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PHYSICAL SCIENCE CONTENT KNOWLEDGE OF FIRST-YEAR PRESERVICE SCIENCE TEACHER TRAINEES AT COLLEGES OF EDUCATION IN SOUTH AFRICA

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A dissertation submitted to the Faculty of Education, University of the Witwatersrand, in fulfilment of the requirements for the degree of Master of Education

Johannesburg, February 1999

DECLARATION

I declare that this dissertation is my own unaided work. It is being submitted for the Degree of Master of Education in the University of the Witwatersrand. It has not been submitted before for any degree or examination in any other University

Sarah Jane Howie

16 day of February 1998

ABSTRACT

First year science teacher trainees' physical science content knowledge was tested in a survey conducted at six historically black Colleges of Education in South Africa. The science achievement tests included questions on oxidation-reduction/ electrochemical cells; velocity/ displacement; periodic table and electrostatics.

This exploratory study revealed that the students had a very low content knowledge of all four science topics. Students had difficulty answering open-ended questions and a high percentage of students were unable to answer questions requiring knowledge of basic scientific facts and principles.

Background questionnaires were also administered to the students. More than 75% of the students tested did not foresee teaching as a career. Furthermore, students' confidence about their content knowledge and positive attitudes towards science did not correlate with their performance in the achievement test.

The study proposes a revised strategy on recruitment and the selection of teacher trainees for physical science at the Colleges of Education.

DEDICATION

To my husband, David for his love and patience;
to my mother and father and my brother David for their encouragement.

ACKNOWLEDGEMENTS

Many people contributed to the successful completion of this study and in particular I am most grateful to my supervisor, Margaret Rutherford, willingness to take me on, for her guidance and support, and for never accepting second-best.

A special word of thanks is owed to the College Rectors who allowed me into the Colleges of Education to conduct this research, the science lecturers who assisted me with the administration of the tests; to those RADMASTE science lecturers who helped me initially with the identification of the science topics and to the students who so willingly participated in my study. I want to thank the science teachers and lecturers who served as my expert panels: Sindi Qobo, Jean Westermann, David Mahlatse, Marissa Rollnick, Thokani Zulu, Dries Drost and Rienie Jansen van Rensburg.

Studying part-time is not easy for the families of us students and I want to thank my long-suffering husband, David Howie for his unwavering support and encouragement (and all the cups of coffee) throughout these past years; my mother and father and my brother for their love and support.

Several friends and colleagues were valuable sources of advice and support. The idea to undertake this study in the first place, I owe to my good friend Peter Wedepohl who believed in me and to Terry Marsh for his support, especially in the initial stages. Special thanks go to my former Director and friend, Peter van Eldik for his encouragement, contribution and for organising the technical support needed to analyse the results. In this regard, I would also like to thank Amanda Lourens for her technical advice and for making statistics easier to understand; and to Klaas Bos for his advice and technical support. Towards the end of my dissertati-

Tjeerd Plomp served as my "critical friend" and I am grateful for his advice and contribution.

Finally, I need to thank my Executive Director, Mokubung Nkomo and my Director, Andre Kraak, for their encouragement and for permitting me the time to complete the study. I am also grateful to the Human Sciences Research Council for their financial support and for granting me study leave for this research.

TABLE OF CONTENTS

		Page
Declaration		i
Synopsis/abstract		ii
Dedication		iii
Acknowledgements		v
List of Figures		xii
List of Tables		xiv
Acronyms and key words		xix
CHAPTER		
1. INTRODUCTION AND PROBLEM STATEMENT		**1**
1.1.	Science Education in Africa	1
1.1.1.	Science Education in South Africa	3
1.1.2.	Performance of South African students in science and mathematics	6
1.1.3.	Science teacher education and science teachers in South Africa	8
1.2.	Research problem statement and hypotheses	9
1.3.	Importance of study	12
1.4.	Plan of study	14
1.5.	Overview of dissertation	15
2. OVERVIEW OF THE LITERATURE		**16**
2.1.	Introduction	16
2.2.	International perspectives on initial science teacher education	17

2.2.1. Literature on science teacher education 17
2.2.2. Reform in science teacher education 19
2.2.3. Policies and trends in initial science teacher education 20
2.2.4. Trends in science teacher education in developing countries 23
2.2.5. Prerequisites for entrance into teacher training institutions 25
2.2.6. Recruitment into initial science teacher training 27
2.3. South African initial science teacher education 30
2.3.1. Trends and policies in science teacher education in Colleges of Education 32
2.3.2. Prerequisites for entrance to South African Colleges of Education 34
2.4. Science knowledge and misconception studies 36
2.4.1. Science concepts 37
2.4.2. The nature of science 40
2.4.3. Physics concepts and misconceptions 41
2.4.4. Chemistry concepts and misconceptions 42
2.4.5. Language and science 44
2.5. Conclusion 46

3. RESEARCH DESIGN 48

3.1. Introduction 48
3.2. Population and sample 49
3.3. Research instruments 50
3.3.1. Physical Science achievement test 50
3.3.2. Student questionnaire 51
3.3.3. College of Education lecturers questionnaire 52
3.4. Procedure 52

3.4.1. Fieldwork, testing and administration of questionnaires 55
3.4.2. Scoring and coding of questions 57
3.5. Data-Analysis 57

4. DESIGN AND DEVELOPMENT OF PHYSICAL SCIENCE ACHIEVEMENT TEST 60

4.1. Role of Science Education Experts 60
4.2. Selection of physical science topics 61
4.3. Construction of the test 64

5. RESEARCH RESULTS FROM STUDENT BIOGRAPHICAL QUESTIONNAIRES 69

5.1. Student's profile 69
5.2. Student's home environment 86
5.3. School environment and student's performance at school 92
5.4. Students' choice of career 111
5.5. Analyses of student background variables 117
5.5.1. Factors relating to students' choice of teacher diploma course 118
5.5.2. Factors relating to students' performance in mathematics 121
5.5.3. Factors relating to students' performance in science 125
5.5.4. Factors relating to the school' facilities and students' achievement in mathematics and science 131
5.5.5. Factors relating to the year students completed matric 131

5.5.6. Factors relating to the length of time that students intend to study 135
5.5.7. Factors influencing students' career choice 136
5.6. Conclusion 138

6. CHAPTER 6 RESEARCH RESULTS OF STUDENTS' SCIENCE ACHIEVEMENT TESTS 142

6.1. Students' overall achievement 143
6.2. Students' overall performance per topic in chemistry and physics 150
6.3. Students' achievement in the different science topics 154
6.3.1. Students' performance in oxidation-reduction and electrochemical cells 154
6.3.2. Students' performance in the periodic table 169
6.3.3. Students' performance in electrostatistics 178
6.3.4. Students' performance in velocity and displacement 190
6.3.5. Students' achievement across all the science topics 201

6.4. Relationship between the students' overall Performance in the science test and their background variables 204
6.5. Similarities and differences between students from different colleges of education 206
6.6. Results from lecturers' questionnaires 210
6.6.1. Profile of lecturers 210
6.6.2. Information pertaining to the students tested 212
6.7. Conclusion 216

7. CHAPTER 7 – KEY FINDINGS AND RECOMMENDATIONS 212

7.1. Students' performance in the physical science test 223
7.2. Students' confidence in their content knowledge of physical science 226
7.3. Students attitudes towards physical science 227
7.4. The profile of the students in colleges of education 228
7.5. Factors related to students' achievement in physical science 230
7.6. Factors influencing the students' choice of teaching as a career 233
7.7. Students' commitment to teaching 234
7.8. Recommendations 235

8. REFERENCES 240

9. BIBLIOGRAPHY 262

10. APPENDICES

10.1. Workshop questionnaire for lecturers
10.2. Workshop lecturers comments
10.3. Science experts' questionnaire
10.4. Students' test
10.5. Students' questionnaire
10.6. Lecturers' questionnaire
10.7. Comments of science experts

LIST OF FIGURES

Figure 1.1.	*Systemic model for improving science education*	*5*
Figure 1.2.	*Framework of the research*	*14*
Figure 3.1.	*Stages in planning the survey of six Colleges of Education linked to framework of the dissertation*	*51*
Figure 5.1.	*Age of the students when tested*	*70*
Figure 5.2	*Gender of students*	*72*
Figure 5.3.	*Language of students tested*	*76*
Figure 5.4	*Areas where students grew up*	*78*
Figure 5.5.	*Students' type of home during their matric year*	*87*
Figure 5.6.	*Levels of education achieved by the students' parents*	*89*
Figure 5.7.	*Students' means of transport to school*	*90*
Figure 5.8.	*Time taken travelling to school*	*91*
Figure 5.9.	*Location of school*	*93*
Figure 5.10.	*Problems experienced by students at their school*	*97*
Figure 5.11.	*The relationship between the mathematics and physical and science points average obtained for matric*	*126*
Figure 6.1.	*Students' overall average percentage obtained on the science test*	*143*
Figure 6.2.	*Students' overall performance by College*	*145*
Figure 6.3.	*Students' overall percentage by age*	*148*
Figure 6.4.	*Students' overall performance by physics and chemistry topic*	*151*
Figure 6.5.	*Distribution of students' overall performance by topic*	*153*
Figure 6.6.	*Students' overall performance on oxidation-reduction and electrochemical cells*	*155*
Figure 6.7.	*The relationship between the students' confidence and their performance in the topic*	*160*

Figure 6.8. *Students' results on oxidation-reduction and electrochemical cells* *163*

Figure 6.9. *The relationship between the number of students answering the question correctly and the cognitive level of the questions* *166*

Figure 6.10. *Students' overall performance on the periodic table* *170*

Figure 6.11. *Students' overall performance on Electrostatics* *179*

Figure 6.12. *The relationship between the students' confidence levels and their performance in the topic* *183*

Figure 6.13. *Students' results on Electrostatics* *186*

Figure 6.14. *The relationship between the number of students answering the questions correctly and the knowledge level of the questions* *189*

Figure 6.15. *Students' overall performance on velocity and displacement-time* *191*

Figure 6.16. *The relationship between the students' perceptions and their performance in the topic* *195*

