvement scale (4.70).

The preferred version of the CALEQ represented students' perceptions relating to how they would prefer the computer-assisted learning environment. The item means for the preferred form of the CALEQ (see Table 4.04) ranged from 3.30 to 3.80 indicating a positive perception towards a preferred computer-assisted learning environment. The Learning Assessment scale had the highest average item mean (3.80) indicating positive perceptions by students with regard to their assessment of their own learning through the use of computers. Two scales, namely Involvement and Integration, had the same average item mean of 3.60. Very little difference was found between the average item means of Open-Endedness scale (3.31) and the Investigation scale (3.30) while the Material Organisation scale had a mean score of 3.40. The scale means across the preferred version of the CALEQ ranged from 26.35 for the Investigation scale to 30.21 for the Learning assessment scale. The standard deviation for the scales of the preferred version of the CALEQ ranged from 4.16 in the case of the Investigation scale to 5.95 for the involvement scale.

In Table 4.04, the average item means for the actual and preferred forms of the CALEQ for students' perceptions of the two schools are summarised. The average item means in Table 4.04 for each scale in the actual and preferred versions for the CALEQ are plotted in Figure 4.01. The average item mean for both actual and preferred perceptions of students were the same in the cases of the Material Organisation (3.40) and Integration (3.60) scales. This indicated that students' perceptions reflected a satisfaction with the way that the computer-assisted classes were organised and that the computer software and hardware were adequate (Material Organisation). The consistency of the item means for the Integration scale reflected that students perceived the extent to which the computer and its programmes were included in the learning environment as being positive. The average item means for three of the remaining four scales showed an increase for all the scales on the preferred forms with a slight decrease (of 0.06) in the Investigation scale. Two-tailed t-tests to determine the statistical significance between the actual and preferred versions of the CALEQ indicated that only two scales were statistically significant, namely the Involvement scale ($p<0.01$) and the Learning Assessment scale ($p<0.05$).

Findings related to Centre A

The Cronbach alpha reliability test was used to determine the internal consistency of the CALEQ actual and preferred forms for Centre A. The Cronbach alpha reliability scores (see Table 4.05) for both the actual and preferred versions of the CALEQ for most scales were greater than the 0.5 threshold for small samples proposed by Nunnally (1978). In the actual form of CALEQ, the reliability coefficients were all below 0.60 except for the Integration scale, which had a reliability coefficient of 0.66. However, the Open-Endedness scale of the CALEQ instrument had Cronbach reliabilities of 0.44 (for the actual version) and 0.46 (for the preferred version) which were below the threshold of 0.5. The low alpha reliability for Open-endedness is consistent with some of the values obtained in the cross-national study of Fraser, McRobbie and Giddings (1993). In that study, this coefficient varied from 0.78 for England to 0.49 for Nigeria. It was on these grounds that the Open-Endedness scale was retained. The reliability coefficient for Investigation also was low. In the preferred form of the instrument the Involvement and Integration scales reached 0.73 and 0.74, respectively, compared to their reliability scores of 0.58 and 0.66 in the actual form of the CALEQ.

Table 4.05
Cronbach alpha reliability of scales for the actual and preferred versions of CALEQ for Centre A (n = 40 [actual]; n= 39 [preferred])

No.	Scale	Alpha Reliability	
		Actual	Preferred
1	Involvement (IVO)	0.58	0.73
2	Open-Endedness (OE)	0.44	0.46
3	Investigation (IVE)	0.53	0.33
4	Material Organisation (MO)	0.52	0.57
5	Learning Assessment (LA)	0.58	0.63
6	Integration (ITG)	0.66	0.74

In total, 40 students completed the CALEQ at Centre A. Unfortunately, one student became ill and could not complete her preferred form. Table 4.06 represents a summary of the mean scores and standard deviation of each scale for the Actual and

Preferred versions of the CALEQ for Centre A. The mean scores of all the scales were above 3 [between sometimes (3) and often (4)] which indicated a positive perception of the computer-assisted learning environment by the students.

Table 4.06
Scale means and standard deviations for the actual and preferred versions of the CALEQ for Centre A only (n = 40 [Actual]; n = 39 [Preferred])

Scale	No. of items	Form	Average Item Mean	Scale Mean	Scale Std. Dev.
Involvement (IVO)	8	Actual	3.41	27.28	4.42
		Preferred	3.60	28.82	5.23
Open-Endedness (OE)	8	Actual	3.32	26.58	4.26
		Preferred	3.38	27.00	3.85
Investigation (IVE)	8	Actual	3.40	27.23	4.13
		Preferred	3.40	27.26	3.56
Material Organisation (MO)	8	Actual	3.49	27.90	5.19
		Preferred	3.55	28.36	5.00
Learning Assessment (LA)	8	Actual	3.46	27.65	5.02
		Preferred	3.66	29.26	5.19
Integration (ITG)	8	Actual	3.71	29.70	5.32
		Preferred	3.60	28.77	6.11

When comparing the item mean scores of the six scales for the actual and preferred formats of the instrument, as indicated by Figure 4.02, the item means ranged from 3.32 to 3.71 for the actual form of the CALEQ and from 3.38 to 3.66 for the preferred version. For the actual version, the Integration scale had the highest item mean (3.71) which pointed to a perceived positive integration of computer lessons within the daily teaching and learning activities of teachers and students. Four scales, namely, Material Organisation (3.49), Learning assessment (3.46), Involvement (3.41) and Investigation (3.40) had similar item means. The Open-Endedness scale had the lowest item mean of 3.32. The preferred version, which represented perceptions of students of how they would prefer the computer-assisted learning environment, pointed towards a more positive preferred learning environment as four of the six scales indicated a higher item mean score than the actual item mean. Of the remaining two scales, the Investigation scale had the same score (3.40) for both the actual and preferred versions of CALEQ, while the item mean for the Integration scale decreased from 3.71 to 3.60. This indicated that students preferred lesser integration of the computer lessons as part of their daily lessons. Two-tailed t-tests (Appendix K) indicated that there were no statistically significant differences between the actual and preferred versions of the CALEQ.

The scale mean scores for Centre A ranged from 26.58 (Open-Endedness) to 29.70 (Integration) for the actual form of the CALEQ and from 27.00 (Open-Endedness) to 29.26 (Learning Assessment) for the preferred form of the CALEQ. The standard deviation score for the six scales ranged from 4.13 to 5.32 for the actual version of the CALEQ, and 3.56 to 6.11 for the preferred version of the instrument. The standard deviation scores for the Integration scale reflected the largest variation of responses for both the actual (5.32) and the preferred (6.11) versions of the instrument. The standard deviation score for the Investigation scale had the lowest range of responses for both the actual (4.13) and preferred (3.56) versions of the instrument.

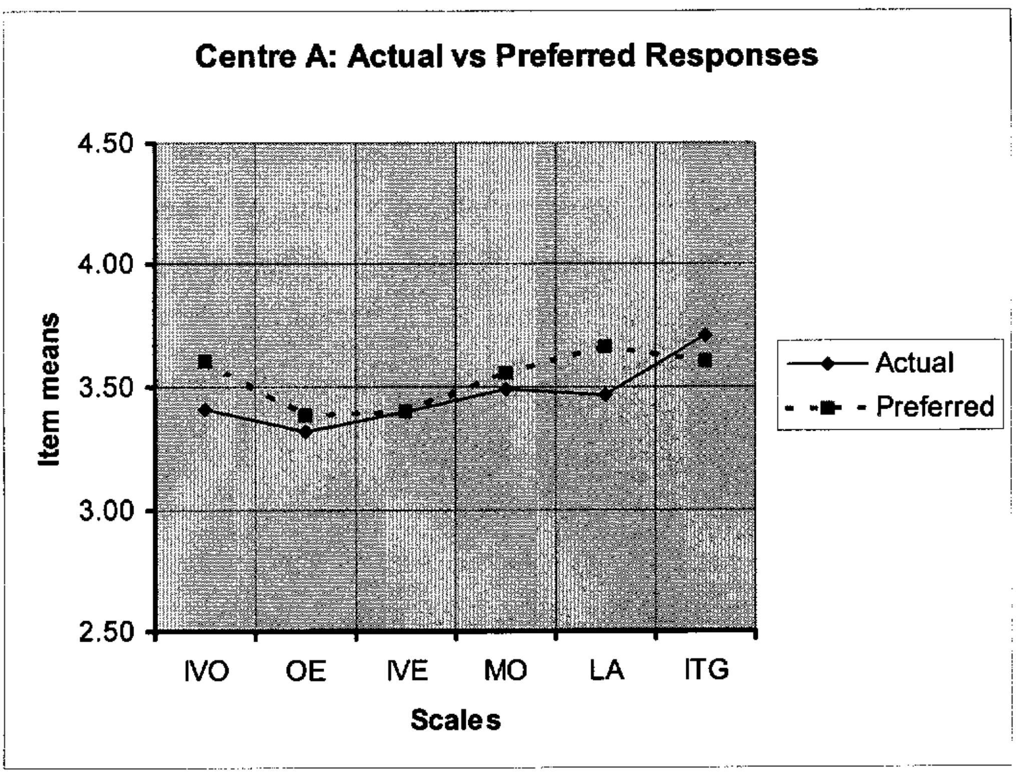

Figure 4.02
A comparison of the actual and preferred forms of CALEQ of students at Centre A
(n = 40 [actual]; n = 39 [preferred])

Findings related to Centre B

The Cronbach alpha reliability scores (see Table 4.07) for both the actual and preferred versions of the CALEQ for all of the scales was greater than the 0.5 threshold for small samples proposed by Nunnally (1978). In the actual form of CALEQ, the reliability coefficients ranged between 0.51 and 0.71 and for the preferred version of the instrument the reliability coefficients ranged between 0.60 and 0.82. The Material Organisation (0.71) and Involvement (0.69) scales had the highest coefficients for the actual version of the instrument. All the scales for the preferred form of the CALEQ had reliability coefficients greater than 0.60 with the Involvement scale having the highest reliability coefficient (0.82) for the preferred version.

Table 4.07
Cronbach alpha reliability of scales for the actual and preferred versions of CALEQ for Centre B (n = 49)

No.	Scale	Alpha Reliability	
		Actual	Preferred
1	Involvement (IVO)	0.69	0.82
2	Open-Endedness (OE)	0.54	0.66
3	Investigation (IVE)	0.67	0.60
4	Material Organisation (MO)	0.71	0.65
5	Learning Assessment (LA)	0.51	0.62
6	Integration (ITG)	0.62	0.67

In total, 49 students completed the actual and preferred versions of the CALEQ at Centre B. Table 4.08 represents a summary of the mean scores and standard deviation of each scale for the actual and preferred versions of the CALEQ at Centre B. The mean scores of all the scales were above 3 [between sometimes (3) and often (4)] which indicated a positive perception of the computer-assisted learning environment by the students.

When comparing the item mean scores of the six scales for the actual and preferred formats of the instrument, as indicated by Figure 4.03, the item means ranged from

3.15 to 3.51 for the actual form of the CALEQ and 3.20 to 3.87 for the preferred version. For the actual version of the instrument, the Integration scale had the highest item mean (3.71) which reflected that students perceived the integration of computer lessons within the daily teaching and learning activities of teachers and students as positive. All six scales had relatively similar item means. The Open-Endedness scale had the lowest item mean of 3.15.

Table 4.08
Scale means and standard deviations for the actual and preferred versions of the CALEQ for Centre B only (n = 49)

Scale	No. of items	Form	Average Item Mean	Scale Mean	Scale Std. Dev.
Involvement (IVO)	8	Actual	3.37	26.94	4.95
		Preferred	3.59	28.74	6.53
Open-Endedness (OE)	8	Actual	3.15	25.23	4.79
		Preferred	3.27	26.12	5.13
Investigation (IVE)	8	Actual	3.33	26.63	5.01
		Preferred	3.20	25.63	4.49
Material Organisation (MO)	8	Actual	3.32	26.57	6.30
		Preferred	3.24	25.94	5.79
Learning Assessment (LA)	8	Actual	3.43	27.41	4.66
		Preferred	3.87	30.96	4.73
Integration (ITG)	8	Actual	3.51	28.08	5.25
		Preferred	3.59	28.74	5.67

The preferred version that represented perceptions of students of how they would prefer the computer-assisted learning environment pointed towards a more positive preferred learning environment. However, the Material Organisation scale and the Investigation scale had lower item means in the preferred compared to the actual version of CALEQ. This result indicated that students preferred a less structured computer session (Material Organisation) and fewer activities that involved investigating answers on their own. An explanation for this reversed situation preferred by students for these two scales is explored in Section 5.4.

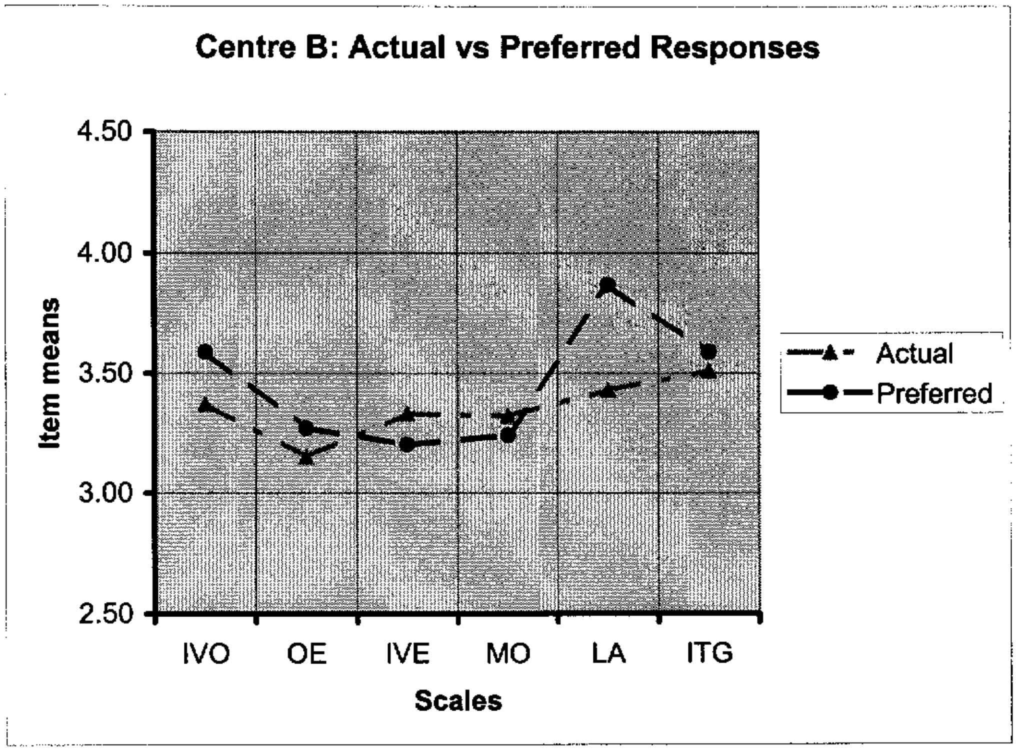

Figure 4.03
A comparison of the item means obtained from the actual and preferred forms of CALEQ of students at Centre B (n = 49)

The scale means ranged from 25.23 (Open-Endedness) to 28.08 (Integration) for the actual form of the CALEQ and from 25.63 (Investigation) to 30.96 (Learning Assessment) for the preferred form. The standard deviation scores for the six scales ranged from 4.66 to 6.30 for the actual version of the CALEQ and 4.49 to 6.53 for the preferred version of the instrument. The Material Organisation scale had the highest standard deviation (6.53) for the actual version of the CALEQ and the Involvement scale had the highest for the preferred version which reflected the largest variation of responses to the two versions of the instrument. The Learning Assessment scale and the Investigation scale had the lowest range of responses for both the actual and preferred formats of the instrument respectively. Two-tailed t-tests (Appendix L) to determine the statistical significance between the actual and preferred versions of the CALEQ for Centre B indicated that only the Learning Assessment scale ($p<0.01$) was statistically significant.

Findings related to the comparison of Centres A and B

A comparison of the item mean scores of the two centres for both the preferred and actual versions of the CALEQ are summarised in Table 4.09 and presented by the line graphs in Figure 4.04. [For ease of comparing data, the results from Tables 4.06 and 4.08 are combined in Table 4.09 and the results in Figures 4.02 and 4.03 are combined in Figure 4.04.]

Table 4.09
Scale means and standard deviations for the actual and preferred versions of the CALEQ for Centres A and B

Scale	No. of items	Form	Av. Item Mean		Scale Mean		Scale Std. Dev.	
			Centre A	Centre B	Centre A	Centre B	Centre A	Centre B
Involvement (IVO)	8	Actual	3.41	3.37	27.28	26.94	4.42	4.95
		Preferred	3.60	3.59	28.82	28.74	5.23	6.53
Open-Endedness (OE)	8	Actual	3.32	3.15	26.58	25.23	4.26	4.79
		Preferred	3.38	3.27	27.00	26.12	3.85	5.13
Investigation (IVE)	8	Actual	3.40	3.33	27.23	26.63	4.13	5.01
		Preferred	3.40	3.20	27.26	25.63	3.56	4.49
Material Organisation (MO)	8	Actual	3.49	3.32	27.90	26.57	5.19	6.30
		Preferred	3.55	3.24	28.36	25.94	5.00	5.79
Learning Assessment (LA)	8	Actual	3.46	3.43	27.65	27.41	5.02	4.66
		Preferred	3.66	3.87	29.26	30.96	5.19	4.73
Integration (ITG)	8	Actual	3.71	3.51	29.70	28.08	5.32	5.25
		Preferred	3.60	3.59	28.77	28.74	6.11	5.67

The data for the Involvement scale indicated that both centres were equally involved in the computer sessions on the actual format and that students at both centres wanted more involvement with computers as indicated by the preferred version. The data for the Open-Endedness scale indicated that students at both centres wanted the open-ended approach to be improved but this was more evident at Centre B. The Investigation scale, which represented the extent to which students were encouraged to find things out for themselves, showed a higher level at Centre A than at B, even though students did not prefer greater investigation than they were actually experiencing. For the Material Organisation scale, student perception at Centre A indicated that the computer centre was more organised than at Centre B. Both centres showed a similar score on the Learning Assessment scale, with students at Centre B wanting this part to improve much more than Centre A. The Integration scale had the highest scores of all the scales indicating perceived good integration of the computer as a tool in the teaching and learning of mathematics and physical science.