Figure 6.17. *Students' results on the Velocity and displacement-time questions* *198*

LIST OF TABLES

Table 3.1.	*The research process of the study and the Involvement of experts*	*53*
Table 4.1.	*Results from the Lecturers' questionnaires*	*63*
Table 4.2.	*Selection of Oxidation-reduction items*	*68*
Table 5.1.	*Average age of students when tested and by gender*	*71*
Table 5.2.	*The average age of the students by college.*	*71*
Table 5 4.	*Information on male and female science students at different colleges*	*74*
Table 5.5.	*Home-languages of students across the Colleges*	*75*
Table 5.6.	*Amount of time that students spent studying in their matric year*	*77*
Table 5.7.	*Time spent on science homework per week*	*80*
Table 5.8.	*Time spent on paid jobs per week*	*82*
Table 5.9.	*Time spent on chores around the house*	*83*
Table 5.10.	*Time spent on leisure activities per week*	*84*
Table 5.11.	*Recreation-type facilities*	*95*
Table 5.12.	*Percentage of students taking science related subjects*	*101*
Table 5.13.	*Students' achievement in physical science mathematics related subjects across grades*	*102*
Table 5.14.	*Students' attitudes toward science at school*	*106*
Table 5.15.	*Students' opinions about what is necessary for a student to do well in science*	*107*
Table 5.16.	*Factors contributing to the enjoyment of students of science at school*	*108*
Table 5.17.	*Students' confidence in their understanding of science*	*109*
Table 5.18.	*Career path advocated by parents*	*111*

Table 5.19.	Teachers advice to students about career paths	112
Table 5.20.	Students first choice of career path	114
Table 5.21.	Students reasons for selecting Colleges	115
Table 5.22.	Students' anticipated length of study at Colleges	116
Table 5.23.	Matriculation symbol conversion Table	118
Table 5.24.	Students' anticipated length of teaching career	120
Table 5.25	Area where students grew up and course	121
Table 5.26	The relationship between students' performance in mathematics and home areas of the students	122
Table 5.27	The relationship between students' performance in mathematics and the areas the students'schools were located in	123
Table 5.28	Factors relating to the disruption of schooling and mathematics achievement	124
Table 5.29	The relationship between the students' area of origin and their performance in physical science	127
Table 5.30	The relationship between the students' school location and their physical science marks	128
Table 5.31	Factors relating to the disruption of schooling and physical science achievement	129
Table 5.32	Students' performance in physical science in their matric year	132
Table 5.33	Students' performance in mathematics in their matric year	133
Table 5.34	Students' matric year and their College of Education	134
Table 5.35	Relationship between the choice of teaching career and intended teaching time	135
Table 5.36	Students' gender and their career choice	137
Table 5.37	Students' anticipated length of career	138

Table 6.1.	*Overall results of science achievement test*	*144*
Table 6.2.	*Percentages obtained by students by college*	*146*
Table 6.3.	*Relationship between students' course and the percentage obtained*	*147*
Table 6.4.	*Relationship between gender and the students' performance*	*149*
Table 6.5.	*Results of the achievernent test by topic*	*152*
Table 6.6.	*Students performance on the topic by college*	*156*
Table 6.7.	*Relationship between students' course and the students' mean percentage for oxidation-reduction and electrochemical cells*	*157*
Table 6.8.	*Relationship between gender and the students' performance*	*159*
Table 6.9.	*Results for individual questions*	*164*
Table 6.10.	*Students performance on the topic by college*	*171*
Table 6.11.	*Relationship between students' course and the students' mean percentage for the periodic table*	*172*
Table 6.12.	*Relationship between gender and the students' performance*	*173*
Table 6.13.	*The relationship between the students' perceptions and their performance in the topic*	*174*
Table 6.14.	*Students performance on the topic by college*	*180*
Table 6.15.	*Relationship between students' course and the students' average percentage for Electrostatics*	*181*
Table 6.16.	*Relationship between gender and the students' performance*	*182*

Table 6.17. Results for individual questions 187
Table 6.18. Students performance on the topic by college 192
Table 6.19. Relationship between students' course and the students' means percentage for velocity and displacement-time 193
Table 6.20. Relationship between gender and the students' performance 194
Table 6.21. Results for individual questions 199
Table 6.22. Topics taught to first year students tested 213
Table 6.23. Lecturers ranking of topics tested, in order of difficulty 214

LIST OF ACRONYMS

African	-	indigenous people of Africa
BOLESWA	–	Botswana, Lesotho and Swaziland
Coloured	-	people of mixed origin
COTEP	–	Committee on Teacher Education Policy
FRD	–	Foundation for Research Development
IEA	–	*International Association for Educational* Achievement
Indian	-	people of Indian or Asian origin
INSET	–	Inservice (Teacher Training)
NEPI	–	National Education Policy Initiative
PRESET	–	Preservice (Teacher Training)
RADMASTE	-	Research and Development of Mathematics, Science and Technology Education
SIMS	–	Second International Mathematics Study
SISS	–	Second International Science Study
SPSS	–	Statistical Package for Social Scientists
TIMSS	-	Third International Mathematics and Science Study
White	-	people of European origin

CHAPTER 1. INTRODUCTION AND PROBLEM STATEMENT

This study investigates the physical science content knowledge of first year science students at selected Colleges of Education and some of the factors influencing this knowledge.

The purpose of this chapter is to provide the context, firstly by giving some background information on science education in Africa and more specifically, South Africa. Then the research hypotheses and research questions are specified and discussed briefly. The rationale for the study and the importance of this research are explained in the latter part of the chapter. Finally, the plan of the study is presented and an overview of the contents of the dissertation is given.

1.1. SCIENCE EDUCATION IN AFRICA

Throughout Africa during the 1960s and 1970s, the focus in education was on the expansion of primary and secondary education. The emphasis shifted during the 1980s to vocational and career education and training, as a direct result of unemployment and pressure from the economic sector in many of these countries (Nieuwenhuis, 1997). As this emphasis on education in the developing world came about, so did the increase in the proportion of the Gross National Product (GNP) spent on education in developing countries. On average, the GDP in these countries grew from 2.3% to 4.5% in 1984 and the proportion of national budgets spent on education grew from 11.7% to 16.1% during this time (World Bank, 1988).

The expansion in the primary and secondary education system was not met by a corresponding growth in the number of trained teachers and Ministries

for Education could not meet the demand for trained teachers. This resulted in the appointment of untrained or less qualified teachers to help ease the pressure of large class sizes (Nieuwenhuis, 1997). In Africa, this pressure for expansion was further exacerbated by the commitment of African governments to "schooling for all" at the primary level in sub-Saharan Africa by 2005, meaning that enrolments at primary school would have to increase by 150% (Colcough, 1994).

African countries share common problems, such as those of overcrowded classrooms and a lack of proper resources to create effective teaching and learning environments. They are also confronted with improving the efficiency and effectiveness of the quality of education delivered, while ensuring greater access, equality and equity.

School science is widely accepted, even in the poorest countries of the world, as an important ingredient for economic development, and accordingly there have been 30 years of large-scale investments in science education, particularly across the developing world. Investment in science education appears to be a priority area in almost every national development plan and policy statement. Despite this, shortages in the supply of science-trained teachers persists, achievement levels are unsatisfactory and science in Third World schools is often considered weak (Caillods, Gottelmann-Duret and Lewin, 1997).

Perceived problems with the science curricula stem from the fact that the science curriculum that still dominates educational practice in many developing countries originated in the wave of curriculum reform that took place in Europe from the 1960s (De Feiter et al, 1998). That combined with the perception that science subjects, physical science in particular, are difficult, and that only clever students take these subjects have resulted in the

unpopularity of school science, technology and mathematics amongst the majority of secondary school students (Ogunniyi, 1996). Therefore, enrolments in science subjects at school are generally low and vary tremendously across Africa (from 10% to 50% in Anglophone countries) (Caillods, Gottelman, and Lewin, 1995).

There is also enough evidence to show that African secondary school students are under-achieving in physical science. The First, Second and Third International Science Studies (conducted by the International Association for the Evaluation of Educational Achievement [IEA]) show that African (Nigerian, Ghanaian, Zimbabwean and South African) secondary school students are falling behind their peers in science (Rosier, 1990; Keeves, 1992; Postlewaite and Wiley, 1992; Howie, 1997; Thulstrup, 1998). So low are their achievement levels that there are concerns about the general levels of scientific literacy and whether students are properly prepared for further study (Caillods, Gottelman, and Lewin, 1995).

1.1.1. Science Education in South Africa

South Africa's challenge is to provide good quality education for all students throughout the country. With an education system still characterised by its racial divisions, the majority of students attend the least adequately funded schools, with the lowest teacher qualifications, poorest facilities and largest class sizes. The senior secondary exams fail large numbers of students and here the racial differences are still stark. The common pattern of the past twenty years has been that about 95% of white candidates pass their senior certificate in contrast to only 40-50% of African students (Christie, 1996).

There has also been an over-emphasis on the humanities and social sciences and an under-emphasis on science, a tendency accentuated in

African (former Department of Education and Training (DET)) schools. South Africa (and other countries in Africa) is producing vast numbers of people with qualifications for which there is no demand in the workplace. If South Africa is to develop economically, it must strengthen its science and technology education. The White Paper on Education is clear on the importance of science and technology education. Its' objectives for science and technology education include, "*developing an understanding of and appreciation for the products of technology; stimulating the kind of thinking and reasoning that will enable students to observe phenomena, identify problems, conceive new ideas, analyse problems and reach solutions, distinguish between alternatives, comprehend technical documents and to visualise the results of a solution*" (Department of Education, 1995:22). The White Paper also emphasises quality education.