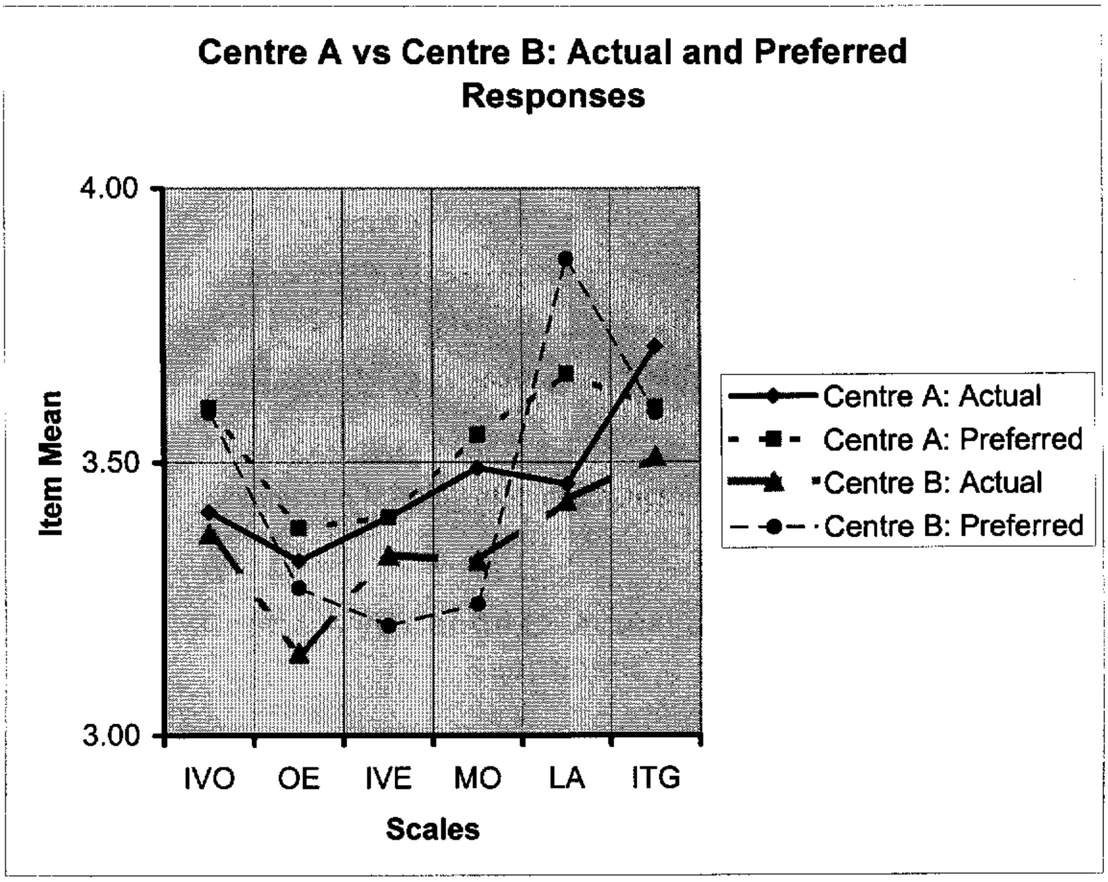

Figure 4.04

Comparison of the item means obtained per scale from CALEQ for Centre A (actual), Centre A (preferred), Centre B (actual) and Centre B (preferred)

Summary

The above results were obtained after analysis of the data for the Computer-Assisted Learning Environment Questionnaire (CALEQ). These quantitative indicators, together with the qualitative data obtained from the interviews with students, are discussed in Chapter 5. The following section reports on data gathered during student interviews.

4.4.3 Student perceptions of computer-assisted classes gathered from interviews

Introduction

Student interviews were held during the August/September 2001 on-site visits. Students' responses on the CALEQ were used as a starting point to gather their perceptions of the inclusion of computers as part of their mathematics and physical science classrooms. Interviews were conducted with individual students (see Appendix M for an example) as well as with groups of two to five students (see Appendix N for an example). A semi-structured interview approach was used with questions structured around a number of areas, namely, some background of the student, students' experiences about the inclusion of the computers as part of their classes, how they perceived their learning taking place, whether working on the computers improved their understanding of the work, and how the inclusion of computers influenced their interaction with their classmates (see Appendix A). Students also were probed for any improvements or changes to their computer-assisted classes that they would prefer. This interview framework was flexible as students discussed different issues related to their experiences. Where students wanted to expand on issues outside the interview framework, the author used his discretion in allowing this discussion until it proved, in the author's opinion, not to be relevant to the investigation.

Student perceptions at Centre A

At Centre A, seven individual interviews and five group interviews were conducted. The groups ranged between two and four students and students were allowed to form their own groups because the author found that students who were not first language English speakers responded better in groups. The five groups consisted of one group of two students, one group of three students, and three groups of four students. A number of students were, however, quite conversant in English, and therefore interviews with some of these students were held individually. Where the author required information about the background of students, this information was obtained in a one-on-one interview.

Background of students

Students at Centre A mostly came from the informal settlement area surrounding the school; many students did not have access to electricity at their homes. There also were, in many instances, no direct water supply to homes and they would share access to a tap with a number of households. Where parents were working, very little supervision of students took place as parents would leave for work early in the morning and arrive at home late. In some cases, students needed to take care of the home and also look after their siblings. The ages of students in the Grade 12 class ranged from 18 to 23 years which were not an unusual phenomenon for black students in South Africa. Four students indicated that they had worked as labourers before deciding to come back to school to complete the matriculation examination. Eight students had failed previous grades, three of them more than once. Two female students each had a child of their own. All the students interviewed indicated that working on the computers at the school was their first encounter in their lives with computers.

Students' first impressions of using computers

The majority of students interviewed indicated that they were extremely excited about the prospect of using computers for the first time when they started at the beginning of the year. Students had participated in the initiation ceremony during the previous year when the sponsors, teachers, parents, community members and outreach programme managers officially opened the Mini-Computer Supported Education Centre at the school. As one student put it:

> We were excited because we were going to be the first ones to try out computers in our area. ... everyone keep saying computers are the future and we must learn how to use them. (A/Gi2/0815)

Students indicated that the idea of the inclusion of computers held great promise and that they were encouraged by the principal and Mr. R to make use of the resource which was made available exclusively for the use of Grade 12 mathematics and physical science students. Students also pointed out that they expected their achievement in mathematics and physical science to increase, as typified by the following statement by one of the students:

> I think by using computers that I will get very good marks in maths and physics. ... My mother said that I should try my best... and that here I had a chance to study for a good job. (A/I4/0815)

It appeared that students were under the impression that with the aid of computers their achievements in the two subjects would undergo a marked improvement which would put them in a better position for further studies or for better employment opportunities. Further encouragement came from the parents of students because the outreach programme organisers had emphasised the goal of the inclusion of computers was to improve the student learning in mathematics and physical science and to prepare students for the future – a goal also identified in Section 4.2. The overall initial impressions of the interviewed students toward their computer-assisted classes could therefore be described as positive and encouraging.

Student experiences of the inclusion of computers in their classroom

The large proportion of the students interviewed expressed the view that they were satisfied with the manner in which the computers was included as part of their daily classes in mathematics and physical science and that, on the whole, Mr. R's organisation of the classes contributed to their satisfaction. They considered their classes as consisting of two parts, a formal section and a non-formal part. The formal section was when Mr. R taught by standing in front of the blackboard, teaching and writing notes on the board. The informal section of the class was when the computers were introduced.

> It's like having two classes in one. Mr. R is a good teacher and he would continue with normal classes, and sometimes we don't use the computers and he would only teach...in other classes Mr. R uses only the computers, then also he would combine both in one, especially during double periods.(A/I3/0814)

The majority of students also expressed the view that they were happy with the way they were being involved in the computer-assisted classes and that they participated readily in discussions with both the teacher and their fellow students. These students indicated that they did not feel insecure in using the computer because of the user-friendly nature of the programmes and the fact that Mr. R was always available to assist, as supported by the following statement:

> We do not have any problems with working the computer…it is fairly simple, even though it needed us getting used to at the beginning on how to punch in a square or a square root. Mr. R showed us all how to do this...everyone got a chance to do this, even after school sometimes.
>
> (A/Gi1/0814)

In terms of open-endedness, a large of number of the interviewed students indicated that they thought Mr. R allowed them sufficient freedom to explore the sections that each individual had difficulty with during other sessions, when the computer room was unoccupied or after school hours. These students were in agreement that it would be unfair to let students go to different sections in the normal classroom situation as Mr. R needed to teach and explain the sections of the work in that time, and that they also needed to complete the syllabus in these classes. The computer-assisted classes were therefore not needed to be open-ended all the time.

Students also generally agreed that Mr. R encouraged them continually to work out problems on their own and that they also were encouraged to assist one another where such assistance was required. According to the students, Mr. R often referred them back to the introductory lessons on the computer and also to his notes that were given to them as part of the formal teaching sections. Students, however, expressed a dire need for additional computers so that they could work on their own.

> There are also not enough computers...I can do so much better if I can have one for my own. …but we are doing our best with what we have for now…..Mr. R knows how to use them [computers]… So we all get some chance.
>
> (A/I4/0814)

A number of students also indicated that they appreciated the use of the computers but that they were not sure whether it was helping them to do better. They also pointed out that even though they sometimes felt that the computers helped, to them the outcomes in the examination was what counted and that they were more concerned with that.

> Computers must help us to pass so we can go to university or technikon. Some of us also want to work and get a high salary. I failed the last exam and therefore I work hard on the computer. (A/I7/0816)

One of the groups, consisting of three students, considered the inclusion of computers of no use. They viewed computers as a complete waste of time and they suggested that Mr. R should teach physical science and mathematics like they were taught in the other subjects. These three students were adamant that nothing constructive happened in their classes when students interacted with computers and suggested that this time could be better spent by having the teacher teaching so that they could finish the syllabus more quickly. In the author's conversation with one student in this group during the interview, the student made the following points:

[S = Student; I = Interviewer]

S: Computers, voetsek (swearing word, like you would chase away a dog that's a nuisance) with computers. They don't help me learning. I can work and get money without computers.

I: Why do you say that?

S: Well, we are here to get matric and computers don't get you matric.

I: And what kind of work do you have in mind?

S: I can work at the taxi rank. I work there and get money.

I: Okay, then why do you need matric then?

S: I just need the paper to show I have been here (school). I did not waste my time.

(A/Gi4/0815)

The other two students agreed with the above sentiments and it was evident to the author that they had discussed their opinion before being interviewed. When the author discussed the particular students with the teacher afterward, he pointed out that one of the students actually worked at the taxi rank and that his attendance at school was not consistent. The same student could be found early in the morning before school at the taxi rank as well as in the evenings. The other two students, who were related to each other, joined the school late in the year and were struggling to learn all the work they had to catch up on. The two students came from a school in another region and Mr. R suspected that they had not attended school regularly, hence their insistence for the traditional teaching method.

Perceived effect of CAL on student learning

All seven individual students interviewed and the majority of students in the groups agreed that they found their learning in mathematics and physical science improved because they managed to answer the questions on the computers after the lessons. Students suggested they were able to fare better in the examinations because they understood the work much better. They considered that learning of the two subjects with computers was much better than their experiences in the previous year (Grade 11). Students also expressed satisfaction with the integration of the work they get in mathematics and physical science lessons and the contents of the programmes on the computers. One of the students did raise an important concern that although they learned better with computers, she still felt that "answering on computer and answering in the exam, these things they are different." (A/I3/0814)

This student did not want to expand when probed as to why she made the above statement. Three students in one group indicated that that they believed no learning took place by sitting in front of a computer and that no matter how much computers were integrated in a classroom, they did not belong in a classroom. When probed by the author, they stated that they believed that computers should not replace humans as their reason for their negativity to CAL.

Interaction within CAL classes

Students indicated that Mr. R encouraged them to form their own groups so that they could therefore better relate to students within their group. Interactions took place between students and the computer, students and students, as well as between students and the teacher. Students also pointed out that when working on a problem, Mr. R wanted each one to try it on their own, and then compare answers and calculations with one another. Students could then discuss how they proceeded to get to the answers with those who are struggling; in this way, students learned from one another. Where students still had problems, Mr. R was called to clarify problem areas. Students pointed out that in many instances, however, students would get one person to work out the problem, then punch the answer in to the computer. If the answer was correct, everyone would write down the entire sum. They also pointed out that there were often not enough time for Mr. R's expected procedure so students used their own means of getting answers to problems by, for instance, making sure that a group contains someone whom they thought would be able to assist in getting the right answers.

The majority of students agreed that through discussion with one another, they gained a better understanding of how to tackle problems in both mathematics and physical science. The group of three students agreed that students could possibly learn from one another, but they would want the teacher to play the central role for "the teacher is the person who has studied to be a teacher, and the teacher gets paid to do the job" (A/Gi4/0815).

Suggested changes/improvements to have preferred CAL classes

The first suggested change, that almost all of the interviewed students were in agreement with, was that they needed additional computers. They suggested that for greater individual involvement, it was important that students were provided with the opportunity to work on the computers on their own. Students pointed out that even though the interactions with fellow students supported their own learning, they also needed an opportunity to investigate their own abilities to complete tasks separately from other students. Many students also linked their improvement in learning with the availability of additional computers, suggesting that they could better follow whether they understood a problem by working on it on their own. The teacher could therefore respond to an individual need instead of a group need, as suggested by the following student:

> If I have a computer for myself, I will work out problems myself in the class. Mr. R can help me with what I don't know. Now he has to listen to everyone talking. (A/I2/0814)

A second recommendation was that the programmes that they were using needed to be upgraded or added to. Students suggested that programmes testing more than just mathematics and physical science content should be included and also programmes that would add to their computer literacy, as indicated by the following comment:

> …Can't we get programmes that help us know how to use the computer? We want to type our tasks on the computer... We also want to use computers like in the movies. (A/Gi5/0816)

Students also suggested that programmes for other subjects which they had difficulty with, like accounting and English, be included on the computer. A number of students recommended that the incorporation of the computers into the classroom take place during earlier grades so that students are exposed to this method of teaching before reaching Grade 12.

Student perceptions at Centre B

At Centre B, nine individual interviews and five group interviews were conducted. The groups ranged between two and five students and students formed their own groups. As at Centre A, students at Centre B were Xhosa-speaking and they responded better in groups where students assisted one another with the English words when needed. The five groups consisted of one group of two students, three groups of four students, and one group of five students. Where information of a more sensitive nature were required, or where students appeared awkward in talking about personal experiences in front of others, for instance information about their home environment, a one-on-one interview took place after the group interview.

Background of students

A large number of Centre B's students came from different areas outside the immediate informal settlement and were transported by taxis to the school. The ages of the students interviewed ranged from 18 to 22 years. Nine of the students interviewed failed at least once in a previous grade and three students came back to school after working. The informal settlements where students lived had no access to electricity or direct supply of water and unemployment levels were high. Many students indicated that they were not living with their parents, but with one of their family members. In many instances parents were living in another province or in rural areas and sent their children to learn in the city resulting in the expansion of peri-urban informal settlements. All the students interviewed, except for one, indicated that working on the computers at the school was their first encounter with computers in their lives. The one student indicated that he had played games on a computer of a friend whom he had visited in the city.

Students' first impressions of using computers

Students indicated that they felt enthusiastic about using computers at the start of the year and that the inauguration of the Mini-Computer Supported Education Centre, like with Centre A, was attended by sponsors, outreach programme organisers, teachers, parents and community members. At the inauguration, students were encouraged by everyone to make use of this resource and were told that teachers would guide them in making maximum use of the computer centre. All students interviewed indicated that they started out with the positive perception that the computer centre would drastically improve their achievement in mathematics and physical science.

Student experiences of the inclusion of computers in their classroom

Students related that the inclusion of the computer centre as part of mathematics and physical science periods took place mostly once and sometimes twice a week. The computer centre was used as a resource centre where additional reinforcement of the work taught in the classroom took place. The everyday teaching of mathematics and physical science would thus take place in the classroom without the inclusion of the programmes on the computers. Consequently, the computer-assisted classes were separate from the lessons that dealt with a particular topic; when students attended the computer centre during a double period, they would be referred to the topic covered in the classroom.

Students indicated that they were satisfied with the way that their classes on the computers were conducted and acknowledged that their level of involvement in the discussions that emanated from their interactions with the computers and fellow students, were adequate. They participated readily in discussions with both the teacher and their fellow students; all three teachers allowed students the freedom to interact with one another about problems on the computer. These students also indicated the programmes were reasonably user-friendly and allowed easy access to the different parts of both subjects.

> ...in mathematics we can jump to problems of different difficulties...we did struggle initially with using some of the keys, but we got used to them very quickly...working with these computers are no big deal.
>
> (B/Gi4/0824)

Many of these students indicated that they made use of the computers during intervals or when they had a free session, for example, when a teacher was absent. Students also pointed out that Mr. U was in the computer centre during lunch intervals and that he allowed them during this time the freedom to explore the sections with which each individual had difficulty.

Students also pointed out that all three teachers encouraged them to work out problems on their own but also encouraged them to share their way of working out problems with fellow students who were struggling. Students emphasised that they were notified at the beginning of the year to bring their notebooks to the computer centre because they were not allowed to sit at a terminal without having an additional resource to refer to. They also were required to write down problems that were presented on the computer and calculate the answers separately before going back to the computer. As pointed out by one student:

> I always have scrap paper to work out. When I get the answer we will then put it in the computer. If the answer is right, ... I mean the computer says 'okay', then I can write it in my notebook. I don't have a textbook you see.. so now I make lots of sums [problems] in my notebook. (B/I1/0822)

Some of the students interviewed also indicated that they were not always sure whether the exercise that they got on the computer would lead to them faring better in the matriculation examination. Some felt that it made no difference if they worked on the computer or were just taught in the classroom.

> We get our classes, then we have to also go once a week to work on computers. ...the work on the computers are the same as what we get in the class. Anyway, there's not enough computers so we sit and talk and work out problems. We can do the same in the class. (B/Gi2/0824)

A few students also had negative feelings about the computers because in their opinion it took too long for there were not sufficient computer terminals to have one for each student.

Perceived effect of CAL on student learning

Most of the interviewed students indicated that they considered the extra exercise from answering questions on the computer to be helpful to their learning. They also pointed out that when they assisted one another in working out problems they were improving their own problem-solving skills. One student related that:

> We are also helping one another, and by helping one another we are also learning at the same time. I can think with one problem in Algebra, I gave an answer which the computer accepted. When ...(friend)... asked me how to work it out, I showed him in my book. It helped me to work out the next question on the computer, and I remembered it in a test we wrote. So it helps to help each other. (B/I3/0823)

Other students indicated that the regular exercise they got on the computer helped them with working out problems more quickly and more accurately. Again a few students pointed out that if there were more computers, then their learning would improve because they would be working on problems on their own and learning in their own way. They considered working on their own as important because:

> I write the exam on my own and would like to work on my own... My marks in Maths did increase but I still need to work harder in the Physics. (B/I5/0823)

In a response to a question by the author to all interviewees, students all agreed that learning of the two subjects was much better than in their previous grades and that the improved learning was at least in part due to their interactions with computers.

Interactions within CAL classes

As pointed out above, most students interviewed linked their interactions in the computer centre with an improvement in learning. These interactions occurred between students, students and the computer and students and their respective teachers. They found these interactions useful because it gave them a chance to discuss the problems in groups where they did not feel threatened by the presence of a person representing authority. The teacher became involved when he was called upon to provide assistance where consensus could not be reached. Students stressed that because they were only allowed to work on the computer once a week during school hours, they considered the time spent on the computer as essential to sharpen some of their skills in answering problems. In one of the groups, a student stated that:

> Sometimes we challenge each other to work out problems on our own and to punch in the answer in the computer. ...We keep our calculations covered like and also wait until one person gets the right answer. We then compare with everyone in the group to see who also get it right. We see who gets the most right answers. (B/Gi5/0825)

However, some students did argue for a reduction in interactions between students and that they should be allowed to work on the computers as individuals to cater for their individual needs.

Suggested changes/improvements to have preferred CAL classes

Interviewed students on the whole wanted more computers. They claimed that the computer centre could hold more than 40 computers and that this would go far to assist them in the two subjects. It would also help those who wanted to work more as individuals while a group of students could still work jointly on one computer.

Students also wanted more and different programmes to be included on the computer. They stressed that the programmes were too curriculum-related and that more interactive programmes should be made available. Other subjects such as geography, accounting and English also should be included on the computers.

Students also mentioned that they could only use ten of the 15 available computer terminals for mathematics due to the licence agreement with the CAMI mathematics programme and that they wanted this licence to be extended so that all computer terminals were available to use in their mathematics lessons.

Summary

The above findings served to address research question three, which dealt with the perceptions of students about their computer-assisted learning environment. These findings were obtained using both quantitative and qualitative procedures. The following section of the results deals with the fourth research question, which reports on outcomes as a result of the implementation of the outreach programme.

4.5 What were the outcomes in mathematics and physical science as a result of the students' participation in the outreach programmes?

4.5.1 Introduction

The learning outcomes were obtained from the results of students in mathematics and physical science examinations. The student outcomes in the 2001 matriculation examination were compared with examination results prior to the implementation of the outreach programme. The science and mathematics teachers involved in the application of the MICSECs in their daily teaching also were interviewed (see Appendix O for an example) for their views on the role that the outreach programme played in the outcomes of students. The interviews conducted with teachers were of a semi-structured nature (see Appendix B for the format of teacher interviews).

4.5.2 Outcomes in terms of the Grade 12 final examination results

It is important to note that schools supported by the outreach programme of the University of the Western Cape were selected because of their academically weak showing in the Grade 12 final examination results compared to other schools in the province. The Outreach Project paid particular emphasis on the results in mathematics and physical science. The two schools selected as case studies in this investigation had consistently been amongst the schools where the pass rate in the externally controlled matriculation examination were below the 50% level, especially in mathematics and physical science. The application of the outreach programme must therefore be seen as a response to the examination results, which has unfortunately been held as a measure of a school's success. Thus, this background needs to be borne in mind when evaluating the achievements of the outreach programme at each school. Some of the intended goals and objectives of the outreach programme have been described in section 4.2 and are used as a measure of the success of the programme. The achievement in the two subjects is considered as a primary outcome for the outreach programme, for this is also used as a basis for funding application to their respective sponsors.

Table 4.10
Pass rate of students in mathematics and physical science for 1999, 2000 and 2001 at Centres A and B obtained from school records.

Centre	Year	Mathematics results*			Physical Science results*		
		No. of candidates	No. passed	Pass %	No. of candidates	No. Passed	Pass %
A	1999	78	17	21.8	39	15	38.5
	2000	66	13	19.7	35	11	31.4
	2001	64	21	32.8	38	22	57.9
B	1999	101	31	30.7	63	46	73
	2000	99	33	33.3	53	37	69
	2001	80	30	37.5	60	50	83.3

*Results were all on the standard grade

Table 4.10 represents the outcomes of the two schools' results in physical science and mathematics on the standard grade for the years 1999, 2000 and 2001. In South Africa, there are two levels at which subjects are presented and consequently written in examinations, namely, standard grade and higher grade. Higher grade examinations test a greater amount of insight, reasoning and application of the content of subjects than the standard grade examinations. Students at both schools wrote standard grade examinations for mathematics and physical science.

According to the principal at Centre A, the pass rate of students in mathematics was consistently less than 30% over a number of years. In the years 1999 and 2000, as indicated in Table 4.10, the pass rate for mathematics was 21.8% and 19.7% and for physical science 38.5% and 31.4%, respectively. Following the establishment of the MICSECs at the end of 2000, the pass rate for both subjects improved in 2001 with mathematics up to 32.8% and physical science to 57.9%. The principal indicated that the pass rate in these two subjects was better than in previous years and that they hoped to build on this improvement in the coming years.

At Centre B, the pass rates in the years 1999 and 2000 for mathematics were 30.7% and 33% and for physical science were 73% and 69% respectively. In 2001, these pass rates were increased to 37.5% in mathematics, and 83.3% in physical science. The teachers at Centre B indicated that although they were disappointed with the outcome there was, however, an improvement in both subjects.

4.5.3 Outcomes perceived by teachers

In interviews with the teachers at both centres, the experiences they related were very similar. Below the author draws on some of the themes that were evident from the interviews.

Teacher-support

Teachers commented that the computer was a useful tool to assist them in their daily teaching by providing more time to deal with students. They also thought that students gained in confidence through their use of computers because it allowed them more freedom to explore their own thinking. At Centre A, Mr. R used the example that students would persist in trying to work out a problem until they got to the one answer that the computer accepted. This situation to them was a sense of accomplishment because students had achieved something for which they received recognition. In line with their culture, this success would receive a jubilant welcoming, when the computer accepted their answer. Before the use of computers, students would work out a problem until they got to an answer and not always care if the answer was right or wrong. They simply arrived at an answer and that was good enough for them.

At Centre B, teachers described the use of the computer as an aid in their daily teaching. They claimed that they tried to use it as often as possible even though the resource had to be shared with the other teachers. However, they mainly used the computers for exercise and revision purposes, and preferred to teach separately from the computer. After each section of the work, they would bring students to the computer centre for additional exercises on that topic. Teachers agreed that they were noticing fewer arithmetic errors by students and attributed this finding to the extra exercise that students had on the computer.

> Well, we use the computer centre for drill and reinforcing of what we teach them in class. I know for my classes ... I think it is important that they [students] get these extra revisions. It helps because after a while they sort out their silly arithmetic mistakes. ... And when you ask them what the problem is, they say, for example, I [student] have worked till here but I can't go any further in order to get to the answer. (B/U/1025)

Mr. R at Centre A also used the mathematics component especially for reinforcement through repeated exercises. Mr. U at Centre B insisted that the additional exercises that students worked on allowed them to realise where they went wrong. In this way, he felt that students were monitoring their own learning. Mr. A also indicated that because the mathematics programme allowed him and his fellow teachers to track the progress made by students when they logged their name into the computer, they were able to structure particular revision exercises on topics which indicated that students had difficulty answering. In this way, the revision exercises were directed for particular groups of students that provided additional exercises both on the computer and extra lessons by the teacher on these identified problematic learning areas.

Learner-support

Teachers commented on the fact that students were following their own line of thinking and understanding by being able to point out which step they did not understand and consequently could not do in order to answer the question. Thus, they were able to tell their teachers up to which point they understood, and that they needed their assistance to proceed from a specific step to the next. Before the introduction of computers, students would just indicate that they did not understand the problem without zooming in at a particular part of the problem. They would simply comment 'A ndi az' (I do not know) without being specific.

Teachers indicated that many of the students who entered Grade 12 mathematics and physical science classes at the start of each year had large deficits in their content-knowledge in both subjects, especially in mathematics. According to the four teachers at the two centres, this problem started with teachers in the lower grades who had gained very little content-knowledge in their teacher's diplomas from teachers' training colleges (see Section 1.3.1). In trying to address the deficiencies in students' knowledge in these subjects, these four teachers used the mathematics and physical science programmes at the beginning of the year to try to teach some of the underlying principles that students needed to start their Grade 12 subjects. Teachers at both schools acknowledged that they were not very successful because the lack of knowledge in these disciplines was so huge.

> The problems I have with mathematics, in particular, is that students enter Grade 12 with backlogs in their content knowledge. This is a problem that comes from Grade 8 and later, and these bad situations are just carried over year after year. I try at the beginning of the year to alleviate some of these problems with the computer programmes, but..[sighs]... the problem is so just so big. All I can do is try to do my best. (A/R/0916)

The teachers emphasised that because schools were evaluated on the basis of the matriculation results principals engaged their most experienced and highest qualified teachers at the Grade 12 level. This compounded the problem at the lower levels where experienced and qualified teachers in both these subjects were in seriously short supply.

Teachers raised another issue dealing with the culture of these students in which children or young people did not always ask questions or directly address someone in authority. More specifically, these four teachers each maintained that they had difficulty to get students to ask questions; when asked if they understood, students would all indicate in the affirmative even though the teachers suspected that this was not the case. With the introduction of computers, they were interacting more readily with teachers and with their fellow students. Students also were more willing to ask questions even though the questions were not necessarily raised during the formal section of the lesson, but during the part of the lesson devoted to their working on the computers.

MICSECs as resource centres

Teachers indicated that students often came to them to use the MICSECs when they had a free session, for example when a teacher was absent. There was also a demand from students wanting to use the computer room outside their normal teaching periods. At Centre B, teachers pointed out that they previously tried to arrange an extra tuition programme for students after school but they had to abandon the programme as too few students attended. Now with the start of the computer centre, they were having difficulty arranging a programme for students after school because there were too few computers available for the number of students who wanted to come after school hours. Mr. R at Centre A indicated that he experienced the same requests from students and held regular classes in both mathematics and physical science for students from his own school as well as for some students from the surrounding schools.

> After school, Mondays we have computers available from 2-4 and then also Thursdays. We have around 64 students, we also have private students. The private students are about 11 students so it leaves you with round about 75 students so you cannot really have one session so that is why I have to have separate sessions on 2 days. Just one group can come on a particular day and the other group on another day. In the beginning we had Saturday mornings also but time constraints does not allow one to do everything, you see because I am the only one that runs the sessions. (A/R/0916)

Mr. R emphasised that the use of computers in learning mathematics and physical science seemed to be the extra incentive for students to attend additional classes, as very few other educational resources were available in that region.

4.6 Conclusion

This chapter has presented the findings of this study by addressing each of the research questions individually. Both quantitative and qualitative data obtained from the *Computer-Assisted Learning Environment Questionnaire*, observations at the two case studies, mining of Outreach Project documents and interviews with students, teachers and Outreach Project managers were presented in this chapter. The discussion of these findings is presented in Chapter 5.

CHAPTER 5

DISCUSSION OF FINDINGS

5.1 Introduction

The purpose of this chapter is to discuss the corresponding data analyses presented in Chapter 4. The discussions are grouped around the research questions representing the four areas of the conceptual framework identified in Section 2.2.

5.2 What were the outreach programmes intended to achieve?

The goals of the outreach programme were stipulated in broad terms in Section 4.2. The first goal dealt directly with the use of technology to support teachers and students in mathematics and physical science, while the second goal dealt with the University's attempt to increase its intake of disadvantaged students in the natural sciences. However, the second goal did not fall within the ambit of this study. The first goal, in line with suggestions by Rossi et al. (1999) reported in Section 2.3.2, was translated into six objectives, which represented concrete statements that were measured at different stages of this study.

The first objective, identified in Section 4.2, was meant to address the needs of teachers of mathematics and physical science in disadvantaged schools. As pointed out in Section 4.2, the outreach programme attempted to meet this objective by, firstly, providing these teachers with the necessary training to use the computers in their classes; secondly, providing them with the opportunity to work on the computers at the UWC outreach centre in order for them to become acquainted with the software; and thirdly, constructing a Mini-Computer Supported Education Centre at their school. The measurement of this objective was reported in Section 4.3, where the implementation of lessons in both Centres A and B was described. The teacher at Centre A used the MICSEC as an integral part of his lesson; in other words, the computer classroom was used for both teaching the traditional class and incorporating the computer sessions. At Centre B, the computer centre was used as an add-on to the normal class that was taught in a different classroom. The difference in application resulted from the particular needs in the respective schools, and was catered for by the outreach programme because no prescriptive application procedures were demanded of schools. This lack of prescription allowed schools to fit the computer-assisted classes within their daily timetable.

The second objective of the outreach programme dealt with the support provided to students to improve their learning of mathematics and physical science. This support came in the form of computer-assisted learning classes that were designed to provide students with interactions with the computer, the teacher and fellow-students, and to enhance their learning through these interactions. The measurement of this objective was done with the aid of the *Computer-Assisted Learning Environment Questionnaire* and interviews conducted with students and teachers, and the results were reported in Sections 4.4 and 4.5. The results of the perceptions of students of the computer-assisted learning environment are discussed in Section 5.4 and teachers' views of student learning using the computer as a supporting tool is outlined in Section 5.5.

As pointed out in Sections 1.4 and 4.2, the low attainment of students in the external matriculation examination served as a criterion for the selection of schools that would be supported by the University of the Western Cape Outreach Project. Secondary schools in South Africa are evaluated on the basis of their results in the matriculation examination, and principals of schools were therefore enthusiastic to use all opportunities available that could lead to an improvement of student achievement in this examination. Consequently, the third objective of the outreach programme was to improve the achievement in mathematics and physical science and also to increase the number of students passing these subjects in the matriculation examination. The data showing the examination outcomes of students in 2001, and comparing those with the results in the previous year, were reported in Section 4.5. These data, obtained from the records of the two schools where Centres

A and B were based, showed that there was a measure of improvement in the numbers of students that passed both mathematics and physical science. This improvement in outcomes is discussed in Section 5.5.

The fourth objective of the outreach programme was to make the MICSECs available as resources that students could use in their own time. Indeed, as part of the outreach programme's philosophy of effective service-delivery, schools were encouraged to work out a programme that would allow students access to the centre after school and during school holidays. The response of the two centres to this objective is highlighted in Section 4.5. However, the prevailing conditions at the two centres determined the extent to which the MICSECs could be used outside normal school hours. At both centres the computers were available after school during the week, and indeed, according to the interviewed teachers in Section 4.5.3, both centres reported a great demand for the use of the outreach programme after normal school hours. During the school holidays, however, Centre A was active for a certain period but Centre B closed completely for security reasons.

The last two objectives dealt with providing students with exposure to computers and the skills needed for their operation. These objectives required computer literacy classes which could not be included at the two centres as the computers were dedicated to mathematics and physical science curriculum activities. The students who were using computers did gain some operational skills as part of their interactions with the programmes associated with the two subjects.

In developing a programme theory for the outreach programme, Chen's (1990) definition (described in Section 2.3.2) was given consideration. As pointed out in Section 4.2, the University of the Western Cape started the Outreach Project in 1982 in response to a need in the disadvantaged communities in South Africa. This need still existed in the year 2001 but the response of the outreach programme is now in a different form. Instead of students travelling to the University campus, the MICSECs have been constructed at schools with the idea that they would serve students where they were taught. In theory, the MICSECs also would serve schools in the surrounding areas. In practice, placing 12 to 15 computer terminals at each centre did not do enough to serve students of a particular school, as reported by many of the students at the two centres. To compound the problem, the CAMI mathematics programme had licence agreements that allowed only ten terminals to operate on a single license. The licences were apparently very expensive which left both schools with only one licence each and thus only ten terminals available for mathematics at each centre. Teachers at each centre, therefore, made use of the MICSEC that would best suit their own environment. This situation was accommodated by the outreach programme that left the day-to-day implementation of the MICSEC (discussed in the next section) over to the respective teachers. At both centres, students expressed a need to be able to work as individuals or in small groups on the computers, even though there are indications, reported in Sections 4.3 and 4.4, that the interactions between students in a group led to improved learning of individual students. This finding of improved learning with computers as a result of interactions of groups of students is consistent with other research findings (Bennett, 1992; Roschelle, 1992; Yalcinalp et al., 1995) reported in Section 2.4.2.

5.3 How were the computer-assisted lessons in the outreach programmes actually implemented, perceived and achieved?

The implementation of the outreach programme was reported in Section 4.3.2 and 4.3.3 by the author outlining his experiences of lessons that were observed at each of the two centres. As described previously, the lessons took on two distinct formats due to the prevailing circumstances at each centre. At Centre A, one teacher taught both mathematics and physical science to Grade 12 students which allowed him to use the computers for virtually every lesson. The lessons observed consisted of two parts, the first part involved the traditional teaching method of talk-and-chalk while students took down notes, and for the second part students were directed to the computers. At Centre B, three teachers taught mathematics and physical science and thus had to share the use of the computers between them. This sharing of the computer centre resulted in teachers teaching their subjects in separate classrooms and only using the computer centre during a certain selected period, mainly during double periods. At Centre B, when students were directed to the computers it was mainly for additional exercises and reinforcement of work taught in the class. At

Centre A, the introductory lessons were used as an integral part of the lesson along with problem-solving approach employed at Centre B. The particular lesson described at Centre B was a mathematics test that students wrote on the computer. The mathematics software allowed teachers to track the progress of students on topics included in the syllabus, and these data, namely, students' responses could therefore assist teachers in structuring revision exercises. This tracking of students' progress was used at both centres and was mainly directed at informing teachers about which topics to place more emphasis on during revision. As reported in Section 4.5.3, teachers indicated that these reinforcement exercises contributed to students monitoring their own learning and making less arithmetic errors.