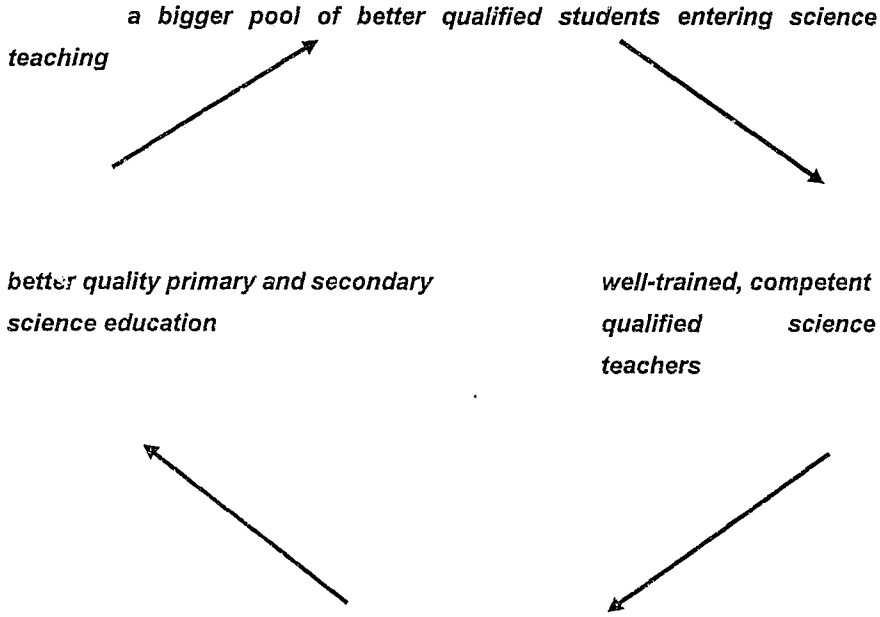
Furthermore, the National System of Innovation quoted in the White Paper on Science and Technology (1996) identifies the need to produce students with these attributes. This White Paper identified five key themes considered to be fundamental to a sound Science and Technology policy, of which two are: "*promoting competitiveness and employment creation*" and "*developing human resources*". The success of such a National System of Innovation depends heavily on the success of science teaching in schools through which children are being prepared for future careers in science and technology.

In order to attain this goal, as well as the other goals set by the government departments of education a systemic approach is needed. The ideal systemic model for the cycle of science education (adapted from De Feiter et al, 1995) is one that has:

- a bigger pool of better qualified students entering tertiary science, technology streams and science teacher education courses at Colleges of Education, technikons and universities, which then results in

- well-trained, competent and properly qualified science teachers which will lead to
- properly qualified science teachers in the schools, who will provide
- better quality primary and secondary science education which then results in, more and better qualified students entering tertiary science.... *and the cycle continues.*

Figure 1.1 Systemic model for improving science education



Presently, there are several obstacles to this model. The inefficiency of the government school sector results in resources being used for pupils who do not progress through the system. This is problematic as most of these schools have very scarce resources. The historical overview by De

Villiers (1997: 79-80) of school enrolments and success rates at schools (between 1985 and 1993) shows the following:

- 69 out of every 100 grade 1 white students complete their matriculation examination within 12 years,
- 62 out of every 100 grade 1 Indian students complete their matriculation examination within 12 years,
- 19 out of every 100 grade 1 coloured students complete their matriculation examination within 12 years,
- 8 out of every 100 grade 1 African students complete their matriculation examination within 12 years.

One of the issues that clearly emerges, is that these high failure rates indicate a problem in the junior phases in the education system. De Villiers (1997) says that pushing up students into a next grade without them seemingly being able to cope with that year's work is resulting in very high failure rates in the final year of schooling.

1.1.2. Performance of South African students in physical science and mathematics

The situation regarding the enrolments in mathematics and science and the matriculation exemption with these subjects, also varies dramatically between ethnic groups. For instance, whilst only 1 in 312 African students entering the school system leaves with physical science and mathematics as final year subjects, 1 in 5 white students, 1 in 6 Indian students and 1 in 46 coloured students obtains a matriculation exemption with physical science and mathematics (Blankley, 1994: 54).

Looking at these figure in more detail, in 1993, 49.6% of all white students took physical science in their final year, compared to only 11.7% of all African students. Of these, 98% of white students compared to 50% of African students passed their final year physical science examination. On average from 1991 to 1994, 45% of African students passed their physical science matriculation examination. The difference between the mathematics and physical science results may be attributed to the greater numbers taking mathematics and the fact that mathematics is a prerequisite for physical science and that a select few (only 13% of African students in 1993) take physical science FRD (1996). Of the total of 119 530 African students who wrote the physical science examination in 1995, only 68 954 passed (54%) (Arnott et al, 1997: 107). A more positive trend at senior secondary level has been the increase in the numbers of girls enrolling in science. Between 1986 and 1990, only 37% of all science pupils were female, but by 1995, 48% of all science pupils were female. (Arnott et al, 1997: 19).

Despite the obvious need for more and better-educated science students, school science and technology-based subjects are still inadequately funded. For the past three decades, reports have consistently shown that the schools are insufficiently funded and (if at all) have poorly equipped laboratories and library facilities (Kahn and Rollnick, 1993) The most recent surveys, including the School Register of Needs (1997), show the real need for well-equipped laboratories, workshops and libraries. Seventy-two percent of schools did not have libraries and between 22% and 75% of schools (depending on the province) did not have physical science laboratories.

1.1.3. Science teacher education and science teachers in South Africa

There is a general recognition of the central role that teacher education has in education, as well as the key roles that teachers play in human resources development and as implementers of change. The National Ministry of Education regards teacher education as "*one of the central pillars of national human resource development strategy*" (Hofmeyr et al, 1995: 18). Whilst there is some ambiguity about the relationship between teacher academic background and student achievement in developed countries, teacher qualifications do appear to be closely related to student achievement in the developing world (Haddad, 1985; Husen et al, 1978; Noonan, 1977; and Ware, 1992).

However, there is a concern that too few students are entering science teacher education. The total number of students registered for science teaching diplomas at the Colleges of Education in South Africa during 1996 was 2 027 and of these 742 were in their first year (Arnott et al, 1997: 57). These figures constitute a very small proportion (less than 5%) of the total population of students attending historically African Colleges of Education (as the total enrolment in historically African Colleges of Education in 1993 was 46742 students (FRD, 1996:199). This represents about 2% of the total student population enrolled in Colleges of Education as in 1994, there were 86 680 students in Colleges of Education (FRD, 1996:199)

Partly as a consequence of the inadequate number of matriculants and subsequently teacher trainees, there is currently an insufficient supply of adequately trained science teachers. Less than 50% of science teachers have accredited training in science. Approximately, 42% of science teachers have only one year of formal training. There is a lack of science teaching experience in both general science and physical science. More than 45% of

general science (that is taught in grades 9 and lower) teachers and nearly 40% of physical science (that is taught in grades 10 - 12) teachers have fewer than two year's experience of teaching. Aggravating the situation, is the fact that there is also a very high attrition rate as about 2100 science teachers leave the teaching profession each year (Arnott et al, 1997:1-2).

The focus of this study is on first year science teacher trainees and their knowledge of physical science. Consequently it bridges two education systems, the secondary school system (where they are coming from) and the higher education system (where they are presently). Therefore, throughout this dissertation, references to both matriculants from secondary school as well as Preservice (PRESET) teacher trainees (both primary and secondary diploma students), the first year students, will be made. It is believed that at this bridge lies the heart of the issue and therefore it is not possible to separate these two systems and discuss the one without the other.

1.2. RESEARCH PROBLEM STATEMENT AND HYPOTHESES

The research problem that constitutes the focus of the study is "to investigate the content knowledge and performance in physical science of first year science students at historically black Colleges of Education; to determine some of the factors that impact on their content knowledge and performance in physical science."

The research null hypotheses are that students entering historically black Colleges of Education to take Diplomas with science specialities have little understanding of basic school physical science; and that a lack of knowledge is attributable to previous educational background and environment.

In order to investigate the problem statement and to accept or reject the hypotheses previously stated, a number of key research questions had to be developed to guide the study. These are the following:

1. How do these students perform in selected topics in physical science?
2. How do the students perceive the level of their knowledge of physical science and how confident are they in their science knowledge base?
3. What are their attitudes towards physical science?
4. What is the profile of the students entering into first year science courses at Colleges of Education?
5. What are the factors that impact on or influence the students' achievement in physical science?
6. What are the factors that influenced the students' choice of teaching as a career?
7. What is the extent of the students' commitment to teaching?
8. Based on the students' performance and their profile, what recommendations can be made for preservice science education at Colleges of Education in South Africa?

In order to address/answer each of these questions, a number of issues for each question have been identified. The following paragraph describes what is meant by, and included, in each of the research questions:

1. How do these students perform in physical science?

To answer this question, the study will investigate the students' performance in selected topics in physics and chemistry as well as their performance in individual science questions within these topics. The relationship between the performance of students from different colleges, different diploma courses, male and female students and students of different age groups will be analysed.

2. **How do the students perceive the level of their knowledge of physical science and how confident are they in their science knowledge base?**
   This question will address students' confidence levels in respect of their content knowledge in the topics in their Grade 12 syllabus as well as the selected topics in the test.

3. **What are their attitudes towards physical science?**
   Students' feelings about learning physical science at school and what contributed towards their enjoyment (or otherwise) of science in their Grade 12 year will be investigated.

4. **What is the profile of the students entering into first year science courses at Colleges of Education?**
   Data will be collected on the students' age, gender, home language, leisure activities, home environment, school environment and their academic studies and performance at school.

5. **What are the factors that impact on or influence the students' achievement in physical science?**
   An investigation will be made into which of the following factors play a role in students' achievement: home environment; school environment; students' achievement in physical science in Std 10 / Grade 12; students' confidence in their knowledge in specific science topics; students' attitudes towards science; and finally, the factors that played a role in the students' performance in physical science at school.

6. **What are the factors that influenced the students' choice of teaching as a career?**
   The study will seek the reasons for students going to Colleges of Education: Firstly, whether or not it was their first career choice; if not what

alternatives they would have chosen; the influence of their parents and teachers; and other factors that may have had an influence.

7. **What is the extent of the students' commitment to teaching?**
   This question will investigate the commitment of the students to teaching by ascertaining the length of time they intend teaching science.

8. **Based on the students' performance and their profile, what recommendations can be made for preservice science education at Colleges of Education in South Africa?**
   This question will be addressed at the end of this study and attempts to make contributions concerning: student intake; current science education policy preparing students adequately for higher education; and a vision for policy development of teacher education.

1.3. IMPORTANCE OF THE STUDY

A survey conducted in 1992/1993 by the author and a colleague in sub-Saharan Africa (Howie and Wedepohl, 1993) investigated science teacher education provided by Colleges of Education and compared science teacher education systems. That survey highlighted a number of problems within the Colleges of Education in South Africa. The most prominent issues emerging from it were the following:

- "the average quality of candidate specialist science teachers who enrol at Colleges of Education is below that required to produce science teachers who will be both competent and confident in the classroom."
- "science lecturers at Colleges of Education have been ignored and neglected for many years in comparison with other members of the educational sector and therefore feel isolated."

- "scarce human and physical resources in Colleges of Education." (Howie and Wedepohl, 1993:6-7)

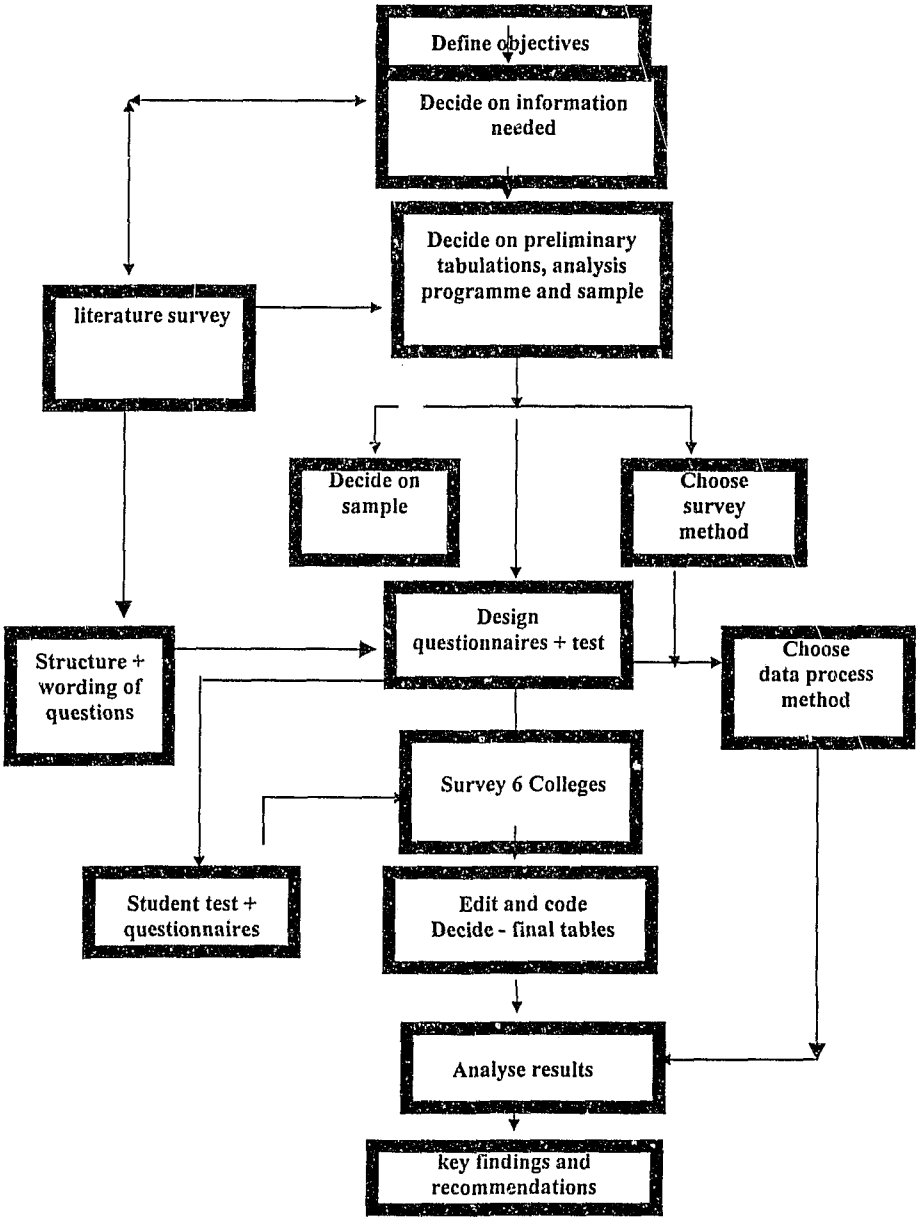
Although these findings related partly to all the colleges visited, all three factors were prevalent at the historically black Colleges of Education in South Africa. A common concern at most of the colleges visited was the increasingly poor quality of the students entering the science courses at these Colleges of Education. This was not only with reference to their attitudes to their courses and to teaching as a career, but also the fact that there were increasing numbers of students entering the colleges with very low matric symbols and seemingly little knowledge of physical science. In most cases there was evidence that the students were entering the colleges with E-symbols and below (less than 50%) in their final physical science matriculation exam. If one looks at the role of knowledge in teacher development, Shulman (1986) suggests that teacher's content knowledge (from which develops his theory of pedagogical content knowledge) is the most important element out of the sources of knowledge that can be identified.

Given the situation regarding the poor performance in Grade 12 physical science (the assessment of which is based on the content knowledge realm) nationally, the survey done at the Colleges of Education (Howie and Wedepohl, 1993) and the issue of suitable candidates entering the colleges, it was decided that the focus of this study should be on the issue of science content knowledge (discipline knowledge source) with regard to students entering first year science courses at historically black Colleges of Education and the secondary part being some of the factors influencing this content knowledge.

1.4. PLAN OF THE STUDY

The following flow diagram gives an overview of the study.

Figure 1.2 Framework of the research



1.5. OVERVIEW OF THE DISSERTATION

In chapter 1, the background to the study has been presented and discussed. In this chapter, the core problem was identified and the hypotheses stated. The key research questions were stated and explained in detail.

In Chapter 2, an overview of the literature is discussed. A review of the history and current status of the problem is discussed including a critical review of the previous investigations in this area. The detail of the literature review will be incorporated into Chapters 3, 4, 5 and 6 where appropriate, to substantiate decisions made in the study or substantiate conclusions drawn from the research findings.

In Chapter 3, the research design of the study is discussed, including the sampling, survey methodology and an overview of the test instruments and questionnaires is described.

In Chapter 4, the details concerning the design and development of the physical science achievement test, as well as, are given.

In Chapter 5, the results of the tests and findings of the questionnaires are described, analysed and discussed.

Finally, the key findings of the study and the recommendations are presented in Chapter 6.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

The literature search was conducted using the databases of ERIC, SABINET, PSYCLIT, URICA and STAR. This search initially turned up more than 15 000 references to Teacher Education and science, however, very few of these *focused on preservice science teacher education.*

The following search terms were used to narrow down the literature search:

- preservice science teacher education or preservice teacher training or initial teacher training or initial teacher education;
- preservice teacher training in developing countries or preservice teacher training in Africa.

These terms identified above were used in conjunction with the following:

- Science or physical science or chemistry or physics and;
- knowledge; misconceptions; concepts; attitudes;
- diagnostic testing;
- English second language and science and;
- students or pupils or student teachers.

In total the literature search was conducted four times, in 1994, 1995, 1997 and finally in 1998 to capture the updated references on the databases.

In this chapter, an overview of the literature related to the study is given. Firstly, the international perspectives on initial science teacher education are discussed, including reforms; policies; trends in developing countries; prerequisites for enrolment in science teacher education; and recruitment of science teacher trainees. Thereafter the literature on South African preservice science teacher education, including trends and policies in science teacher education in Colleges

of Education; and prerequisites for enrolment in Colleges of Education, is discussed. Finally, the last section concentrates on science knowledge and misconceptions studies, including a discussion of the literature on science concepts generally; physics concepts and misconceptions; chemistry concepts and misconceptions; and the role of language in science

2.2. INTERNATIONAL PERSPECTIVES ON INITIAL SCIENCE TEACHER EDUCATION

"Preservice Teacher Education refers to "*formally organised programmes to provide more knowledge and skills to prospective teachers in teacher education institutions and is usually one of a number of strategies to improve education in any country's' education system*" (Tatto, 1997: 405). The products of teacher education and the consequer products of the mainstream education system in different capacities determine what goes on in schools.

The term teacher education is also described in different ways in the literature. The equivalent terms found were initial teacher training and initial teacher education. First year students in teacher education institutions were also called by different names, these were: prospective teachers; candidate teachers; initial teacher trainees; student teachers and preservice students.

2.2.1. Literature on science teacher education

In the teacher education publications surveyed, there appear to be few studies looking specifically at the question of science in initial teacher education although the importance of science is widely acknowledged and most countries are concerned to some extent about their children's performance in science as well as the decline in the numbers taking science.

The scarcity of literature on preservice science education was remarked on by Lewin, (1992: 149-150) who said that "*Preservice education of science teachers is an under researched area.*" and *"there is a shortage, especially at the individual country level, of systematic attempts to trace the products of science teacher education through into the school and evaluate the adequacy or otherwise of their training.*" Furthermore he states that "*strategic issues such as, how many teachers are trained, what are their backgrounds and level of achievement in science are under researched questions (amongst others) in many developing countries and thus go unanswered whilst debates about training methods will therefore continue.*" Lewin also suggests that one of the pressing issues is to determine the cognitive capabilities of entrants to the teaching profession in order to identify misconceptions and misunderstandings of science among trainee teachers.

Some studies have been done in relation to preservice teachers in general, but not in relation to intending science teachers. The shortage of literature is further confirmed by Orion (1996: 578), who says that whilst *" the preservice teacher who comes to teacher training is a learner*", there is "*very little in ERIC in relation to prior beliefs and views of preservice secondary science teachers about science education and science teaching.*" He says that although some general understanding of preservice student teachers is available, there is a need for more intensive studies in the area of secondary preservice science education.