5.4 How did students perceive their computer-assisted learning (CAL) classes?

The perceptions of students were obtained from both the CALEQ and interviews conducted with students. On the actual version of the CALEQ, the mean item scores of all scales for the combination of centres A and B (Table 4.04) were above three, indicating a positive perception by students. This perception was supported by a number of students who held the first viewpoint (discussed below) indicating that computers played an important role in their learning. This result supported the findings of other researchers over a number of decades, as reported in Section 2.4.2 (Bear, 1984; Cavin & Lagowski, 1978; Geban, et al., 1992). Many students, however, wanted more computers and expressed the view that they also wanted to work on their own which could have attributed to the mean item scores not exceeding 4, that is, mean scores between the responses of sometimes (3) and often (4).

The Integration scale was scored the highest (3.60 for the actual version of the CALEQ) which indicated firstly, that students at both centres were satisfied with how computers were integrated in their daily classes, and secondly, that students related the work done in regular class with the work that they encountered on the computer. The perceived positive integration of computers in the classroom is supported by the views expressed by students in the interviews (discussed in Section

4.3.3). As discussed in Section 5.3, the integration of computers at the two centres took on different formats, with Centre A having both formal (talk-and-chalk) and informal (computer-assisted) sessions in one teaching period. On the actual version of the CALEQ, the Integration scale of Centre A had a higher mean item score than Centre B (Table 4.09) which reflected a greater satisfaction of computer integration of their classroom by these students. However, students at Centre A indicated that they preferred less integration of the computers in physical science and mathematics classes, while students at Centre B preferred more. Even though many students indicated during the interviews that they were positive about the integration of computers, some students felt that with the small number of computers that were actually available, they preferred that more teacher-centred classes be included. Their reason for this was that the computer classes catered for group learning instead of individual learning. Another group of students, especially at Centre A, did not want any more computer-assisted classes and claimed that they preferred the traditional teacher-centred method. This finding appears to contradict the purported effectiveness of computer-assisted learning that has been reported previously by other researchers (see for example, Bangerdowns et al., 1985; Barman, 1993; Johnson, 1995; Wainwright, 1989).

The item mean scores for the Learning Assessment scale for Centre A (Table 4.06) and Centre B (Table 4.08) were similar at around 3.4 (between sometimes and often) for the actual version of the CALEQ. At both centres, the preferred scores for the Learning Assessment scales were higher, with students at Centre B indicating a greater preference for monitoring their own learning. This result is consistent with what was reported in the qualitative data. Students wanted more computers at their centres and also emphasised their individual needs to have a computer of their own in order to assess their own learning. The significance in the higher scores for this scale on the preferred level at Centre B could possibly be attributed to the fact that students, in most instances, only worked on computers once a week and expressed a desire to have enough computers to work on their own. At both centres, a number of students linked the monitoring of their learning to learning on their own. Students pointed out that the additional exercise they gained from working on the computers improved their problem-solving skills and the speed and accuracy with which they worked. This improvement in problem-solving supports the research findings of

Yalcinalp et al. (1995). However, in the interviews, about one quarter of the students at both centres (seven at Centre A and six at Centre B) questioned whether or not their learning improved as a result of their interactions with the computers. These students expressed the view that the amount of time spent to discuss problems with each other was counter-productive to their own personal learning needs.

For the Involvement scale, the mean item scores for Centre A and Centre B for the actual version of the CALEQ were similar (3.41 and 3.37 for Centres A and B, respectively). In the preferred version of CALEQ, the mean item scores were higher than the actual version, but similar for both centres (3.60; 3.59) though these were not statistically significant. Most students were satisfied with the way that they were involved in computer-assisted classes and indicated that they readily participated in discussions with fellow students and with the teacher about the work on the computer. From reports of the interviewed teachers, more students were willing to share their ideas and thoughts on topics that were based on the work from the computer but were reluctant to participate in the formal class. Students were encouraged by their teachers to interact with each other while answering questions on the computer. This interaction allowed greater involvement in the classroom tasks because students had to work in groups around the limited number of computers. Some students reported co-operative relationships with their peers, which were also encouraged by Bennett (1992) and Yalcinalp et al. (1995).

The scores for the Investigation and Material Organisation scales at Centre B showed a different trend compared to that at Centre A. The scores at Centre B indicated lower levels of these two scales for the actual version of the CALEQ (3.33 for Investigation; 3.32 for Material Organisation), and then even lower scores for the preferred version (3.20; 3.24) though these were not statistically significant. However, the trend of these results indicated that students at Centre B preferred less investigative activities and less organisation in the computer centre. Indeed, many students at Centre B indicated that they did not like to work out problems with the teacher standing behind their backs looking over their shoulder. Some students considered it as distracting "I cannot think so fast when Mr. U is looking over my shoulder" (B/U/L05/0508/S_3), and suggested that they preferred to call the teacher when he was needed. Also, students indicated that they preferred the situation where the teacher worked out the problems on the board and then they could just follow what the teacher was doing, instead of struggling with problems on their own. These situations possibly could be attributed to the lower investigation preference by students at Centre B. The lower mean item scores for Material Organisation at Centre B (3.32 for actual; 3.24 for preferred) also could possibly be attributed to the fact that the computer centre was used only for additional exercises and reinforcement of work already taught in class. During the interviews, students indicated that they wanted to work on the computers as individuals which could imply that they preferred a less structured approach in the computer centre.

From the interviews held with students, three distinct views were obtained from the transcripts. The first view, which formed the majority viewpoint, was held by students who considered the computer-assisted lessons as being supportive because they found their interactions in the classroom conducive to learning. Students with this view wanted the group interactions, and preferred to discuss the problems with one another, and where needed, called for the assistance of the teacher. Students indicated that they learned from one another by providing assistance to one another when attempting to answer questions on the computer. This idea of supporting one another seemed to be emanating from teachers at both centres, as they were continually encouraging inter-student assistance in some of the lessons that the author observed. This group was therefore quite satisfied with the status quo.

The second view was held by students who wanted computer-assisted learning but believed that the current situation was not catering for their individual learning needs. These students were not sure whether the inclusion of computers in their daily lessons made any difference in their learning, as they considered the teacher having a greater effect and actually preferred a more teacher-dominated lesson. The impression gained from the interviews was of many students not being convinced that using the computers would guarantee them success in the final examination. However, this group did not represent the significant view point; most students' views were somewhere between the first view and the second. In both views, the overwhelming recommendation for improvement was for additional computers to address their personal needs.

The third view, which represented the minority view, was held by a few students who wanted their lessons without computers. This view was more strongly expressed by a group of students at Centre A (three students), and to a lesser degree at Centre B (one student), but also came to the fore when student perceptions of their computer-assisted learning environment were measured. These students indicated that computers played no part in their passing of examinations from the lower grades up to Grade 12 and suggested that the teachers should continue with the teacher-centred lessons to which they had become accustomed.

It is important to note that the students' culture plays an important role in South Africa. As Ogunniyi (1998) puts it, "in African culture what an elder says about a phenomenon is considered weightier than what a youth might hold to be true or what he/she has determined empirically as the actual case" (p. 41). The traditional teacher-centred method of teaching has been the model that students were used to and were exposed to for almost their entire school career. Consequently, the author is not surprised that students indicated that it was important for the teacher to take the lead. In many of the interviews, students expressed a trust in what the teacher did and preferred to listen to the teacher who represented the authority figure. Statements such as those reported in Chapter 4, for example "Mr U explains well", "Mr. R knows how to use them [the computers]" and "Mr. R is a good teacher" are indicative of the trust vested in the teachers because students accepted their competencies. In Grade 12, this trust would be even more so because students depended on the teacher to help them pass the matriculation examination.

At both centres, students wanted some measure of teacher-centred classes, not just because this was what they were accustomed to but also because they viewed the teacher as being the accepted expert and authority to guide them through the learning process. This view would explain, to a certain extent, the reason for the low scores in the Open-Endedness scales for both the actual (3.32 for Centre A; 3.15 for Centre B) and preferred (3.38; 3.27) versions of the CALEQ for students at both centres. The group of three students at Centre A who rejected computer-assistance as a form of learning clearly articulated their standpoint for only teacher involvement. At both centres, the teaching approach was problem-based which is consistent with the findings of Hobden (2001) and Mamiala (2002) who pointed out that the teaching of physical science in South Africa occurred mostly by means of problem-solving. Students were taught how to answer problems on the concepts that needed to be taught to satisfy syllabus requirements. In Grade 12 especially, the learning environment in mathematics and physical science is dominated by examination-oriented teaching (Mamiala, 2002). Students reflected this situation at both centres by their low scores on the Open-Endedness scale on both the actual and preferred formats and expressed a desire for more teacher-centredness in order to complete the syllabus and also prepare for the examination.

The data of the CALEQ at Centre A showed a trend which indicated an increase in their preferred environment, but the analyses of the data indicated that there were no significant statistical differences between the students' actual and preferred perceptions (Appendix K). This meant that students' responses indicated that they were satisfied with their computer-assisted classes and did not prefer an improvement of the learning environment. At Centre B, the same trend as at Centre A was noted with the exception of the Investigation and Material Organisation scales which showed that students wanted less investigative activities and less structured computer sessions. The analyses of Centre B's data for students' actual and preferred perceptions showed that only one scale was found to be statistically significant, namely the Learning Assessment scale ($p<0.01$) (Appendix L). This result meant that the students' responses indicated that they preferred more opportunities to assess their own learning and that they did not prefer a significant improvement in open-endedness, involvement and integration in their computer-assisted classes. In fact, as indicated previously, the students at Centre B preferred lower investigation and material organisation.

One explanation that could have contributed to the non-statistically significant results with the CALEQ was that the sample sizes of 40 and 49 at the two centres, respectively, were too small to provide sufficient variances in student responses. Another possible explanation could be that the language of the questionnaire was not explicit enough to facilitate the students' understanding, as all students were second and, even in some cases, third language English speakers. Even though the questionnaires were checked for language content by the four mathematics and physical science teachers at the two centres and by five students from a different school (as reported in Section 3.5.3), students still asked the author to explain words like 'proceed', 'programme' and 'investigate' when the questionnaires were administered; Similar requests were made by students during interviews following the administration of the questionnaires. Another plausible explanation could be that because this was the first time students were exposed to computers, they were not sure what a preferred situation would be. Students also inherently trusted their teachers to provide the best learning opportunities to them, and therefore regarded what was granted to them as possibly the best in the context of their school. For this reason, it is most likely why students asked for the same situation to be extended to other subjects like accounting and English.

Although there was a large support for the inclusion of computers in students' everyday classrooms, this support was by no means expressed by students as a confident support. In the South African context, and especially at disadvantaged black schools, these inconsistencies should not be surprising as schools are going through a transitional and transformational stage, and students are continually confronted with new and changing approaches to education (Jita, 2002; Johnson, Scholtz, Hodges & Botha, 2002; Rogan, Grayson, van den Akker, Ndlalane, Dlamini & Aldous, 2002). Students tend to cling to what they know and are familiar with, become engaged in new approaches with some suspicion, and depend mostly on the teacher to provide guidelines on how to proceed. The introduction of computers into their classroom would therefore follow the same process, resulting in students holding different views of the computer-assisted learning environment, perceiving it as a positive step because the teacher considered it as important, but when probed also articulated other views.

5.5 What were the outcomes in mathematics and physical science as a result of the students' participation in the outreach programmes?

The outreach programme was geared to meet the goals and objectives that were identified in Section 4.2 and discussed in Section 5.2. The extent to which these intended outcomes were achieved was reported in Section 4.5. In the following subsections outcomes for the specified objectives are addressed.

5.5.1 Teacher support

During the interviews with the teachers involved at both centres, they indicated that the support received from the outreach programme was in the form of training to acquaint themselves with the specific programmes that were on the computers and also some guidelines of how to include computers to assist them in their daily lessons. The CAMI mathematics programme distributors also provided training to teachers for the use of their product. The biggest support that teachers were provided by the Outreach Project was the construction of the Mini-Computer Supported Education Centre at each school. As pointed out in Section 4.5.3, teachers considered the implementation of the computer-assisted learning classes as supportive of their teaching because it served as an additional resource that helped them in their preparation of classes and the computers served as an additional tool to their daily teaching. Teachers indicated that they could use the computer centre for revision and reinforcement purposes by planning exercise sessions for students. In situations where there was a shortage of textbooks (Centre A) or when learning material was insufficient, the computers provided an alternative resource because teachers could refer students to the relevant sections on the computer. As reported in Section 4.5.3, teachers pointed out that many students entered Grade 12 with tremendous academic deficits in mathematics and physical science and the teachers used computer-assisted classes to try and address some of these deficits. Teachers were also of the opinion that allowing students to work on the computer freed up some of their teaching time so that they could spend time with students who were weaker than others in the tests and examinations.

5.5.2 Learner support

The intention of the outreach programme was to support students by providing computers and programmes that would give opportunities for learning to take place. Teachers indicated that through their interactions with the computers, students were identifying the gaps in their own learning. When teachers enquired about the solution of a problem, students were able to point out at which step of a problem they did not understand and then asked the teacher to explain a particular step in a problem. Students were therefore monitoring their own learning. Student perceptions in the

CALEQ highlighted the Learning Assessment scale as an important indicator of their learning. For Centre A, the item mean score for this scale at the actual level was 3.46 and preferred was 3.66 (Table 4.06; Figure 4.02), while for Centre B, it was 3.43 for the actual level and 3.87 for the preferred (Table 4.08; Figure 4.03). Through this scale, students identified that they could monitor their own learning and that they preferred an increase in this activity at both centres. Teachers indicated that a great deal of student learning took place as result of the interactions that occurred among students when they discussed and debated answers to questions. This point was supported by a number of students during interviews as well.

5.5.3 Achievement

Schools in South Africa are evaluated by their student outcomes in the matriculation examination, which places a great burden on Grade 12 teachers who teach at this level to have as many students as possible passing this examination. At the two schools, like in many schools in South Africa, the highest qualified and most experienced teachers are asked to teach the Grade 12 subjects. This situation has unfortunately influenced the teaching style of teachers who present students with as many problem-solving opportunities as possible. Therefore, in this study, the achievement of students was measured in terms of the numbers of students that passed physical science and mathematics examinations; this phenomenon was also the issue that attracted the outreach programme to these particular schools. At both centres, the percentage of students that passed the examination in physical science in 2001 increased by more than 20% after the implementation of the outreach programme.

The mathematics outcomes were less dramatic where a 10% increase in Centre A and 5% increase in Centre B in the number of students passing the examinations were reported. The lower increase in pass rate in mathematics could be ascribed to the lack of background knowledge that students had in this subject. Although it is difficult to directly relate the increases in the number of students passing the examination to their interaction with the computers, the teachers and principals of the two schools indicated that they were convinced that the use of computers was a partial contributor. Further, the teachers and principals of the two schools stated that they expected the pass rate to improve as teachers became more accustomed to use the computer-assisted learning approach.

5.5.4 Resources

The outreach programme indicated, as one of its objectives, the availability of the MICSECs as a resource for a number of schools in the region to use. Unfortunately, due to the limited number of computer terminals at the two centres, this was not always possible. A number of students from other schools were allowed to use the centre during after-hour sessions but this was very limited. As resource centres, the MICSECs were used mainly by students of the schools where they were based; this situation also applied to after-school sessions, vacation periods or whenever the computers were made available. However, teachers did indicate that there was great demand for the use of the centres by their own students and that they had to work out a programme to provide everyone with an opportunity to use the centres. The demand rose especially before examinations which indicated that students valued the use of the computers even though some had earlier expressed some reservations.

5.5.5 Computer literacy and skills

The computers of the outreach programme were reserved for the use of mathematics and physical science activities only and, therefore, there was no structured computer literacy programme associated with them. However, the exposure that students got from working on computers for the first time, from switching-on the computers, learning how to select different programmes, to typing in answers in different formats provided them with some skills to operate computers even though this also limited their cognitively active time in the lessons.

5.6 Conclusion

In this chapter, the findings for each of the four research questions were analysed and discussed. The following chapter summarises the major findings, draws implications from the research in this study, highlights the limitations of this study and provides recommendations for future action and study.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 Introduction

This chapter concludes the thesis by addressing five important areas. Section 6.2 summarizes the study by providing a brief overview of its background, objectives and methodology. Section 6.3 considers the major findings of the study by briefly answering each of the research questions. Section 6.4 considers the implications of this study, while 6.5 addresses the limitations of the study. Suggestions for further research are provided by Section 6.6.

6.2 Overview of the scope of the thesis

This thesis begins in Chapter 1 by providing the background to the educational situation in South Africa. During the last 20 years of apartheid, a large number of black schools ceased to function, particularly secondary schools, where school grounds became battle fields for protests, boycotts, disruptions, challenges to established authority and the establishment of endemic resistance. Two decades of almost continuous protests on the rejection of Bantu Education combined with the poverty, material deprivation and disruption of communities characteristic of apartheid resulted in what have been widely termed the "breakdown of teaching and learning" in many schools (Mkhatshwa, 1999, p. 340). The transformation of education from its segregated past to a democratic future required a complete revamp of the "liberation before education" culture (Khan, 2000, p. 2).

With the change to a democratic dispensation in 1994, a number of huge challenges faced the first democratic government of South Africa. One of these challenges was an existing human resource deficit in science, engineering and technology fields, coupled with the low numbers of students taking mathematics and science subjects at the secondary level needed to address this deficit. This dilemma was especially prevalent in the historically disadvantaged schools. The poor showing of South African learners in the 1997 Third International Mathematics and Science Study and the status of South African mathematics and science teachers provided by the Arnott et al. (1997) report, coupled with other indicators, prompted the President of South Africa, Mr. Thabo Mbeki, to emphasise the urgent need for the improvement of school mathematics and science (Department of Education, 1999). A National Consultative Conference was called where one of the recommendations was to give high priority to interventions in language, science, mathematics and technology, and the evaluation of the success of such interventions (Department of Education, 2000).