The literature reveals that there is considerable criticism of college preservice training programmes in many countries (Lewin, 1992). Many policy makers and educational critics believe that teacher education is ineffective (Ashton, 1996) and for instance, Singh (1986 in Lewin, 1992: 149), says of teacher training in Asia and the Pacific that " *the pre-service training of science teachers does not always match the demand of new curricula in terms of the needed teacher competencies*".

2.2.2. Reform in science teacher education

A large body of researchers believe that there is a gap in the recommendations of theories on teaching and learning, and a lack of implementation of these theories in practice. This gap is considered to be a crisis in science education globally and the recognition of this gap has resulted in many calls for reform in teacher education (Tatto, 1997; De Feiter et al 1998; Ashton, 1996). In many parts of the world, there is a serious concern about the shortcomings of existing pre-service science training programmes in "producing" science teachers to meet the requirements necessary for reform (Caillods, Gottelmann-Duret and Lewin, 1997). It is believed that it is essential to "*reform initial teacher education, in order to increase the supply of new teachers who are adequately prepared for the more demanding forms of (science) teaching required in the schools*" (De Feiter et al, 1998). Despite these calls, there is little improvement in the way that prospective teachers are trained (Tatto, 1997). Furthermore, Tatto (1997: 407) makes an important point that "*only rarely have teacher educators and teachers been permitted to participate in the dialogue that results in the construction of new curricula or other policies concerning teacher education.*"

Behind the calls for reform lies extensive public criticism of teachers from a number of sources. This arises according to Spencer (1996) from the low-status that teachers hold in our society. Teachers have endured a long history of criticism on many fronts. Cycles of reform have included demands for teachers' increased professionalism, through more advanced credentials, and adherence to standards. Simultaneously, teachers have been pressed to adopt innovations in their classrooms before these innovations have been evaluated. Teachers have been expected to accept and introduce blueprints for change, regardless of whether they might be workable in their own school context. Spencer defends teachers and claims that many calls for reform in teacher education promote

idealistic images of classrooms that are unrealistic and emphasises the pressures on teachers by describing the multiple roles they fulfil.

Internationally, faltering confidence in the teaching profession was caused firstly by a gradual disenchantment with the results of major structural reform in the early 1970s, secondly, by a lack of public confidence in the "muddled" vision of reform and, thirdly, by what appears to the tragic inability of the teaching profession itself to make plain to the public what it stood for. Teacher education is perceived as a major weakness. According to Eggleston (1995) among others, the pressure on the teacher training institutions and the whole practice of teacher training is immense.

2.2.3. Policies and trends in initial (science) teacher education

Lewin (1995:203) states that "*the developing world is littered with educational reform proposals that either have not been seriously implemented or that were overtaken by events before their effects were transparent*" and King (1994) warns against making universal prescriptions for higher education in different countries. Furthermore King feels that it is important to recognise that the diversity of countries' contexts and their circumstances critically influence the nature of policy analysis in higher education and that one should be cautious about generalising about higher education systems, their problems and strategies for addressing them.

The distinction between the developed and developing countries is particularly marked in pre-service teacher training. Beeby's (1966) classification in terms of stages in the growth of a primary school is useful to illustrate the differences between the developed and developing countries. The developed countries e.g. the United Kingdom and the United States of America would best be described by

Beeby's stage 4 called "Meaning". In this stage the teachers are well educated and well trained.

For most developing countries, Beeby's stage 1, 2 (and in some cases stage 3) describes the situation well. Stage 1 is called "Dame School" and the teachers in this stage are ill-educated and untrained. The curriculum is unorganised and relatively meaningless and the subject content very narrow as the 3R's (reading, writing and arithmetic) are considered all important. The standards are very low and the method of learning is memorising which is considered all-important. In Stage 2, ("Formalism"), the teachers are ill-educated but trained. Here learning is highly organised and the syllabus rigid with its emphasis on the 3 R's. Memorising is once again heavily stressed as is the use of a textbook. Stage 3 one could regard as the situation existing only the most developed of the developing countries and in the least developed of the developed countries. This stage Beeby refers to as "Transition" where the teachers are better educated and are trained. The learning goals are similar to stage 2, but are more efficiently achieved and there is more emphasis on meaning. The syllabus and the textbooks are less restrictive but the teachers are hesitant to use their greater freedom, probably as the final examination often restricts experimentation.

It would appear that in developed countries, decentralisation in governance is common although does not appear to occur in the rigid sense and still has some functions that are centrally controlled. Whereas, in the developing countries the opposite could be said to be true as education is largely centrally controlled with some functions being managed at a local level (Rideout and Ural, 1993).
Eggleston (1995: 449) summarised the key trends in teacher education in the developed countries of Western Europe, (which have much in common with developed countries outside Europe) as the following:

- huge growth in teacher education student numbers because of demographic changes

- moves to enhance status of teacher education by fuller incorporation into higher education institutions
- changing content of teacher education
- "*the realisation in that much, if not most, of the subject curriculum knowledge required by teachers in the upper secondary schools (and even by those teaching lower down the age ranges) could be achieved by teaching given in relevant subject departments of the universities rather than teacher education departments*".

Preservice science teacher training and consequently the qualifications of science teachers vary tremendously across the world. The British education system appears to have had a considerable impact on many parts of the world. The teacher training in the Commonwealth and eastern countries appears to have followed the British system, i.e.: that primary teachers are commonly trained in colleges (although this has changed in the United Kingdom and is the main difference to its ex-colonies). Furthermore, secondary teachers are trained at university either by the concurrent or the consecutive systems and thus become graduate teachers as opposed generally to the non-graduate primary teachers. Teacher qualifications vary to a large extent in Africa. Teachers may hold a certificate, a college diploma; a postgraduate diploma, an undergraduate degree in science or education or as it has also been widely reported across Africa, that large numbers of unqualified teachers are teaching science (Ware, 1992).

Hand in hand with the debate on graduate teachers, is a considerable tension about the academic and pedagogic knowledge of science teachers (and in teacher education generally). Lewin, (1992) states that it is important to know the subject matter, but also to be able to represent that knowledge to others. In most developing countries, teacher training is heavily content-orientated. In countries where entrants into science teacher training have low scores on school leaving examinations, understanding science will be a problem for prospective

teachers. Lewin states that where teaching is an unpopular choice of profession such low entry scores are not uncommon.

2.2.4. Trends in science teacher education in developing countries

Some developing countries still distinguish between two categories of teachers in secondary schools: lower secondary and upper secondary. Lower secondary teachers are often trained in 2-3 years after secondary school in regional pedagogical centres or teachers colleges (e.g.: Morocco, Thailand, Papua New Guinea, Senegal). Alternative routes exist and students can be offered one year of pedagogical training after two years at the university (e.g. Morocco, Senegal and Burkina Faso). Upper secondary teachers are trained in four to five years after secondary school in teachers colleges (e.g.: Morocco recently and Thailand) and teacher training institutes (for example Argentina, Chile). An increasing number of countries have moved to training secondary science teachers through programmes combining pedagogical training with a science degree course (3-4 years of study in a Faculty of Science) or through a one year postgraduate teacher training course after obtaining a science degree (Caillods, Gottelmann-Duret and Lewin, 1997).

Avalos (1995) concludes that faculties of science are, in most countries, the place where secondary teachers can acquire the highest possible level of subject knowledge. However Avalos has reservations about the programmes in that they may not offer important topics (e.g. integrated science). Moreover he concludes that they are not geared towards the special needs of prospective science teachers and such courses do not generally teach how to teach science. He states that pedagogical universities or teachers college seem to be better positioned to tailor their programmes to the specific needs of science teacher training and also to respond to possible curriculum changes. However he notes that their programmes tend to be dominated by pedagogical procedures at the

expense of the provision of quality subject matter knowledge. Many science education specialists maintain that the science knowledge component of teacher training should be offered in the Faculties of Science and that only some complementary pedagogical training in Faculties of Education should be given. They (including Eggleston as mentioned previously) further feel that this is preferential to teacher training colleges as it is a less costly option (Caillods, Gottelmann-Duret and Lewin, 1997).

De Feiter, Vonk and van den Akker (1995) found that science teacher training programmes in Southern Africa had considerable problems - common to many developing countries. The programmes did not attract enough students with adequate qualifications and therefore the output of science teachers (and scientists) was far below the needs of national economies and educational systems. They claimed that the major cause for this inadequate number of entrants into tertiary science streams was the quality of science learned in the secondary schools. They developed a model which reflected the vicious cycle through the following causal chain: few properly qualified science teachers in schools resulted in many science classes being taught by unqualified, underqualified or expatriate teachers on contract. Alternatively, schools offered only limited science options insufficient as preparation for tertiary studies that led to poor quality and low output of secondary science education. Consequently, few students entered tertiary science streams leading to few newly trained science teachers, particularly serious as the secondary school system was expanding rapidly. To try to break this chain, these researchers were part of a team that established one of the inter-university co-operation programmes between the Dutch and the BOLESWA (Botswana, Lesotho and Swaziland) countries which was to introduce bridging courses between school and university.

These researchers found that in science education in these BOLESWA countries:

- there was insufficient confidence and mastery by many teachers of science subject content and basic teaching skills (like questioning);
- there were language problems for both teachers and students in the teaching and learning of science;
- there was a disjuncture between school science often Western -based curricula and textbooks (if available) and African life outside the school environment;
- there was a tension between African culture (e.g.: values about the relation between adults and children) and the spirit of inquiry and critical questioning required in school science;
- there were poor materials and/or facilities (e.g.: equipment) in schools and classrooms;
- there was a weak alignment of innovative curricular aims and typical assessment and examination practices.

2.2.5. Prerequisites for Entrance to Teacher Training Institutions

The literature indicates that a variety of different criteria are used to gain entry into pre-service programmes. Most countries, including South Africa, rely on some form of secondary school results for selection to pre-service teacher institutions. Some countries like Japan (Sato and Ushiwata, 1990) have entrance exams to these institutions. Canada has an unusual problem as their pool of candidates has improved academically and professionally and it is difficult to gain entrance to teacher education institutions. An average of 80% is required to gain entry to some of the Canadian colleges/institutions (Wideen and Holborn, 1990).