This study was therefore geared to address one aspect of this recommendation by evaluating the effectiveness of the computer-based outreach programme of the University of the Western Cape. This outreach programme, which started as a part of the Outreach Project in 1982, was in its twentieth year of existence in 2001 and provided support in mathematics and physical science to Grade 12 students and teachers from historically disadvantaged schools. This study examined the role that the outreach programmes played at two schools during 2001 and endeavoured to provide descriptions of the intended, implemented, perceived and achieved programmes for this year. Therefore, the purpose of this study was to investigate the effectiveness of this outreach programme in providing support to both teachers and students in the teaching and learning of mathematics and physical science.

Chapter 2 looked into the development of a conceptual framework for this study from its roots in curriculum research to the formation of the framework consisting of four representations of the curriculum/programme investigated, namely, the intended, implemented, perceived and achieved programmes. In addressing the purpose of this investigation and in line with the conceptual framework, four research questions were identified, namely, (1) What were the outreach programmes intended to achieve?, (2) How were the lessons in the outreach programme implemented, perceived and achieved?, (3) How did students perceive their computer-assisted learning classes?, and (4) What were the outcomes in mathematics and physical science as a result of the students' participation in the outreach programmes?

Further, Chapter 2 explained each of the framework representations, examined a number of evaluation studies in South Africa by applying the framework to these studies, and also reviewed studies where computers were employed in various contexts in school mathematics and science subjects. Finally, a number of learning environment instruments used in computer-assisted classes were considered.

The methodology employed in this study was described in Chapter 3. Firstly, an explanation of the four programme representations in the conceptual framework was provided and linked to the research questions. This explanation was followed by a detailed description of the research techniques and approaches used in this study, namely, the case study, the narrative and interviews. Background to the two centres that were used as case studies was provided and data collection procedures as well as purposeful sampling were elaborated in order to answer each of the research questions. Particular emphasis was placed on the development of the *Computer-Assisted Learning Environment Questionnaire (CALEQ)* that was used to obtain students' perceptions of the computer-assisted classes. The CALEQ, which consisted of six scales with eight items describing each scale, was constituted from a number of learning environment instruments that have been used in other non-western countries. Finally, some aspects of data analyses and coding procedures were discussed and issues with regard to the validity of the study were raised.

The results obtained in this study were presented and discussed in Chapters 4 and 5, and were collated to address each of the research questions. Issues that were unique and common to each of the centres were explained in terms of the different social, geographic and learning contexts.

6.3 Major findings of the study

The results of this study are organised around the four programme representations, namely, the intended programme which is the original vision underlying the programme, in the form of the stated objectives or programme theory; the implemented programme represented by the actual instructional processes implemented; the perceived programme that relates the actual learning experiences as perceived and/or experienced by the students; and the achieved programme represented by the resultant learning outcomes of the students.

6.3.1 The Intended Programme

The first research question that addressed the intended programme was: What were the outreach programmes intended to achieve?

In developing the intended programme, cognisance had to be taken of the overall goals of the outreach programme, which had a 20-year history and had developed a well-set programme theory that described the desired goals, what needed to be done to achieve the goals, and other elements that could necessarily influence the working of the programme (Chen, 1990). The outreach programme was designed to respond to a need by teachers in historically disadvantaged schools in the Western Cape. It was initially intended to support the many underqualified mathematics and physical science teachers who in turn produced students who were poorly prepared to enter tertiary institutions or the job-market. Subsequently, the teachers seized the opportunity to draw their learners into the programme which catered for both the teaching and learning situations. Therefore, the theory behind the outreach programme was to support the teaching and learning of mathematics and physical science at the Grade 12 level by using technology-based classes. Towards the later years of the outreach programme, the technology was transferred from its central position at the University of the Western Cape to the classrooms of students at selected disadvantaged schools.

In the year 2001, the goals of the outreach programme remained largely unchanged as the legacy of decades of apartheid rule still plagued education. These goals were broadly stated and needed more explicit objectives (Rossi et al., 1999) that were both quantifiable and qualifiable. The findings related to this research question were obtained from the Outreach Project documents, including brochures, annual reports, applications for funding and the University of the Western Cape magazine articles, as well as interviews held with two of the Outreach Project managers.

Two broad goals were identified, one of which did not fall within the ambit of this study as it related to the University of the Western Cape's aspirations of increasing its intake of students in the natural sciences. The second goal, which considered the use of technology in the teaching and learning situations in science and mathematics in disadvantaged schools, was further subdivided into six objectives (see Section 4.2) that were measured at various stages of this study and reported in Section 4.5 and discussed in Section 5.5. The outcomes in mathematics and physical science as a result of students' participation in the outreach programmes were measured in terms of the extent to which these goals and objectives were met.

6.3.2 The Implemented Programme

In order to address the implemented programme, the second research question was investigated: How were the computer-assisted lessons in the outreach programmes actually implemented, perceived and achieved?

The author made on-site visits to each of the two centres. During these visits he observed a number of lessons that was taught at each centre. A narrative description related the setting of the schools where each centre was located and the author's experiences at each centre; in this way, the author attempted to provide a thick description of activities at the two centres and thus increase the external validity of the study (see Section 3.7.2). The lessons at each centre incorporated the outreach Mini-Computer Supported Education Centre in varying degrees. At Centre A, the computer-assisted lessons took place in the MICSEC utilising the computers immediately after a concept was taught. The lessons consisted of two parts. The first part was a formal lesson which included the traditional chalk-and-talk teaching method where the teachers did most of the work and occasionally tried to get the students involved by asking questions. This part was followed by an informal lesson whereby students were directed to the computers to further explore introductory lessons about the concept that was taught before commencing problem-solving on the computer. This type of teaching was consistent with those reported in studies conducted by Hobden (2001) and Mamiala (2002) in South African physical science classrooms, where the main activities of the lessons involved problem solving.

Mamiala (2002) pointed out that this approach by South African teachers could be associated with the examination-oriented environment that is dominant in Grade 12.

At Centre B, the computer centre was used as an additional resource that students visited at least once a week during a double period. For the rest of the week, students were taught in their normal classrooms and the teaching approach was the same as described above by Hobden (2001) and Mamiala (2002), and consistent with Mamiala's (2002) perception of examination-oriented teaching styles in South Africa. The computer centre was used mainly for additional exercises on problems and reinforcement of previously learnt concepts, and thereby was a continuation of the problem-based approach in both mathematics and physical science.

As discussed in Section 5.4, students' perceptions of the lessons took on three differing views at both centres. On the one hand, a group of students indicated satisfaction with the way in which the computer-assisted lessons were conducted and valued the contribution that these lessons made to their learning. The second group of students accepted the computer-assisted lessons but questioned the contribution it made to their individual progress and learning needs. The third group of students held the view that the computers were not needed at this stage of their learning and that they preferred a more teacher-centred teaching approach. A particular group of students at Centre A were quite vociferous in their opposition to the inclusion of computers as a part of their everyday lessons.

At Centre A, the intentions of each lesson were indicated to students at the start of the lesson and were generally achieved at the end. In instances where the time allocated was too short, the lesson was continued on the following day. At Centre B, students were also notified in advance which topics they had to work through on the computer. The teachers regularly monitored the students' progress to assess if they had successfully completed the selected topics.

6.3.3 The Perceived Programme

The perceived programme was explored through the use of the third research question: How did students perceive their computer-assisted learning (CAL) classes?

In addressing this research question, the author made use of the *Computer-Assisted Learning Environment Questionnaire* (CALEQ) and student interviews to obtain the students' perceptions of their computer-assisted classes. By triangulating the results obtained from both qualitative and quantitative data, the author attempted to improve the internal validity (see Section 3.7.1) and reliability (see Section 3.7.3) of the outcomes of this study. The CALEQ, which was constructed for the purpose of collecting data in the South African context, consisted of six scales, each scale represented by eight items. The scales employed — Involvement, Open-Endedness, Investigation, Material Organisation, Learning Assessment and Integration — were imported from a number of previously tested instruments, as described in Section 3.5.3. The CALEQ made use of a five point Likert scale which range from 1 to 5, where 1 is the most negative perception that represents almost never, 2 represents seldom, 3 represents sometimes, 4 represents often and 5 is the most positive perception, which represents very often. An actual and preferred version of the CALEQ were used for data collection purposes in order to obtain students' perception of their actual experience on the one hand, and their perceptions of how they would prefer these experiences to be, on the other.

The findings obtained from the CALEQ reflected a positive perception of the computer-assisted learning environment by students with item mean scores all between 3 (sometimes) and 4 (often) which indicated their perceptions were positive for the inclusion of computers in their mathematics and physical science classes. This situation was true for both actual and preferred versions of the CALEQ for Centres A and B. The item mean scores on the actual version of the CALEQ for the combination of the two centres, represented in Table 4.04, showed that the Integration (3.60) and Learning Assessment (3.44) scales have the highest mean item scores. This finding indicated that students at both centres perceived the integration of computers into their classes as positive and that they were better able to assess their learning through computer-assisted classes. The Open-Endedness scale, which represents the degree to which students perceive the teacher adopting an open-ended approach in the computer-assisted classes, had the lowest item mean score (3.23) of all the scales but this still indicated a mean positive perception by students. Students also had a positive perception of their involvement, the material organisation and investigation in the computer-assisted classes.

The findings related to Centre A (Table 4.06 and Figure 4.02) for the actual version of the CALEQ, which reflected student perceptions of their actual experiences of their computer classes, showed that the item mean score for the Integration scale (3.71) was the highest which indicated a perceived positive integration of computer-assisted lessons into their mathematics and physical science classes. Four scales, namely Material Organisation (3.49), Learning Assessment (3.46), Involvement (3.41) and Investigation (3.40), had similar mean item scores which indicated that the students perceived the organisation in the classroom, opportunities for assessing their own learning, their involvement in the lessons and investigative activities that they experienced in the computer-assisted classes at a similar level. The students perceived fewer opportunities for open-endedness (3.23) in their computer-assisted classes based on the lower item mean score for this scale compared to the other scales.

The data of the CALEQ at Centre A showed a trend which indicated an increase in their preferred environment, but the analysis of the data indicated that there were no significant statistical differences between the students' actual and preferred perceptions. The findings for the preferred version of the CALEQ at Centre A, which represented students' view on how they would prefer the computer-assisted learning environment, pointed to a preferred greater activity than currently existed based on the mean score on the four scales — Involvement (3.41[Actual]; 3.60[Preferred]), Open-Endedness (3.32[A]; 3.38[P]), Material Organisation (3.49[A]; 3.55[P]) and Learning Assessment (3.46[A]; 3.66[P]). The preferred mean item scores were higher than the actual means indicating that the students would prefer more involvement, open-endedness, organisation and learning assessment opportunities in their computer-assisted classes. The mean item scores of the remaining two scales, namely, Investigation (3.40[A]; 3.40[P]) and Integration (3.71[A]; 3.60[P]), remained unchanged for the former and decreased from actual to preferred for the latter scale. Students' perceptions at Centre A, therefore, indicated that they would prefer a decrease in the integration of computers in their every day classes whilst investigation procedures in their classes should remain the same.

Table 4.08, which represents the findings at Centre B for the actual version of the CALEQ, shows that student perceptions indicated the Integration scale (3.51) had the highest item mean score and the Open-Endedness scale (3.15) the lowest. These mean scores reflected a positive perception of the integration of computers as part of the students' learning of mathematics and physical science but that the students perceived less open-endedness in their computer-assisted classes than the other dimensions.

The analyses of Centre B's data for students' actual and preferred perceptions showed that only one scale was found to be statistically significant, namely the Learning Assessment scale ($p<0.01$) but the same trend as at Centre A (a preferred increase in activities) was noted with the exception of the Investigation and Material Organisation scales. When the findings of the actual and preferred versions of the CALEQ at Centre B were compared (represented by Figure 4.03), these two scales, namely, Investigation (3.33[A]; 3.20[P]) and Material Organisation (3.32[A]; 3.24[P]) were found to have less value for the preferred version. This result pointed to student perceptions that they would prefer less structured computer sessions with fewer activities where students had to investigate answers to questions on their own. The findings for the preferred version of the CALEQ at Centre B also indicated that the students' mean item scores were higher than the actual means on the four scales — Involvement (3.37[A]; 3.59[P]), Open-Endedness (3.15[A]; 3.27[P]), Learning Assessment (3.43[A]; 3.87[P]) and Integration (3.51[A]; 3.59[P]). These results indicate that students would prefer to be more involved, to have more open-endedness in their classes, to increase the learning assessment opportunities and to have a greater level of integration of computers in their mathematics and physical science classes.

A comparison of the students' perceptions at Centres A and B (Figure 4.04) indicated that the mean item scores for the Involvement scale were very similar for both centres for the actual version of the CALEQ. The almost identical preferred item mean scores at both centres indicated that the students would prefer to be more involved and students at both Centres A (3.41[A]; 3.60[P]) and B (3.37[A]; 3.59[P]) valued their involvement in the computer-assisted classes to the same degree. Based on the mean scores at both centres (see Table 4.09), the students perceptions indicated that they would prefer an increase in open-endedness, learning assessment and integration. The preferred Learning Assessment scale reflected the biggest change — at Centre A an increase from a mean of 3.46[A] to a mean of 3.66[P] and at Centre B from 3.43[A] to 3.87[P]. This increase in the Learning Assessment means indicates that the students would prefer to assess their own learning in the computer-assisted classes. This view was also articulated by the majority of the interviewed students who held the position that the inclusion of computers in their classes could lead to an improvement in their learning.

The mean score on the Material Organisation scale in the preferred version at Centre A showed that the students would prefer an improvement in the organisation of the computer sessions (3.49[A]; 3.55[P]) but at Centre B the students indicated that they would prefer a decrease in the material organisation (3.32[A]; 3.24[P]). The preferred decrease in material organisation at Centre B could be ascribed to the method of implementation of the computer-assisted classes at Centre B (discussed in Section 6.3.2) where the students used the computers once a week. In the interviews, the students indicated that the structure of the current (once-a-week) application of the computer-assisted classes did not cater for all their needs. The students at Centre B would prefer to have a greater integration of computers in their daily classes compared to students at Centre A who would prefer a decrease in integration. These preferences also could be linked to the different implementation strategies adopted by the two centres because students at Centre A, who used computers on a daily basis, would prefer less integration (3.71[A]; 3.60[P]) while students at Centre B, who used the computers once a week, would prefer greater integration (3.51[A]; 3.59[P]) of computers in their lessons.

Similarly, the Investigation scale for Centre B indicated that the students would prefer less investigative activities (3.33[A]; 3.20[P]) while at Centre A the students would prefer that the investigations in their computer-assisted classes remained the same (3.40[A]; 3.40[P]). This preference for a non-increase at Centre A and a reduction at Centre B in activities where the students had to investigate answers for themselves was also articulated in the interviews with students who wanted the teacher to explain and work out the problems. At both centres there was a preference for more teacher-centred teaching within the computer-assisted classes.

The findings from student interviews indicated that the students supported the idea for computer-assistance in their classes, albeit to different degrees. From many of the interviews with the students reported in Section 4.4.4 and discussed in Section 5.4, three viewpoints with regard to the inclusion of computer-assistance in classes became evident. One viewpoint indicated that the students considered the inclusion of computer-assisted learning as important to their learning, and that they were convinced that their interactions with the computer, with their fellow-students and with the teachers led to an improvement in their learning. Proponents of this viewpoint wanted group interactions, preferred to discuss the problems with one another and called for teacher assistance when needed; this group wanted a continuation of the status quo. The second viewpoint conveyed a message of insecurity in the use of computers for they were not sure whether their working with computers made any difference to their learning. Many of the students' views were somewhere between the first and the second views which left the impression that these students were not convinced that using the computers would guarantee them success in the matriculation examination. In both views, the overwhelming recommendation for improvement was for additional computers to address their personal needs. The third view was strongly articulated by a group of three students at Centre A and to a lesser degree by a group at Centre B who held the view that the new computer-assisted classes played no role in their learning and that teacher-centred classes would produce better results.

The findings from student interviews also indicated that the students considered the teacher as the one with the authority to decide on how they needed to learn. These students were in Grade 12 and in a number of interviews the students referred to the trust vested in the teacher whom they depended on to help them pass the matriculation examination. The students wanted some measure of teacher-centred classes, not just because this was what they were accustomed to, but also because they viewed the teacher as the accepted expert and authority to guide them through this learning process. Consequently, for the combination of the CALEQ data of the two centres (Table 4.04 and Figure 4.01), the item mean scores for the Open-Endedness scale were the lowest of all the scales at both the actual and preferred levels (3.23[A]; 3.31[P]) indicating that the students would prefer less open-endedness in their classrooms compared to the other scales and articulated for more teacher-centred lessons during the interviews.

6.3.4 The Achieved Programme

The major outcomes in mathematics and physical science were built around the objectives that were identified in Section 4.2. The achieved programme was addressed by the fourth research question: What were the outcomes in mathematics and physical science as a result of the students' participation in the outreach programmes?

As reported in Section 4.5.3, the teachers involved at the two MICSECs considered the implementation of the computer-assisted learning classes as supportive of their teaching because it served as an additional resource that helped them in their preparation of classes and the computers served as a useful tool for their daily teaching. Each of the teachers indicated that they could use the computer centre for revision and reinforcement purposes by planning exercise sessions for students as well as when there were shortages of textbooks or when the normal learning materials were insufficient. The computer-assisted classes also were used to support teachers in trying to address students' lack of content knowledge in mathematics and physical science when they entered Grade 12. This knowledge deficit developed over a number of years because students in the lower grades were taught by mostly underqualified teachers, as discussed in Section 1.3.1. The teachers in Grade 12 are the more experienced and qualified teachers and have the responsibility to produce pass results for students in the matriculation examination in order to provide a good image of the school.

The findings of student learning indicated that the students used the computer to monitor their own learning because they were able to identify particular steps of a problem that they did not understand and then ask the teacher to explain this specific step. This monitoring of learning was further emphasised when student responses on the Learning Assessment scale of the CALEQ had the highest item mean scores of 3.66 and 3.87 for the preferred version for Centres A and B, respectively.

The finding for the achievement of the students (Table 4.10) indicated that at both centres the percentage of the students that passed the examination in physical science in 2001 increased by 10% and 20%, respectively, after the implementation of the outreach programme. The mathematics outcomes were less dramatic with 10% and 5% increases in Centre A and Centre B, respectively, in the number of students passing the examination. Although it was difficult to ascribe the increases in the number of students passing the examination directly to their interactions on the computers, the teachers and principals of the two schools claimed that they were convinced that the students' use of the Mini-Computer Supported Education Centres played a pivotal role in this improvement. Further, they expected the pass rate to improve as the teachers became more accustomed to the use of the computer-assisted learning approach.

6.4 Implications of the study

This study has described the development and application of a new instrument (*Computer-Assisted Learning Environment Questionnaire*) to measure the learning environment in two computer-assisted classes. Three of the six scales used in this instrument — Involvement, Open-Endedness and Investigation — were selected from other instruments (discussed in Sections 2.5 and 3.5.3) that were tested and applied in other non-western countries. A fourth scale — Material Organisation — was combined from two other scales. The author created the two remaining scales — Learning Assessment and Integration — after experiences during on-site visits to two disadvantaged *black* secondary schools in the Western Cape. The results obtained from the application of the actual and preferred CALEQ could serve as baseline data for research into computer-assisted learning environments in other secondary science classes in schools in South Africa.

This study has shown that students at the Grade 12 level preferred a continuation of teacher-centred teaching, and indeed more of this kind of teaching even in the computer-assisted classes. By the low mean item scores for Open-Endedness as well as opinions articulated during interviews, students indicated that they would prefer more teacher-dominated classes which they believed would prepare them for the matriculation examination. Based on the results of this study, when students are expected to write a matriculation examination in order to get access to work opportunities and tertiary study, they prefer their teachers to play a central role in preparing them to pass the examination. This finding has important implications for an outcomes-based education system in South Africa that encourages teachers to engage in more learner-based activities when the final Grade 12 externally set examination still is used as a measure of the success of the students, teachers and schools. The finding indicates that despite concerted attempts from education authorities to encourage outcomes-based strategies, students indicated that their immediate needs in Grade 12 would be best served by a return to (or in many instances, continuation of) the teacher-centred approach. This study has also found that the introduction of computer-assisted classes at Grade 12 left many students unsure of the effectiveness of these classes due to their limited exposure to and experience of this type of teaching. An important implication of this study is, therefore, that computer-assisted classes be introduced at an earlier stage, for example during Grade 11, so that students would have sufficient time to adapt to the CAL approach and do not have the added pressure of an external matriculation examination.

The teachers also identified in the interviews (reported in Section 4.5), a need to implement computer-assisted classes in the lower grades and to support both the teachers and the students in mathematics and physical science before the students reach Grade 12. The inclusion of computer-assisted learning at an earlier stage may assist students where the content-knowledge of the teachers may be lacking because, in many instances, teachers of the lower grades held diplomas from teachers training colleges or were qualified in other subjects. This lack of content-knowledge by the teachers is supported by the data of Arnott et al. (1997) which, unfortunately, results in students who enter Grade 12 having large deficits in their content knowledge in mathematics and physical science. This situation is further weakened by the prominence given to matriculation examination results and the rewards for schools that achieved significant improvement in these results which prompted schools to place their most qualified and experienced teachers at Grade 12 level.

This study also responds to a recommendation made by the National Consultative Conference (Department of Education, 2000) for strategic interventions to improve mathematics, science and technology in schools and for the evaluation of the success of such interventions. The results of this study may serve as an example of the evaluation of the effectiveness of outreach programmes and other computer-based interventions in mathematics, science and technology at the Grade 12 level in disadvantaged *black* schools.

The data collected from this study also provide insight into the implementation of computer-assisted classes in South African disadvantaged schools. The literature on the implementation of computer-assisted learning suggests, on the one hand, the use of computers as a part of everyday classes (Duchateau, 1995; Songer et al., 2002), such as in Centre A in this study, and, on the other hand, as an add-on to the normal classes (Mushayikwa, 2000; Yalcinalp et al., 1995) as in Centre B in this study, without supporting any particular method of implementation. This situation implies, therefore, that for schools with centres like Schools A and B, it would be important in the implementation of these centres in mathematics and physical science classes that a balance be established between the inclusion of computer-assistance in every lesson on the one hand, and working on the computers only once a week, on the other. This balance will depend on the prevailing conditions at the school, for example, how the centre could be fitted into the timetable.

The findings related to achievement of the students in the matriculation examination, as well as findings involving the number of computers available and the types of computer programmes needed, have implications for outreach programme managers. Many of the students found that learning with computers was helpful and wanted this type of learning to be extended to other subjects as well. Both the students and teachers indicated that they would prefer more computers for mathematics and physical science in addition to the limited number provided to each centre. For some students, this shortage in computers has a perceived impact on their learning as well as on the individual needs of students to assess their own learning progress. The problem was compounded with licence restrictions on the CAMI mathematics programme that limits ten computers per licence. However, the principals from both schools have indicated that the schools did not have the finances to purchase additional licences and it is possible that this limitation could further impact on the students' mathematics learning outcomes. The teachers also indicated that the programmes needed to include more interactive material that challenged the students to apply their content knowledge to various real-life situations and to make connections of the relevance of school subjects to out-of-school activities. It is important to note that the students indicated that they would prefer more teacher-centred teaching while at the same time asking for more computers to support their learning because the students at Grade 12 level want to make use of all opportunities to prepare themselves for the matriculation examination.

6.5 Limitations of the study

A number of limitations with regard to the samples engaged in this study are identified. Firstly, only two of a possible nine centres were included as study sites; these centres have been established throughout the Western Cape, making travelling to them very costly. The author did make an attempt to include two more centres, but in the end only two centres were involved in this study. One of the schools approached did not want a researcher to intrude on their Grade 12 classes while the principal at another school did not answer the author's repeated requests for visiting the school. Secondly, the sample size of students at the two centres — Centre A had 40 students and Centre B had 49 — also is identified as a limitation because this small number of students might have reduced the chances of observing significant trends between actual and preferred environments for the two centres. A third limitation that might have contributed to the low statistical significance of the actual and preferred comparative data was that this was the first time students were exposed to computers and they were not always sure what a preferred situation would be. This lack of exposure could have influenced students' perceptions identified in the preferred version of the CALEQ.

A fourth limitation, identified in Section 4.4.2, is that the application of the CALEQ could not be trial tested with a large sample. In the Western Cape, relatively small numbers of schools from the disadvantaged *black* areas had access to computers that teachers could employ in their daily teaching. While one or two computers might be available in schools, these were mainly used for administrative purposes. As pointed out previously, it was logistically difficult to include more schools where MICSECs were placed even though an attempt was made to include two more schools in this study.

Language is the fifth limitation in this study. The students at the two centres were Xhosa mother-tongue speakers and only had English as a second or third language. Even though they were taught in the English language, and the questionnaires were checked for the language content by teachers involved at each centre, by two science and mathematics teachers from neighbouring schools and by five students from neighbouring schools of each centre, students still asked the author to explain words like 'proceed', 'programme' and 'investigate' when the questionnaires were administered. Similar questions about these words were asked during student interviews that were held afterward.

A sixth limitation is that student outcomes were measured on only one occasion by their achievement in the final matriculation examination. It might have been preferable to monitor students' achievement at regular intervals during the course of the study so as to obtain some data prior to their examination.

6.6 Recommendations for further research

A study of the development of the Outreach Project over its 20 years existence could be investigated as a follow-up to this study. By doing an in-depth study for the period 1982 to 2001 of the outreach programme run by University's Outreach Project, the data could possibly identify useful performance indicators (for example, the relevance of an outreach programme within a specific community) that could form a framework for good practice for programmes of this nature. This investigation could involve the use of interviews and questionnaires to obtain the perceptions, experience and advice of participants in the Outreach Project over the 20-year period. These participants could include Outreach Project personnel who worked on the outreach programme over the 20 years and students, teachers and principals of schools who made use of the outreach programme over the years. Records of student performance at these schools and Outreach Project documentation also could be explored as part of this investigation.

A follow-up study also could investigate the effectiveness of the use of computers at lower grade levels and how these computer-assisted classes impacted on student preparation for the upper grades. In South Africa, the physical science and mathematics syllabi requirements of Grade 12 include large sections of the Grade 11 physical science syllabus and the entire Grade 11 mathematics syllabus. This study identified that some students at the Grade 12 level wanted more teacher-centred lessons in order to complete the syllabus. A study examining the introduction of the computer-assisted classes at an earlier stage, for instance at the Grade 11 level, could provide useful data about the effectiveness of computer-assisted lessons on student learning as students would have more time available to get used to this method of teaching. Similarly, these studies could assess the attitudes of students to computer-assisted classes. Future research also could include the further use of the *Computer-Assisted Learning Environment Questionnaire* to examine a broader range of students' perceptions in the South African context.

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APPENDIX A

Format of semi-structured interviews with individual and student groups

1.	Background	What is your name and age? Is this your first year in Grade 12 ? Did you repeat any other grades? Where do you live? Do you have access to water, electricity at your home? How many family members do you have? When was your first contact with computers?
2.	Actual CAL classes	When the computer centre opened last year what was your first impressions of using computers? How do you experience the inclusion of computers in your mathematics and science class? What is the interaction between you and your fellow students like when working on the computer? What does the teacher do during this time? Do you consider working on the computer as helpful to you learning mathematics and physical science? Please explain. I see you indicated in the actual questionnaire (CALEQ) the following, could you please explain what you meant with......[responses to scale items]
3.	Preferred CAL classes	Given that you have now worked on the computers for most of this year, would you suggest that next years matriculants also work on the computer? Why? What changes would you suggest to possibly improve the computer classes? I see in the preferred questionnaire you indicated the following, could you please explain....[responses to scale items]

APPENDIX B

Format of semi-structured interviews with teachers

1. Background

   Which subjects are you responsible for?
   How many classes, students?
   What are your qualifications?
   How many years teaching experience do you have?
   How many years teaching Grade 12?
   How long have you been at this school?

2. Actual CAL classes

   What was your initial impression of the inclusions of computers to assist your teaching?
   Did the UWC Outreach Project provide training to assist with the use of the MICSECs in you daily classes? Explain
   How do you implement the MICSECs in your classes? Explain
   Does the inclusion of the MICSECs assist with students understanding and learning of your subject? Please elaborate.
   In your opinion, is the computer programme for your subject adequate? Would you suggest any improvements?
   From your experience in the class, how do students find the interaction with computers?
   What are the interactions like between students when they work on the computers?
   Are there any noticeable improvements in the achievement of students in your subjects due to their interaction with computers?

3. Preferred CAL classes

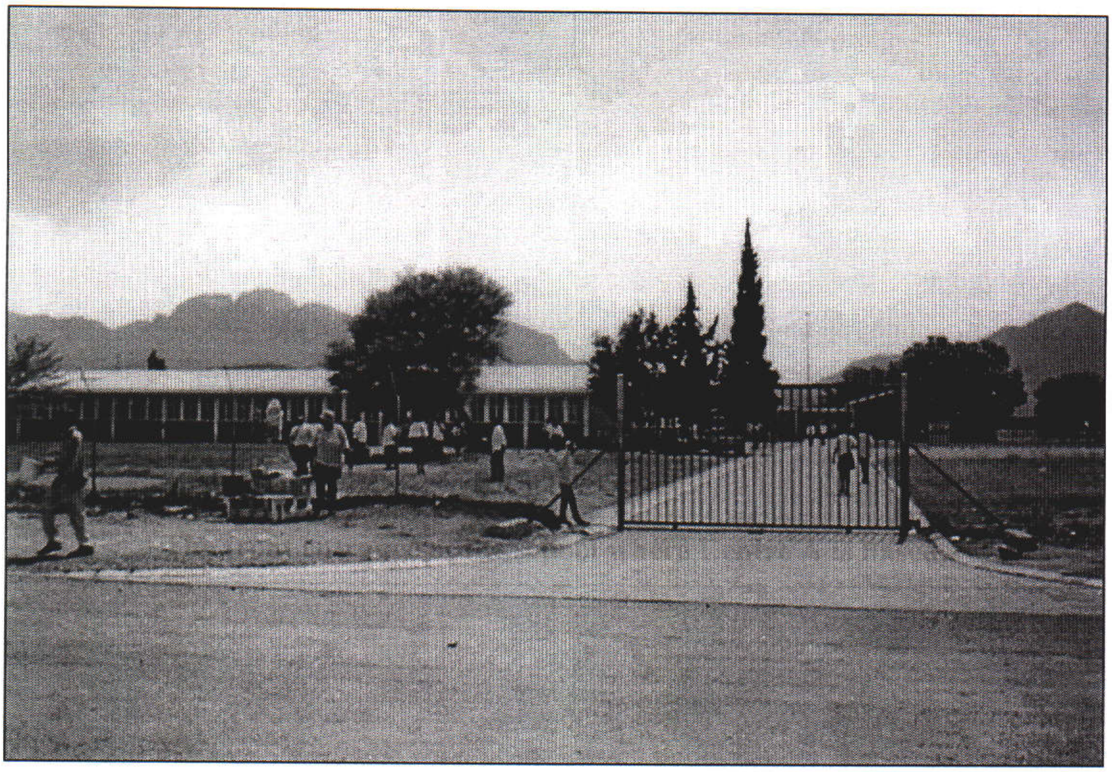
   Given that you have now worked on the computers for most of this year, would you suggest that next years matriculants also work on the computer? Why?
   Would you consider using computers for the lower grades? Why?
   What changes would you suggest to possibly improve the computer classes?

APPENDIX C

Photographs of the schools where the two centres are located and interactions of students during group work on the computers.

Centre A

The front entrance of the school where Centre A is based.

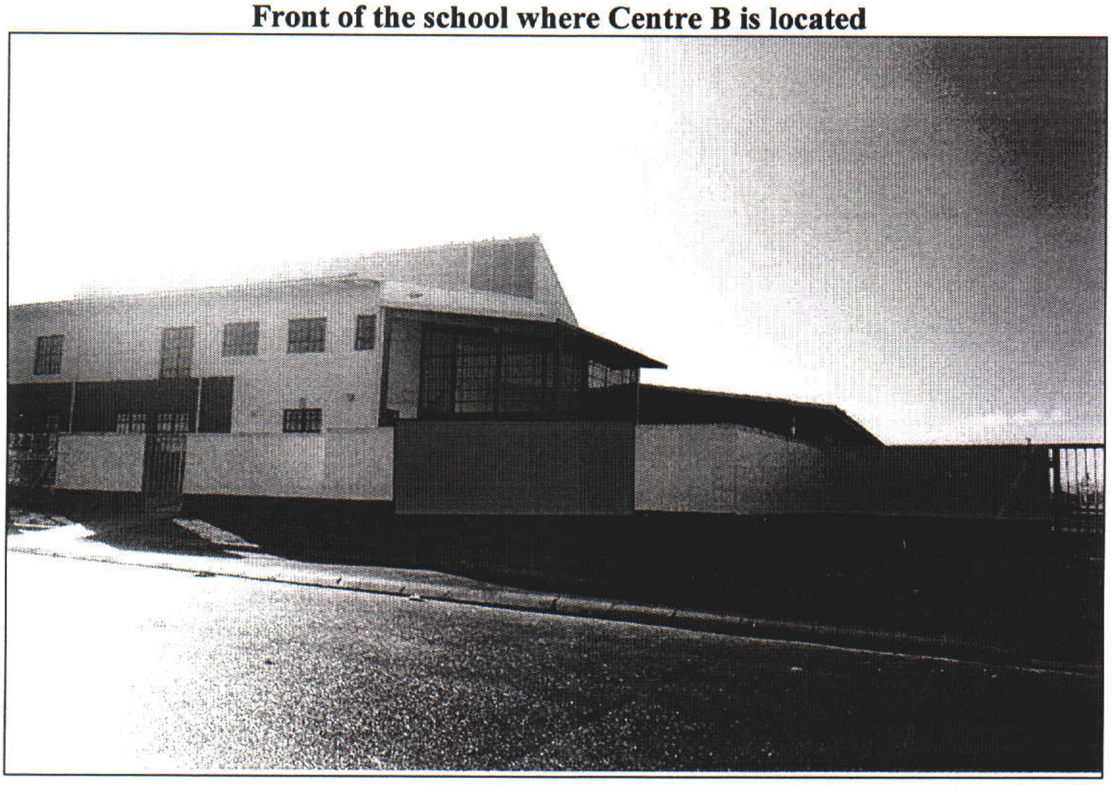


A side view of the school where Centre A is located.