Zimbabwe is another example of a growing pool of potential candidates of improved overall academic quality wishing to gain entrance into colleges of education. Here too, for some institutions "B" symbols achieved for "O" level examinations are required and sometimes straight A symbols are necessary

(Howie and Wedepohl, 1993). With a fast growing primary and secondary expansion in education, many teachers are needed but simultaneously, the pool for prospective teachers has expanded. With only two universities and a small number of colleges, competition is fierce.

The USA situation is also competitive and it is also difficult to get into the teacher training courses. In their case, 99% of all teachers have at least bachelor degrees. A high school diploma is a prerequisite for entrance into the university courses, although prospective teachers are often also required to write an entrance exam (Rideout and Ural, 1993).

Differentiation in most countries takes place between the prerequisites for primary teaching as opposed to those for secondary teaching. In India, to enter into pre-service primary courses, a candidate must have passed the higher secondary school certificate at the end of class 12. However indications are that some states take those with only a class 10 pass. Teaching training for secondary school teaching is quite different, with a class 12 pass to gain entrance to a university to study a bachelors degree usually followed by a one year teachers training course. However, there are also exceptions, a graduate with a masters degree is considered qualified to teach and is not required to undergo a teacher training course (Rideout and Ural, 1993).

In Namibia there used to be a large discrepancy between the prerequisites for entering into the different training courses. To enter the Lower Primary Teachers Course, a pass in Std 5 was needed (until it was phased out in the mid-1980's), whilst Std 8 was required for the Primary Teachers course and Std 10 for the Junior Secondary Course. A recommendation has been made for Std 10 to be the minimum requirement for primary teacher training and all the courses are currently under review. (Rideout and Ural, 1993)

The difference in the prerequisites is once again illustrated by the situation in Mexico. Candidates for pre-primary and primary teaching can enter training after obtaining their secondary school certificate. There are schools/colleges for training these teachers who follow a 3 or sometimes 4 year programme combining general and educational studies. However, for secondary school training, a secondary school leaving diploma is required and thereafter they follow a 4 year course (Rideout and Ural, 1993).

In Malaysia's system, although it has been influenced by the British system, the majority of teachers are non-graduates from the teacher training colleges. Graduate secondary teachers are in the minority of teachers trained and there are almost no graduate primary teachers (Rideout and Ural, 1993). However, in recent years this picture is changing rapidly as Malaysia moves towards graduate secondary science teachers.

2.2.6. Recruitment into initial science teacher training

Different countries have tried to solve the recruitment problem in different ways. Here are a couple of examples: Pakistan introduced special teaching contracts with stipends to science graduates and a special monthly allowance (Ware, 1992). Botswana pays science teachers more than teachers of other subjects (Howie and Wedepohl, 1993). Kenya pays its science teachers a special allowance (Howie and Wedepohl, 1993) and has also lowered the minimum score for admission in order to attract students into science education.

There have been reductions in recruitment and rigorous profiling of the numbers admitted to training in Europe. For instance, in the UK by the 1990s, the government had become very concerned about recruitment and training of primary school teachers, and teacher training became target for radical reform. The reform of teacher education, which occurred between the mid-1980s, was

part of the educational reforms being focused on raising educational standards (Hoyle and John 1998).

The UK government was also concerned about decreasing numbers of students leaving school with science subjects and more students lacking interest in science (Huggins, 1994). Shortages of science teachers have been a consistent feature of the UK education system. In more recent years, a number of initiatives have been attempted to increase the supply of teacher trainees in science, which have met with little success (POST, 1996).

The Pacific-rim countries appear to be experiencing the typical problems experienced by developing countries and developed countries, i.e.: the shortage of candidates with adequate academic backgrounds and the unpopularity of the teaching profession. These in turn facilitate the vicious circle of affecting the quality of the teachers produced.

Likewise, most African countries seem to be characterised by problems of inadequate supply of qualified applicants (into teacher training), and the output of trained teachers is insufficient to meet the demand from the secondary school system (Ndawi, 1997). Ndawi quotes examples from Zimbabwe, Malawi, Tanzania, Ghana and Namibia, each of whom have different approaches for coping with the sudden expansion of education in Africa. Ware (1992) quotes the example of Zambia where the awareness of the problems in teaching in general has resulted in that teaching profession becoming more professional, more highly motivated and more confident of its ability to master the adverse working conditions. This has been attributed to an organisation run by the Zambian teachers "for teachers, by teachers" and has been instrumental in raising the morale and professional awareness of teachers.

Attracting a sufficient number of good science graduates into the teaching profession remains a serious problem where alternative career opportunities

exist. In order to improve the quality of the entrants some countries are very selective, e.g.: Morocco, where admission to a teachers College and to the regional centres is also conditional on the students' success in an entrance examination.

The research of Stewart and Klair (1996) confirmed earlier findings that there are problems in recruiting adequate numbers of physics teachers due to several personality factors. They suggest that to recruit more physics teachers, it will be necessary to attract more females into physics courses; to make a more positive attempt to advertise the merits of a teaching career in physics and to try and interest students in gaining experience of working with young people.

Ware, (1992) claims that the recruitment of students into science teaching depends on two important factors: the actual and perceived rewards of teaching and their opportunities for or access to employment in other professions. For scientifically gifted students the main consideration is the latter factor. The choice of science teaching is often the fall-back position of science students as teaching has the lowest status of the science-related professions.

The truth is that in many developing countries, working conditions are difficult and do not inspire the better students to enter teaching. Across developing countries, the number of teachers trained in science continues to decline in relative terms. Drastic measures are being taken to attract more students into science teaching. In some countries it is not necessary to succeed in any examination to enter the science teacher training colleges (e.g. Thailand) and teachers who are trained by these institutions are chosen less selectively (Caillods, Gottelmann-Duret and Lewin, 1997). This less than desirable situation cannot be readily resolved unless the status of the teaching profession in the developing countries (and to some extent in developed countries) is improved together with the profession's working conditions.

2.3. INITIAL SCIENCE TEACHER EDUCATION IN SOUTH AFRICA

There were 20 universities, a couple of technikons and more than a 100 colleges of education in South Africa offering teacher training courses up to 1995. Colleges of Education in South Africa have always played a Cinderella role in the hierarchy of tertiary education and in the field of science teacher education. Most of these Colleges, offer diplomas in primary education and secondary education. However, science teacher training has suffered at college level, as many colleges are unable to offer science in the secondary course.

Due to the apartheid policy the colleges developed at different levels according to race group (white, Indian, coloured and African). Their development was determined by the facilities, equipment and the staff, the quality of which varied vastly depending on how the various criteria for employment were interpreted and enforced (NEPI Teacher Education, 1992). Science courses at some colleges (especially those of the House of Representatives and many of the historically black colleges) were phased in the late eighties and early nineties. Often these colleges had neither the staff to teach the subject nor the equipment and facilities.

Very little information is available from the literature on Colleges of Education in South Africa. However, largely because of the political transformation process, various agencies have been investigating primary and secondary education. Some of the studies conducted also touched on teacher education. Both the National Education Policy Investigation (1994) document on teacher education and the Education Renewal Strategy (1991) looked at pre-service teacher education in South Africa and made recommendations for proposed changes.

Since 1995, a few key documents on teacher education (PRESET and INSET) have been published, although there is still a dearth of information and research on

preservice science education in Colleges of Education specifically. Few comparative studies exist of pre-service teacher education between South Africa and other countries. In addition the theses in which these studies are reported are more than 10 years old. Mathivha, (1981) conducted a study on teacher training in South Africa and Malawi during the decade 1964 to 1974. Le Roux wrote in 1980 on the autonomy of colleges of education which was a historico-comparative doctoral thesis. Prior to 1995, it would appear that while general aspects and systems of teacher education have been touched upon, virtually nothing was documented/published regarding either pre-service science training or colleges of education.

One of the most important documents on teacher education in South Africa to have emerged since 1994 was the National Teacher Education Audit, published in 1995 (Hofmeyr and Hall, 1995). The objective of this audit was to analyse teacher demand, supply, utilisation and costs; and to evaluate teacher education institutions, including the Colleges of Education. Although important, the audit suffered from severe time constraints and a lack of reliable and comparative data on teachers. However, it is to *date "the most comprehensive set of data on teacher supply, utilisation and development"* (Hofmeyr, 1996: 4). The audit found that the *"quality of pre-service training is generally poor; that there are huge disparities across institutions, that the present system of teacher education is inefficient; present policies of teacher supply, utilisation and development are underpinned by inadequate concepts and driven by wrong incentives; and that system reconstruction is essential"* (by this it is meant that the severe nature of the problems would not benefit from mere minor modifications, but required rather wider-ranging system-level changes). A direct result of this Audit was that the Council of Education Ministers in October 1995 "*decided to limit the intake of students into the Colleges and to redirect the bursary system towards scarce subjects in 1996*" (Hofmeyr, 1996: 4). These scarce subjects included physical science.

What is interesting to observe is that the Committee on Teacher Education Policy (COTEP) document on norms, standards and governance was published in July 1995, about 18 months prior to the National Teacher Audit (December, 1996). Hence, it was not underpinned by this investigation.

2.3.1. Trends and policies in Science Teacher Education in Colleges of Education

According to the NEPI report on teacher education (1992), there were 14 different certificates and diplomas offered in 1991 by the more than 100 colleges of education in South Africa. Of these, the majority catered for African students and they followed the syllabus of the Department of Education and Training (even those in the homelands, with the exception of Bophuthatswana and Transkei). The colleges have come under much criticism in South Africa and the NEPI report referred to them being isolated from debate on professional and academic matters; many of them prior to 1992 were small and insufficient; very few were cost-effective and academic development was considered very difficult in the colleges. There was no tradition of research in the colleges and there was no expectation of lecturers to engage in research. In general, the facilities for research do not exist and those lecturers motivated to do research are often those whose timetables and lecturing load do not allow for it.

The trend in South Africa in the applicant profile of aspirant teachers to colleges of education has changed quite radically over the last 20 years. There has been a sharp decline in the number of white students applying to the colleges, largely due to the poor prospects of employment in teaching as well as the lack of encouragement and support in the education system by the education authorities (Sieborger and Kenyon, 1992).

The historically white colleges traditionally had the highest degree of autonomy amongst the colleges and all these colleges had agreements with universities to

facilitate movement between the colleges and universities for students. The historically Indian colleges had almost the same amount of autonomy as the white colleges but still had to negotiate movement of students from the college to the university. The historically coloured colleges were held under a tight rein by the House of Representatives (the governing body). Very little, if any, autonomy existed. There was no co-operation between the 13 colleges and the universities. Likewise the African colleges, like the coloured colleges had virtually no autonomy or power.

Surveys (Howie and Wedepohl, 1993; Arnott et al, 1997) have found that Colleges of Education are under resourced in terms of staff, facilities and equipment. Furthermore, these Colleges have been isolated from other higher education institutions in most cases resulting in the lack of an academic environment in these institutions. Although, it must be said that in Transkei and Bophutatswana as well as for a couple of the former white Colleges, formal linkages were established with local universities (Kaya and Mabetoa, 1997) in attempt to strengthen the development of the curricula and provide academic support for the colleges.

Arnott et al (1997) reported that there is still little evidence of true innovation or research in science education at these colleges. They also reported that the lecturer morale was low due to the flux in the College system and the restructuring of this sector. Despite the fact that in general the science lecturers' academic qualifications have improved (most science lecturers had science degrees), a worrying finding was the lack of school teaching experience by the lecturers at several of the Colleges.

As a result of past policies and neglect, there is currently an insufficient supply of (qualified) physical science and general science teachers (Kahn 1993, FRD, 1996). Although most science teachers have professional qualifications, less than half have accredited training in the subject they are teaching, meaning that for instance qualified geography teachers may be teaching physical science for which

they have no qualification (Arnott et al, 1997: 1). Fewer than 42% of science teachers have at least one year of specialised training in science. The majority of these science teachers received their training at Colleges of Education (only 25% of qualified science teachers have degrees). About 40% of the science teachers have fewer than two years' teaching experience (Arnott et al, 1997: 1). All of these facts result in the low numbers of qualified physical and general science teachers in South Africa.

2.3.2. Prerequisites for Entrance to South African Colleges of Education

South African Colleges of Education do not produce teachers of quality but that this is because they struggle to attract academically talented and committed students (NEPI, 1992). The current debate blames this on the low entrance requirements of the colleges. The colleges only require a senior certificate with higher grade in those subjects that the student intends to pursue as majors in college, and one additional higher grade subject. In South Africa, matriculation results are the main criteria for selection at colleges. However, the Human Sciences Research Council (HSRC) reported that almost 30 colleges are using the HSRC developed tests to assist college personnel in the selection of students. They state that preliminary research shows that the results play an extremely important role in assisting the selection of the best candidates for the teaching profession. These tests are aimed at providing information on the general ability, differential mental aptitudes, interests and attitudes towards study and education (Landman, 1994).

Initially, colleges accepted students with a Std 6 (Grade 8) certificate. Their two year certificate corresponded to a junior certificate. Later the entry level became the junior certificate (Grade 10), with the teacher's certificate corresponding to a senior certificate (Grade 12). Until 1992, this was still the case for most primary

teachers in the Bantu Education system. The next stage was a 2-year post senior certificate teacher's certificate which in turn became the 3 year diploma. Soon afterwards some colleges introduced the 4-year diploma, which is the norm in some departments of education. It was only in the early 1980's that the Department of Education and Training introduced the first 3-year post senior certificate diploma for both primary and secondary school teachers.

Control over the admission of students to initial teacher-training institutions is a complex issue, which in the past was further complicated by apartheid policies. Traditionally there was a complete lack of co-ordination of entrance requirements to teacher training. Each of the previous education departments actually specified whom the colleges could train as teachers and in what subjects, with little coherence on a national level. The issue concerning the quality of the candidate teachers was often overlooked. No screening was carried out to ascertain whether or not the student demonstrated an inclination towards working with children and the youth. Amongst the communities, teacher education was often seen as the easy route to upward mobility (Sieborger and Kenyon, 1992), although more recently this perception is changing. Nevertheless, it is still often seen to be the only opportunity for further education.

The COTEP document (1995) proposes changes to the admission policy for teacher education. The minimum admission requirements for **all** initial teacher education programmes are the following: a senior certificate including passes in two official languages; language of instruction for the teacher education institution must have been passed at second language higher grade level or first language standard grade level; three subjects passed on the higher grade (which may include the languages). The alternative prerequisites for candidates who are an un- or under-qualified teacher without a Senior certificate may be admitted to further training if they have five years teaching experience and they complete a series of tests successfully. These tests include language proficiency, mathematical proficiency and a test of cognitive development.

2.4 SCIENCE KNOWLEDGE AND MISCONCEPTIONS STUDIES

Schulman (1986) builds his foundation for teaching reform on an idea of teaching that emphasises comprehension and reasoning, transformation and reflection and discusses the notion of the knowledge base for teaching. The actions of policy makers and teacher educators, according to Schulman, have been consistent with the formulation that teaching requires basic skills, content knowledge and general pedagogical skills. One of the areas of knowledge Schulman (1986) discusses is the importance of content knowledge. *"Teaching is essentially, a learned profession. A teacher is a member of a scholarly community. He or she must understand the structures of subject matter, the principles of conceptual organisation, and the principles of inquiry that help answer two kinds of questions: What are the important ideas and skills in this domain? and how are new ideas added and deficient ones dropped by those who produce knowledge in this area"* He goes on to state that "*this view of the sources of content knowledge necessarily implies that teachers must have not only depth of understanding with respect to the particular subjects taught, but also a broad liberal education that serve as a framework for new understanding. The teacher has special responsibilities in relation to content knowledge, serving as the primary source of student understanding of subject matter.*" Furthermore, Schulman feels that " *In the face of student diversity, the teacher must have a flexible and multi-faceted comprehension, adequate to impart alternative explanations of the same concepts or principles. The teacher also communicates, whether consciously or not, ideas about the ways in which "truth" is determined in a field and a set of attitudes and values that markedly influence student understanding. This responsibility places special demands on the teacher's own depth of understanding of the structures of the subject matter, as well as on the teacher's attitudes toward and enthusiasms for what is being taught and learned. These many aspects of content knowledge, therefore, are properly understood as a central feature of the knowledge base of teaching.*" (1986:5)

Having clearly established the importance of the teacher's knowledge base, Schulman (1986:7) also makes the point that this *"knowledge base is not fixed and final"*. In attempting to understand the transition from a student teacher trainee/ learner to a teacher, he explains that this transition involves the teacher trainee commuting from "*being able to comprehend subject matter for themselves, to becoming able to elucidate subject matter in new ways, reorganise and partition it, clothe it in activities and emotion, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students*"

Fenstermacher (1978) argues that the goal of teacher education is not to indoctrinate or train teachers to behave in prescribed ways, but to educate teachers to reason soundly about their teaching as well as to perform skilfully. This requires both a process of thinking about what they are doing as well as an adequate base of facts, principles and experiences from which to reason (Schulman, 1986). Having argued the importance of content knowledge, Schulman also described what he called pedagogical content knowledge that he claims is unique to teachers. This is grounded in the importance of good content knowledge as it is to " *understand what a pupil understands will require a deep grasp of both the material (content) to be taught and the processes of learning. This understanding must be specific to particular school subjects and to individual topics within the subject*" (1986:7).

2.4.1. Science concepts

Marcelo (1987 in Mellado 1998:197) attributes the changing paradigm of research on teachers from *"technical rationality to one of teacher thinking"* as a consequence of Schulman's work on pedagogical content knowledge. From the constructivists' perspective science teachers are considered to have inherited deeply seated scientific concepts (from their school days) of the nature of science and the way to teach and learn it (Hewson and Hewson, 1989).

Many researchers claim that when prospective teachers begin their teacher education science courses, they have ideas, conceptions and attitudes about science teaching and learning (Shaw and Cronin-Jones, 1989; Briscoe, 1991; Gunstone, Slattery, Blair and Northfield, 1993; and Gustafson and Rowell, 1995) as well as their conceptions of science knowledge (Hewson and Hewson, 1989; Bendall and Goldberg 1993; Bitner 1992; Ginns and Watters, 1995). Therefore these ideas, conceptions and attitudes influence their learning and the way they learn during their teacher training. Moreover, Aguirre and Haggerty (1995) found that these ideas, conceptions and attitudes did not change during their teacher education course.

A great deal of research has been published on misconceptions held by children, students and teachers in Solomon, 1993; Driver, 1983; Gilbert and Watts, 1983; Johnstone and Cassels, 1978; Sadler, 1998; Weaver, 1998; Thijs and van den Berg, 1995; Woolnough, 1997a; Bitner, 1992; Blosser, 1987; Ginns and Watters, 1995; Newton and Driver, 1997; Rollnick, 1988. These misconceptions are also described by various researchers as alternative ideas, preconceptions, children's science (Gilbert and Watts, 1983) and alternative frameworks. Students often have concepts of the natural world which are different to those of scientists. Over a wide range of students these alternative ideas are consistent and these ideas are resistant to change when exposed to traditional methods of instruction (Watts, 1983; Finegold and Gorsky, 1991).

Ginns and Watters (1995:205) investigated the intuitive scientific ideas and understanding of 321 preservice teacher education students in their second year. They argue that "*teachers should have a sound conceptual knowledge base in order to implement effective problem-solving strategies in the elementary science classroom. The importance of teaching science in elementary school is widely acknowledged, therefore teacher educators must identify and implement more effective strategies for science instruction in preservice teacher education*

courses that will enable all students to construct scientifically accurate concept knowledge."