A view of the road on the way to Centre A

Centre B

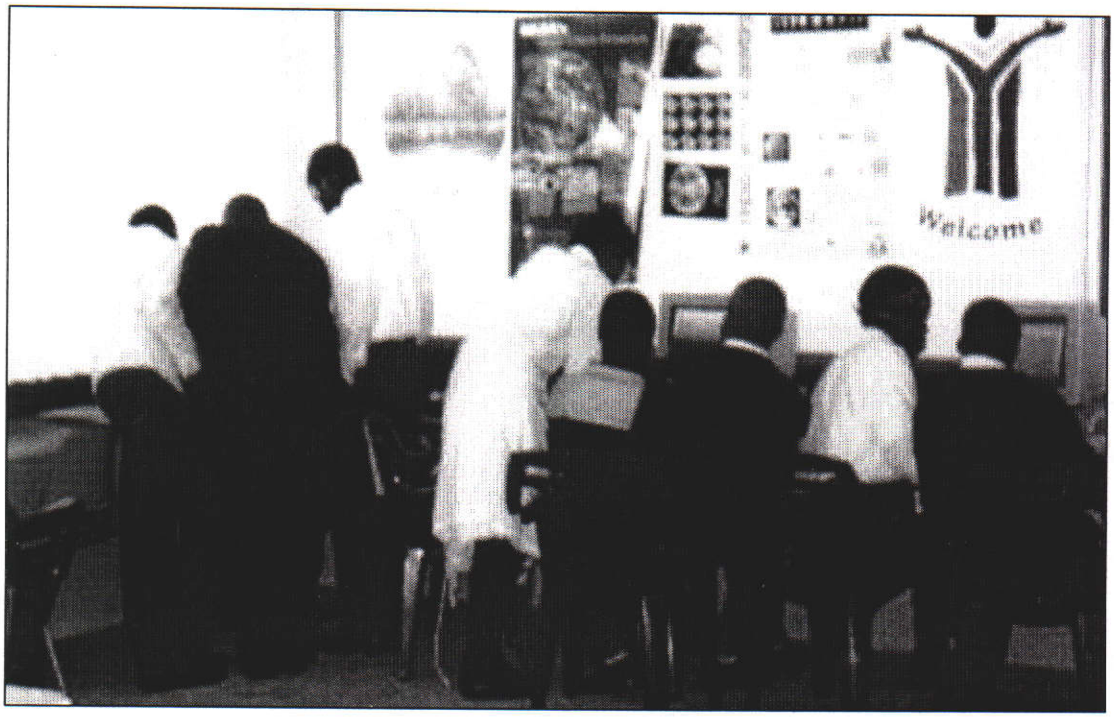
Front of the school where Centre B is located

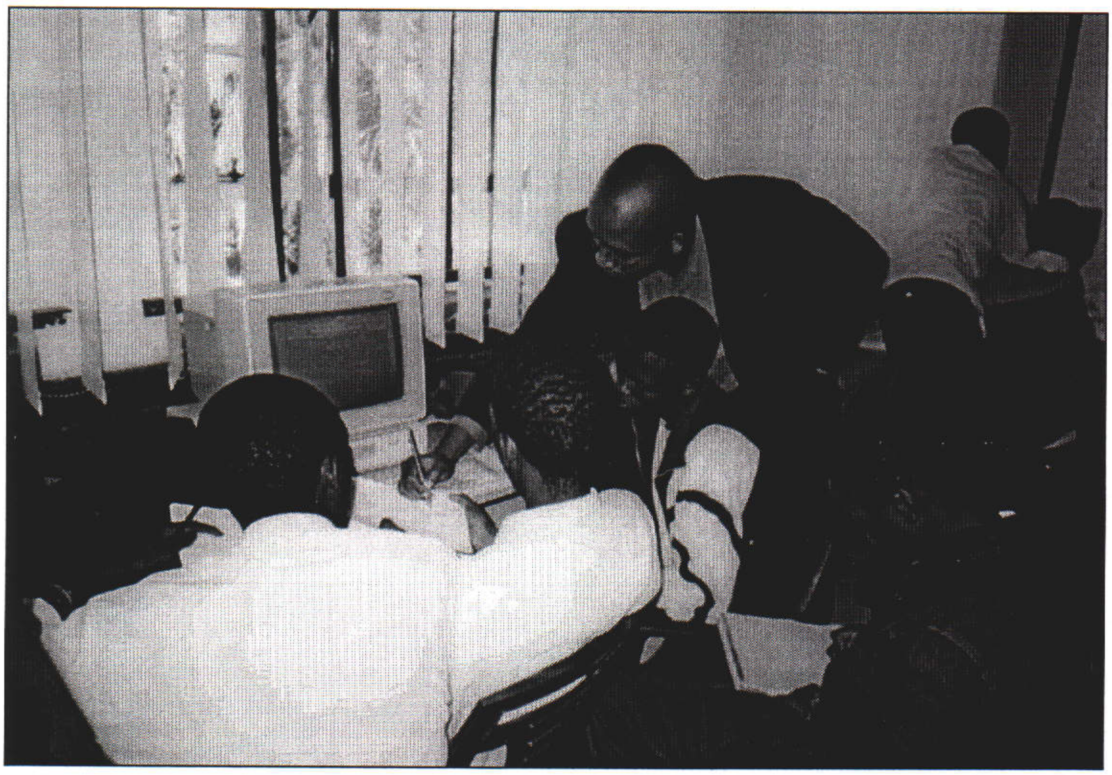


Side view of the school where Centre B is located

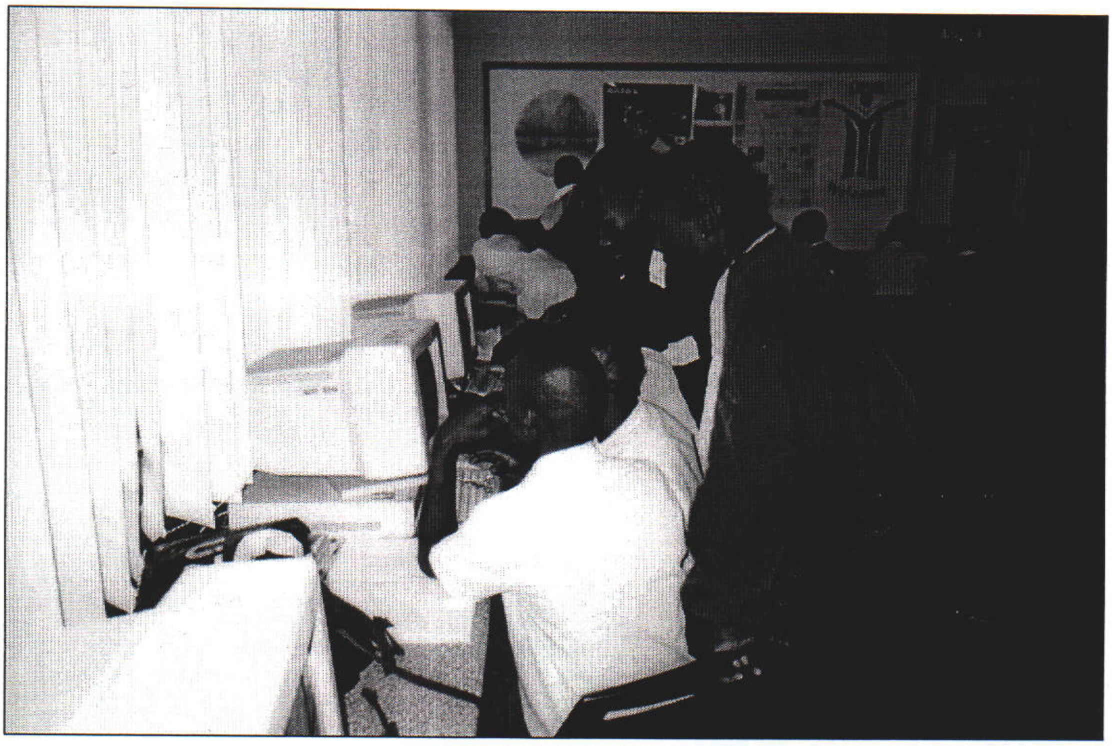
Entrance (double door) to Centre B and the school hall in front for meetings and where community members sell their food and beverages during lunch

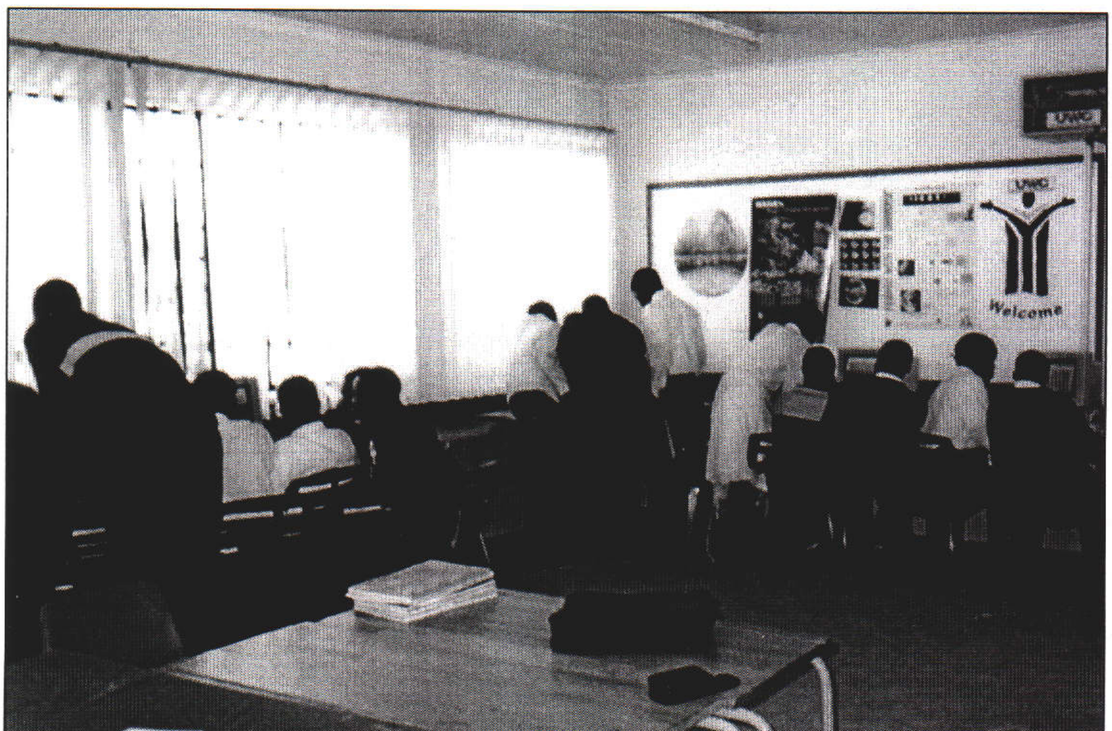
The teacher assisting students in solving problems on the computer

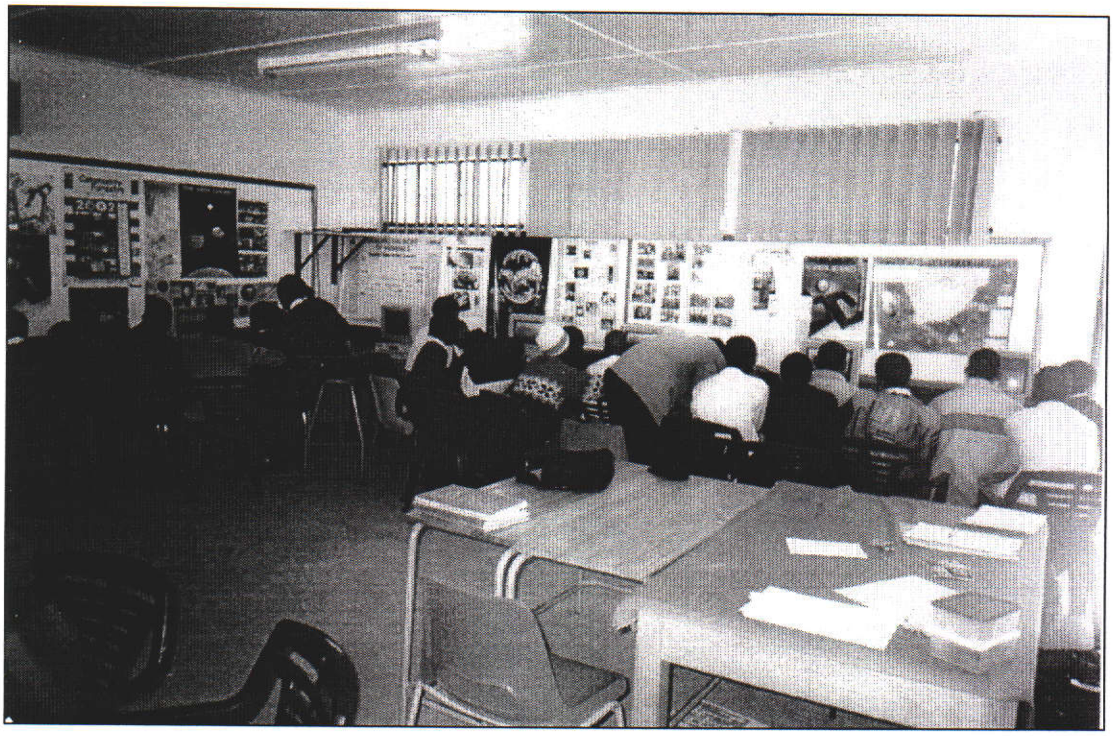




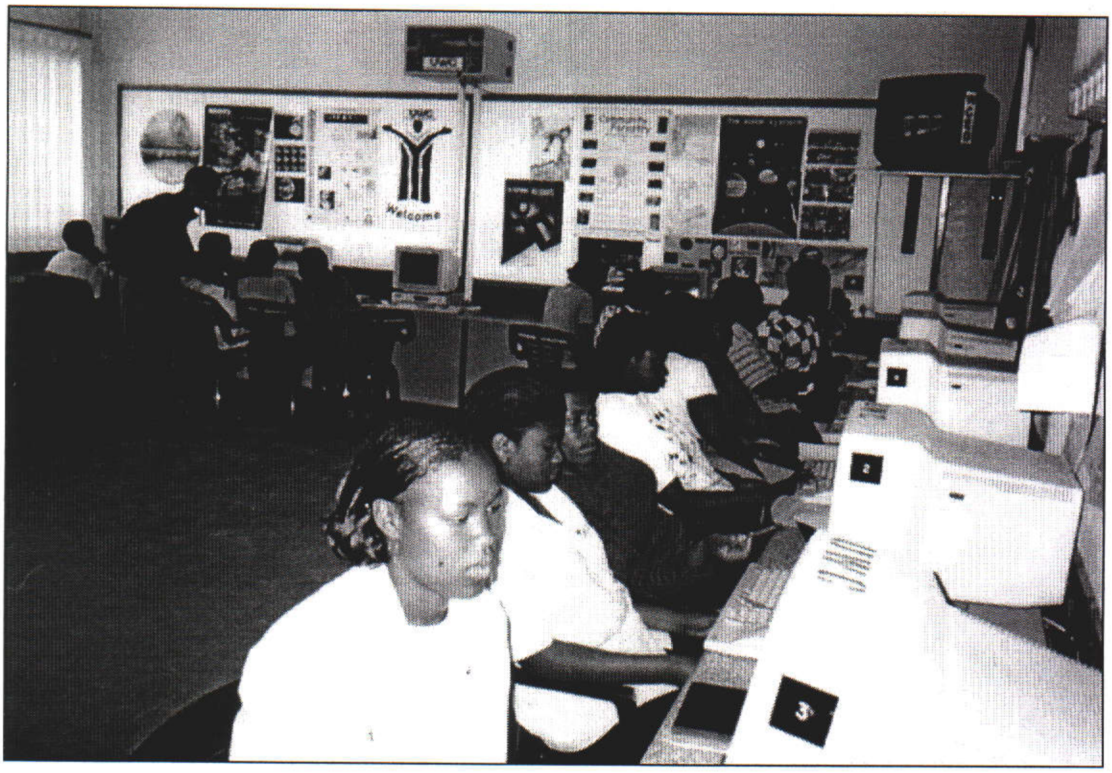
Student interactions and deliberations about problems on the mathematics and physical science computer programmes

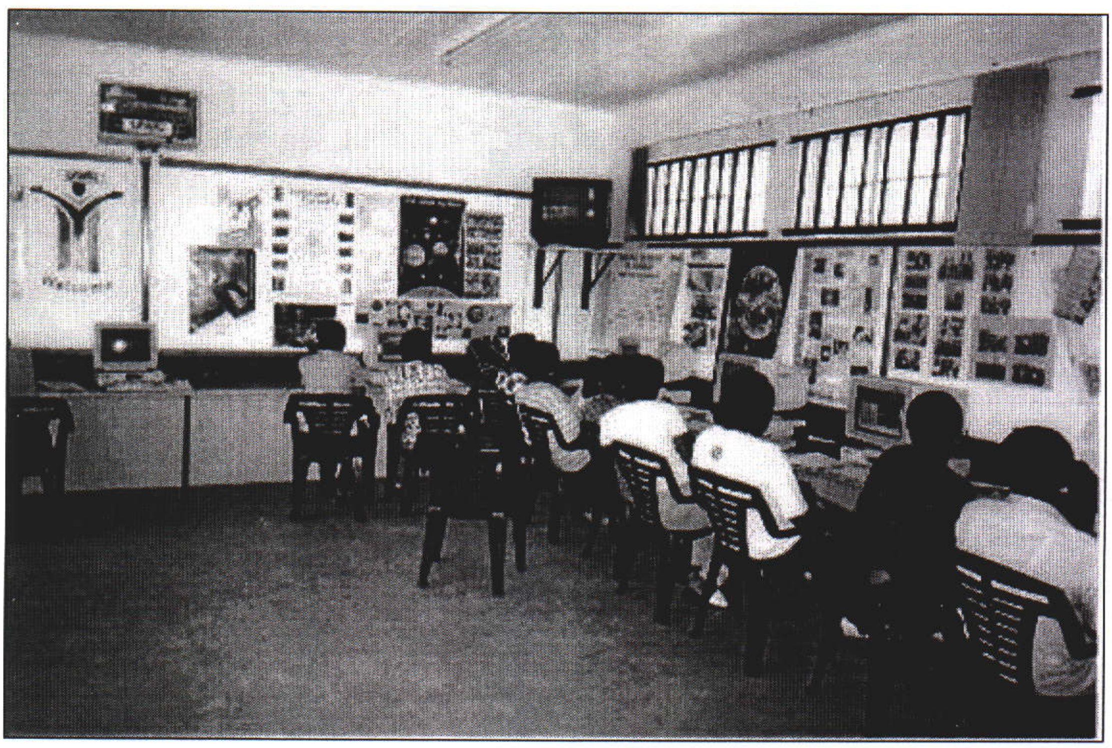


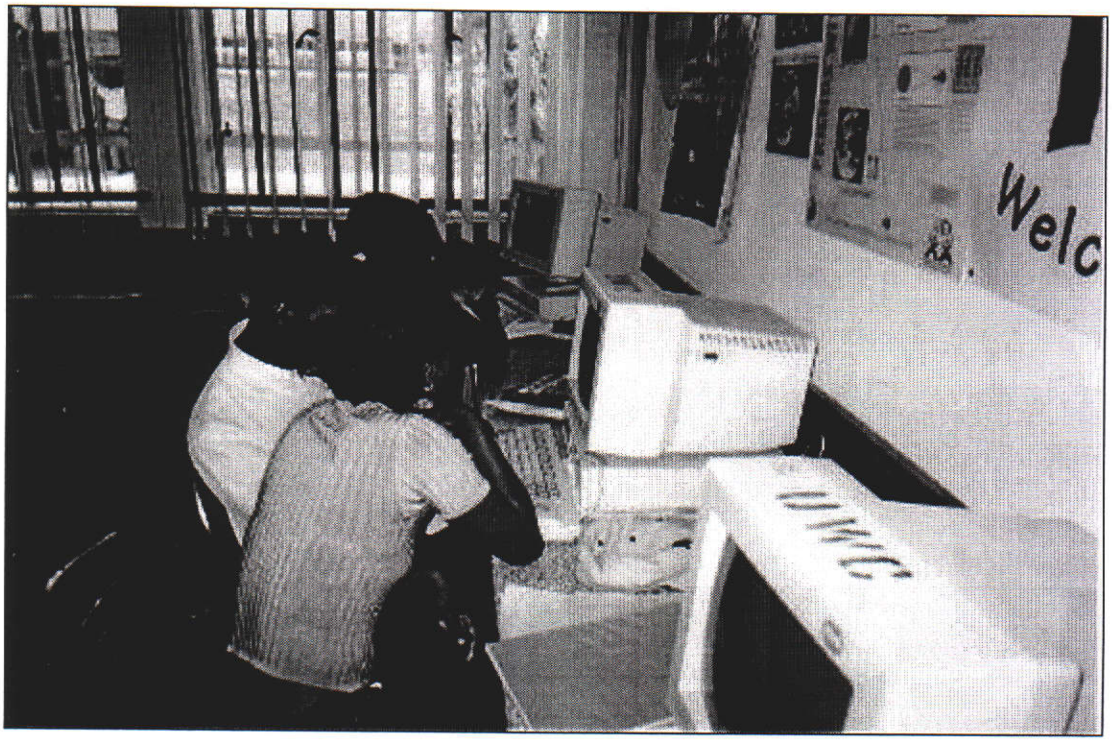

Welcome



Students participating in sessions after school hours



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OF MINERALS

APPENDIX D

Examples of the Outreach Project documentation from which information about the goals, objectives and operation of the outreach programme was obtained.

1983 Report by Mehl, M.C. and Sinclair, A.J.L.
1989 Report by Sinclair, A.J.L. and Kansky, R.J.
1993 Report by Mehl, M.C. and Rhodes, J.S.
1998 Report by Ogunniyi, M.B. and Isaacs, B.
2000 Report by Ogunniyi, M.B. and Isaacs, B.

APPENDIX E

***Computer-Assisted Learning Environment Questionnaire* (CALEQ) scales and their classification according to Moos's scheme**

Scale	Description of Scale	Sample item	Scoring	Moos's General Category
Involvement	Extent to which students have attentive interest, participate in discussions, perform additional work, and experience the CAL classes.	I am asked to explain how I solve problems.	Positive	Relationship
Open-endedness	Extent to which an open ended approach is adopted in the CAL classes.	I must answer questions in a prescribed way.	Negative	Personal Development
Investigation	Extent to which student is encourage to engage in the learning process.	I find out answers to questions by doing investigations.	Positive	Personal Development
Material Organization	Extent to which CAL classes are organized and computer hardware and software are adequate.	The computer programs are hard to use.	Negative	System Maintenance
Learning assessment	Extent to which the learner can assess his understanding of subject content	I have improved my ability to solve problems by using the computer.	Positive	Personal Development
Integration	Extent to which the computer is included as a tool in daily teaching of mathematics and physical science.	The computer work is integrated with the regular science and mathematics class work.	Positive	System Maintenance

APPENDIX F

Computer-Assisted Learning Environment Questionnaire:
Actual Form

COMPUTER-ASSISTED LEARNING ENVIRONMENT QUESTIONNAIRE

ACTUAL FORM

Directions

This questionnaire contains statements about practices which take place in the computer-assisted classes for the subjects mathematics and physical science. You will be asked **how often** each practice **actually takes place.**

There are NO 'right' or 'wrong' answers. Your opinion is wanted.

Think about how well each statement describes what this computer-assisted class is actually like for you. Draw a **CIRCLE** around:

1	if the practice actually takes place	ALMOST NEVER
2	if the practice actually takes place	SELDOM
3	if the practice actually takes place	SOMETIMES
4	if the practice actually takes place	OFTEN
5	if the practice actually takes place	VERY OFTEN

Be sure to give an answer for ALL questions. If you change your mind about an answer, just cross it out and circle another.

Practice example: Suppose you were given the statement: "I play games on the computer." You would need to decide whether you thought that you **actually** play games *Almost Never, Seldom, Sometimes, Often, or Very Often.* If you for example select *Almost Never*, you would circle number 1 on your answer sheet.

Do not forget to write your name and other details below:

Name:.............................. School:........................

Class:...............

In the computer-assisted class:	Almost never	Seldom	Sometimes	Often	Very Often	Office Use
1 I discuss my ideas.	1	2	3	4	5	....
2 The teacher decides the best way for me to proceed.	1	2	3	4	5	....
3 I carry out investigations to test my ideas.	1	2	3	4	5	....
4 I find that the computer session is well organised.	1	2	3	4	5	....
5 I don't like using computers to learn.	1	2	3	4	5	....
6 What I do in our regular science and mathematics class is unrelated to the work on the computer.	1	2	3	4	5	....
7 I give my opinion during class discussions	1	2	3	4	5	....
8 I select the topic that I wish to do.	1	2	3	4	5	....
9 I am expected to think about the evidence for statements	1	2	3	4	5	....
10 The computers are in good working condition	1	2	3	4	5	....
11 I can point out which part of a problem I don't understand	1	2	3	4	5	....
12 The computer work is related to the topics that I study in regular science and mathematics class.	1	2	3	4	5	....
13 The teacher asks me questions.	1	2	3	4	5	....
14 I do different topics than some of the other pupils.	1	2	3	4	5	....
15 I solve problems by using information obtained during my own investigations.	1	2	3	4	5	....
16 The computers are suitable for operating the programs.	1	2	3	4	5	....
17 I cannot get to the answers on the computer.	1	2	3	4	5	....
18 My regular science and mathematics classwork is integrated with computer work.	1	2	3	4	5	....
19 My ideas and suggestions are discussed during classroom discussions.	1	2	3	4	5	....
20 Pupils are allowed to solve the problems in their own way.	1	2	3	4	5	....
21 I investigate answers to questions coming from	1	2	3	4	5	....
discussions.	1	2	3	4	5	....
22 There are not enough computers for students to use.	1	2	3	4	5	....
23 Computers assist me to improve my understanding of problems.	1	2	3	4	5	....
24 I use the theory from our regular mathematics and science class in the computer lessons.						
25 I ask the teacher questions.	1	2	3	4	5	....
26 I am allowed to do more advanced problems.	1	2	3	4	5	....
27 I explain the meaning of statements, diagrams and graphs.	1	2	3	4	5	....
28 The computer programs available enable students to make good use of the computer	1	2	3	4	5	....
29 I prefer that the teacher explain the solution of problems.	1	2	3	4	5	....
30 The topics covered in regular science and mathematics class work, are quite different from topics with which I deal with on the computer.	1	2	3	4	5	....

In the computer-assisted class:	Almost never	Seldom	Sometimes	Often	Very Often	Office Use
31 I explain my ideas to others.	1	2	3	4	5	……….
32 I am required to come up with my own solution to a problem.	1	2	3	4	5	……….
33 I explore different options to answer questions which puzzle me.	1	2	3	4	5	……….
34 There are enough computer programs available for our lessons	1	2	3	4	5	……….
35 I use the computer for additional exercise work only.	1	2	3	4	5	……….
36 What I do on the computer helps me to understand the theory covered in regular science and mathematics classes.	1	2	3	4	5	……….
37 Students discuss with me how to go about solving problems.	1	2	3	4	5	……….
38 There is opportunity pursue your own interests.	1	2	3	4	5	……….
39 I carry out investigations to answer the computer's and teacher's questions.	1	2	3	4	5	……….
40 The computer programs run without any problems.	1	2	3	4	5	……….
41 I find using computers a waste of time.	1	2	3	4	5	……….
42 The computer work and the regular science and mathematics are unrelated.	1	2	3	4	5	……….
43 I am asked to explain how I solve problems.	1	2	3	4	5	……….
44 I must answer questions in a prescribed way.	1	2	3	4	5	……….
45 I find out answers to questions by doing investigations.	1	2	3	4	5	……….
46 The computer programs are hard to use.	1	2	3	4	5	……….
47 I have improved my ability to solve problems by using the computer.	1	2	3	4	5	……….
48 The computer work is integrated with the regular science and mathematics class work.	1	2	3	4	5	……….

APPENDIX G

Computer-Assisted Learning Environment Questionnaire:
Preferred Form

COMPUTER-ASSISTED LEARNING ENVIRONMENT QUESTIONNAIRE

PREFERRED FORM

Directions
This questionnaire contains statements about practices which could take place in the computer-assisted classes for the subjects mathematics and physical science. You will be asked **how often** you would **prefer** each practice to take place.

There are NO 'right' or 'wrong' answers. Your opinion is wanted.

Think about how well each statement describes what this computer-assisted class is actually like for you. Draw a **CIRCLE** around:

1	if you would prefer the practice to take place	ALMOST NEVER
2	if you would prefer the practice to take place	SELDOM
3	if you would prefer the practice to take place	SOMETIMES
4	if you would prefer the practice to take place	OFTEN
5	if you would prefer the practice to take place	VERY OFTEN

Be sure to give an answer for ALL questions. If you change your mind about an answer, just cross it out and circle another.

Practice example: Suppose you were given the statement: "I would play games on the computer." You would need to decide whether you thought that you would **prefer** to play games *Almost Never, Seldom, Sometimes, Often, or Very Often*. If you for example select *Almost Never*, you would circle number 1 on your answersheet.

Do not forget to write your name and other details below:

Name:.............................. School:.......................

Class:...............

In the computer-assisted class:	Almost never	Seldom	Sometimes	Often	Very Often	Office Use
1 I would discuss my ideas.	1	2	3	4	5	....
2 The teacher would decide the best way for me to proceed.	1	2	3	4	5	....
3 I would carry out investigations to test my ideas.	1	2	3	4	5	....
4 I would find that the computer session is well organised.	1	2	3	4	5	....
5 I would not like using computers to learn.	1	2	3	4	5	....
6 What I do in our regular science and mathematics class would be unrelated to the work on the computer.	1	2	3	4	5	....
7 I would give my opinion during class discussions	1	2	3	4	5	....
8 I would select the topic that I wish to do.	1	2	3	4	5	....
9 I would be expected to think about the evidence for statements.	1	2	3	4	5	....
10 The computers would be in good working condition.	1	2	3	4	5	....
11 I would point out which part of a problem I don't understand.	1	2	3	4	5	....
12 The computer work would be related to the topics that I study in regular science and mathematics class.	1	2	3	4	5	....
13 The teacher would ask me questions.	1	2	3	4	5	....
14 I would do different topics than some of the other pupils.	1	2	3	4	5	....
15 I would solve problems by using information obtained during my own investigations.	1	2	3	4	5	....
16 The computers would be suitable for operating the programs.	1	2	3	4	5	....
17 I would not be able to get to the answers on the computer.	1	2	3	4	5	....
18 My regular science and mathematics class work would be integrated with computer work.	1	2	3	4	5	....
19 My ideas and suggestions would be discussed during classroom discussions.	1	2	3	4	5	....
20 Pupils would be allowed to solve the problems in their own way.	1	2	3	4	5	....
21 I would investigate answers to questions coming from discussions.	1	2	3	4	5	....
22 There would not be enough computers for students to use.	1	2	3	4	5	....
23 Computers would assist me to improve my understanding of problems.	1	2	3	4	5	....
24 I would use the theory from our regular mathematics and science classes in the computer lessons.	1	2	3	4	5	....

In the computer-assisted class:	Almost never	Seldom	Sometimes	Often	Very Often	Office Use
25 I would ask the teacher questions.	1	2	3	4	5	....
26 I would be allowed to do more advanced problems.	1	2	3	4	5	....
27 I would explain the meaning of statements, diagrams and graphs.	1	2	3	4	5	....
28 The computer programs available would enable students to make good use of the computer	1	2	3	4	5	....
29 I would prefer that the teacher explain the solution of problems.	1	2	3	4	5	....
30 The topics covered in regular science and mathematics class work, would be quite different from topics with which I deal with on the computer.	1	2	3	4	5	....
31 I would explain my ideas to others.	1	2	3	4	5	....
32 I would be required to come up with my own solution to a problem.	1	2	3	4	5	....
33 I would explore different options to answer questions which puzzle me.	1	2	3	4	5	....
34 There would be enough computer programs available for our lessons	1	2	3	4	5	....
35 I would use the computer for additional exercise work only.	1	2	3	4	5	....
36 What I do on the computer would help me to understand the theory covered in regular science and mathematics classes.	1	2	3	4	5	....
37 Students would discuss with me how to go about solving problems.	1	2	3	4	5	....
38 There would be opportunity pursue your own interests.	1	2	3	4	5	....
39 I would carry out investigations to answer the computer's and teacher's questions.	1	2	3	4	5	....
40 The computer programs would run without any problems.	1	2	3	4	5	....
41 I would find using computers a waste of time.	1	2	3	4	5	....
42 The computer work and the regular science and mathematics would be unrelated.	1	2	3	4	5	....
43 I would be asked to explain how I solve problems.	1	2	3	4	5	....
44 I would answer questions in a prescribed way.	1	2	3	4	5	....
45 I would find out answers to questions by doing investigations.	1	2	3	4	5	....
46 The computer programs would be hard to use.	1	2	3	4	5	....
47 I would improve my ability to solve problems by using the computer.	1	2	3	4	5	....
48 The computer work would be integrated with the regular science and mathematics class work.	1	2	3	4	5	....

APPENDIX H

Scale Allocation for Items in the Computer-Assisted Learning Environment Questionnaire

Involvement

1. I discuss my ideas.
7. I give my opinion during class discussions
13. The teacher asks me questions.
19. My ideas and suggestions are discussed during classroom discussions.
25. I ask the teacher questions.
31. I explain my ideas to others.
37. Students discuss with me how to go about solving problems.
43. I am asked to explain how I solve problems.

Open-Endedness

2. The teacher decides the best way for me to proceed.
8. I select the topic that I wish to do.
14. I do different topics than some of the other pupils.
20. Pupils are allowed to solve the problems in their own way.
26. I am allowed to do more advanced problems.
32. I am required to come up with my own solution to a problem.
38. There is opportunity pursue your own interests.
44. I must answer questions in a prescribed way.

Investigation

3. I carry out investigations to test my ideas.
9. I am expected to think about the evidence for statements
15. I solve problems by using information obtained during my own investigations.
21. I investigate answers to questions coming from discussions.
27. I explain the meaning of statements, diagrams and graphs.
33. I explore different options to answer questions which puzzle me.
39. I carry out investigations to answer the computer's and teacher's questions.
45. I find out answers to questions by doing investigations.

Material Organisation

4. I find that the computer session is well organised.
10. The computers are in good working condition
16. The computers are suitable for operating the programs.
22. There are not enough computers for students to use.
28. The computer programs available enable students to make good use of the computer
34. There are enough computer programs available for our lessons
40. The computer programs run without any problems.
46. The computer programs are hard to use.

Learning Assessment

5. I don't like using computers to learn.
11. I can point out which part of a problem I don't understand
17. I cannot get to the answers on the computer.
23. Computers assist me to improve my understanding of problems.
29. I prefer that the teacher explain the solution of problems.
35. I use the computer for additional exercise work only.
41. I find using computers a waste of time.
47. I have improved my ability to solve problems by using the computer.

Integration

6. What I do in our regular science and mathematics class is unrelated to the work on the computer.
12. The computer work is related to the topics that I study in regular science and mathematics class
18. My regular science and mathematics class work is integrated with computer work.
24. I use the theory from our regular mathematics and science class in the computer lessons.
30. The topics covered in regular science and mathematics class work, are quite different from topics with which I deal with on the computer.
36. What I do on the computer helps me to understand the theory covered in regular science and mathematics classes
42. The computer work and the regular science and mathematics are unrelated.
48. The computer work is integrated with the regular science and mathematics class work.

APPENDIX I

Lessons and test on momentum which form part of the physical science component of the computer programme developed by the University of the Western Cape

APPENDIX J

Test on factorisation with and without using the formula which form part of the mathematics computer programmes developed by Computer Aided Mathematics Instruction (CAMI)

APPENDIX K

Comparison of Actual and Preferred Item Means for each scale of the *Computer-Assisted Learning Environment Questionnaire* for Centre A

Scale	N	Actual Item Mean (Av. Item St. Dev.)	Preferred Item Mean (Av. Item St. Dev.)	t-value
IVO	39	3.41 (0.56)	3.60 (0.65)	-1.51
OE	39	3.32 (0.54)	3.38 (0.46)	-0.38
IVE	39	3.40 (0.52)	3.40 (0.45)	0.08
MO	39	3.49 (0.60)	3.55 (0.63)	-0.10
LA	39	3.46 (0.61)	3.66 (0.65)	-1.12
ITG	39	3.71 (0.67)	3.60 (0.76)	0.74

APPENDIX L

Comparison of Actual and Preferred Item Means for each scale of the *Computer-Assisted Learning Environment Questionnaire* for Centre B

Scale	N	Actual Item Mean (Av. Item St. Dev.)	Preferred Item Mean (Av. Item St. Dev.)	t-value
IVO	49	3.37 (0.62)	3.59 (0.82)	-1.56
OE	49	3.15 (0.60)	3.27 (0.64)	-0.92
IVE	49	3.33 (0.63)	3.20 (0.56)	1.07
MO	49	3.32 (0.79)	3.24 (0.72)	0.47
LA	49	3.43 (0.58)	3.87 (0.59)	-4.03*
ITG	49	3.51 (0.66)	3.59 (0.71)	-0.60

*$p < 0.01$

APPENDIX M

An example of a transcribed interview with an individual student

APPENDIX N

An example of a transcribed interview with a group consisting of three students

Note: For privacy reasons Appendix N has not been reproduced.

(Co-ordinator, ADT Project (Bibliographic Services), Curtin University of Technology, 30/09/03)

APPENDIX O

An example of a transcribed interview with a teacher

Note: For privacy reasons Appendix O has not been reproduced.