Furthermore they felt that "*teachers who have misunderstandings will have greater difficulty identifying and correcting elementary students' misunderstandings, thus hindering the development of scientifically literate citizens capable of making important decisions concerning society and the environment. It is therefore important to investigate preservice elementary teachers understanding of basic science concepts.*" (Ginns and Watters, 1995:219)

Ginns and Watters claim that "many prospective elementary teachers demonstrate a range of inaccurate scientific concepts in the areas of science that form important components of the elementary science curriculum." This claim coincides with those of Tilgner (1990) that many elementary school teachers have an understanding of scientific concepts that is not much different from that of the pupils whom they are teaching. These findings are supported by Lawrenz (1986), Crawley and Arditzoglou (1988) and Bitner (1991) who have discovered that a large number of elementary school teachers and preservice teachers have misconceptions about a number of basic physical science concepts. For instance, more than half of the elementary teachers who were tested by Lawrenz (1986) had misunderstandings, no understanding or were confused about the questions asked (about mass, motion, electromagnetic phenomena, electricity and light).

To be effective, elementary school teachers must have a sound content knowledge base and correct ideas about fundamental concepts in science (Claxton (1992), Tilgner (1990) and Lawrenz (1986)). However, preservice teachers exhibit a number of misunderstandings, are familiar with the scientific terminology but yet tend to have a superficial understanding of the underlying processes and concepts inherent in the items (Crawley and Arditzoglou, 1988).

Prospective teachers with a limited background in physical science and low reasoning ability may not be able to plan and implement effective science programmes (Garnett and Tobin, 1984).

Inadequate teacher background in science is one of three major obstacles to teaching referred to by elementary teachers (Tilgner, 1990). Teachers believing in their own abilities will teach science well and this belief is dependent on their own successful experiences with conceptual knowledge and/or problem solving (Linn, Clement, Pulos and Sullivan, 1989).

2.4.2. The nature of science

Science for All Americans declares that an understanding of the nature of science is one criterion of scientific literacy (Abell and Smith,1992) and there are many studies focusing on examining the secondary science teacher views (through a multiple-choice instrument) of the nature of science (Akindehin, 1988; Billeh and Hasan, 1975; Collins, 1986; Kouladis and Ogborn, 1989; Lederman, 1986; Lederman and Zeidler, 1987; Wavering, 1990).

It would appear that many science teachers also misunderstand and misrepresent the nature of science (Benson, 1989; Hodson, 1988). Furthermore, the science teachers' views of the nature of science can influence their students' conceptions of science (Wolfe 1989 and Zeidler and Lerderman 1987.

Other researchers examined preservice elementary teachers' conceptions using open-ended questionnaires and analysing their written responses to questions about the nature of science (Bloom, 1989 and Abell and Smith, 1992) with similar results.

Due to the migration in the world today, almost every science classroom can be considered to have a multicultural population to some extent, especially in the urban Western classrooms (Krugly-Smolska, 1992). In the context of a Science, Technology and Society interaction perspective, the history of science in other cultures is an important aspect, for much of Western science is built on foundations established in other contexts. To observe how certain problems are approached and solved in other cultures may offer alternate solutions to our own present day Science, Technology and Society dilemmas. Krugly-Smolska's conclusion was that the search for knowledge should not be divorced from the context of the everyday and should be available to a wide segment of the population.

2.4.3. Physics concepts and misconceptions

There are many international studies that have found extensive conceptual difficulties across physics. In particular Newtonian mechanics has been well researched (McDermott, 1984; Trowbridge and McDermott, 1981; Govender, 1998). Studies by Helm (1980) report that certain misconceptions in physics are shared by pupils, students and some teachers. Several studies have shown that students have difficulty with the concepts velocity and displacement, among others (Peters, 1992; Champagne et al, 1980; and Trowbridge and McDermott, 1981).

In studies of student teachers' misconceptions of physics, Bendall and Goldberg (1993) report that they found few investigations of preservice elementary students' prior knowledge of light although there were many studies involving other groups of students. Walsh et al (1993) felt that it is important that students of physics develop both quantitative and qualitative understanding of physical concepts and principles. Although accuracy and reliability in solving quantitative problems is necessary, a qualitative understanding is required in applying concepts and principles to new problems and real-life situations (Walsh et al, 1993).

Earlier in 1981, Clement showed that students who are adept at using mathematics equations in the solution of physics problems are not necessarily able to demonstrate understanding of the underlying physics concepts and are not able to provide physical interpretations of the solution. The main point that Walsh et al (1993); Clement (1981); and Lindner and Erikson (1989) make, is that their research has shown that although students' understanding of mathematical procedures is necessary to learn physics, it is not sufficient.

2.4.4. Chemistry concepts and misconceptions

Students conceptions and chemical phenomena have been widely researched (Duit, 1993; Driver et al, 1994; Pfundt, 1981, Ahtee and Varjola, 1998; Boo, 1998; Ben-Zvi and Genut, 1998; Abraham, Grzybowski, Renner and Marek (1992); Garnett and Treagust, 1992a; Garnett and Treagust, 1992b; Hesse, 1992; Lee and Fensham, 1996; and Zoller, 1990). However, none of these studies focused on preservice students in particular.

Zoller (1990:1063) attributed freshman chemistry students' difficulties to "*the many abstract, nonintuitive concepts which are not based on, and /or derived from, and/or interrelated logically with one another, at least not in a simple and straightforward sense*".

Abraham et al (1992) found that 66% of the responses to the test items in five chemistry topics presented to eighth grade American students they had tested, indicated that students either had no understanding or had developed specific misconceptions of these concepts. However, with the periodicity concepts they found that there were very few misconceptions and students either showed understanding or had no idea. What concerned these researchers was that the concepts tested were central to any beginning study of chemistry.

According to Abraham et al (1992), chemistry is dependent on a single central model - the atomic model. The concepts associated with atoms and the actions of atoms are used in almost all explanations of chemical phenomena. However, the literature is filled with evidence concerning the lack of understanding of the atomic models as well as examples of misconceptions about the nature of atoms and molecules (Andersson, 1986; Novick and Nussbaum, 1981; and Gabel, Samuel and Hunn, 1987). The consequence of the lack of understanding and misconceptions, is an avoidance of using atoms and molecules when explaining chemical phenomena. However, because the atomic model is so central to understanding chemical phenomena, scientifically satisfactory explanations are difficult, if not impossible, without the atomic model. Ahtee and Varojola's (1998) research on first year chemistry students revealed that students had problems in the usage of terms "*substance*" and "*atom*" and very few students were able to describe properly the meaning of chemical reaction. This is supported by the research done by Abraham et al (1992) on 11th and 12th grade students.

2.4.5. Language and Science

The role of language is an important one when discussing science education. In South Africa and many other developing countries, the influence of second language learning in science is of particular importance. Many studies have been conducted in developed countries as more immigrants enter these countries, (e.g.USA and UK) and these have been reported in studies by Vandrick, Messerschimtt and Hafernik, (1996) amongst others. However, fewer studies have been conducted in developing countries (Reinhard, 1996; Rollnick and Rutherford, 1993; and Hameso, 1997).

Rollnick and Rutherford (1993) reported that the results of studies on Third World countries, produced conflicting findings and some researchers argued for using mother tongue instruction whilst others suggested the use of a second language only. Rollnick and Rutherford's study, conducted amongst Swaziland primary teacher trainees, investigating the use of mixed language, concluded that the use of a "*mixed language strategy* (both mother tongue and second language instruction*) was the most effective in alleviating misconception, but not necessarily in replacing them with scientific conceptions"* (1993:363).

The issue of language and instruction in science is a contentious one in Africa (Kulemeka, 1994). The majority of children in Africa (contrary to many countries in Asia and Latin-America) are taught in a foreign language (second language English or French), a hangover of former colonial powers (Reinhard, 1996). Students usually make the transition from mother tongue instruction to a second language instruction in their primary schooling (between Grade 5-7, depending on the country). Seldom is an indigenous language prescribed, an exception being Tanzania and Zanzibar where KiSwahili is the medium of instruction in schools (Ross, 1998). Kulemeka (1994:73) concluded "*one of the most important goals in education is that pupils utilise the knowledge they acquire in school in solving problems in their own lives. By teaching subjects in a language*

which pupils use in their home environment we will be able to make an immediate connection between classroom knowledge and its application at home".

As appealing as that sounds, the choice of the language of instruction is often a political decision and not an educational one. The whole issue of language in the instruction of physical science in secondary schools, where major international scientific languages are not the home language, has long been debated (Caillods, Gottelmann and Lewin, 1997). The reality is that scientific research and technological applications are progressing rapidly and publications are presented in the languages of "metropolitan powers" and increasingly in English.

Caillods, Gottelmann and Lewin, (1997) found that pupils learned science more easily at school and performed better in science if the language of instruction and learning used was their mother tongue. However, with the majority of countries in Africa maintaining the usage of a non-indigenous language for science teaching there are also a number of disadvantages evident. For instance, Fuller et al (1994) found that in Botswana, pupils' achievement in science (and other subjects) was directly related to their proficiency in English. Eisenon (1992) found that tests conducted with Kenyan and Burundi pupils in their mother tongue produced higher performance levels and pupils performed poorly in their second language.

Morocco, in contrast, allows for science education in the mother tongue (Arabic) until the end of secondary schooling and then provides post-secondary science programmes in French, the predominant second language (Caillods, Gottelmann and Lewin, 1997).

An overview of the literature reveals that there are likely to be more problems with science learning where the medium of instruction is the second language. However, they are show an international language is

important for students pursuing a scientific or technological career and that the options for specific language policy for science education are greatly restrained by the fact that it is determined by the national policies on education.

2.5. CONCLUSION

Little reference could be found regarding the initial science teacher trainees' content knowledge of physical science and almost no information could be found with regard to South African College of Education students. It appeared from the literature that preservice education of science teachers was generally an under-researched area internationally and this is certainly the case in South Africa. Therefore only literature on initial teacher training generally could be found with separate studies concerning students' knowledge of physical science. This study was therefore an exploratory study with few studies to refer to directly for guidance.

CHAPTER 3 RESEARCH DESIGN

3.1. INTRODUCTION

Descriptive research involves *the "collection of data in order to test hypotheses/answer questions about the current status of the subject of the study*" (Gay, 1987: 189). One method of Descriptive research is the use of surveys. Surveys are used to gather data (such as attitudes, opinions, characteristics, demographic information, and academic achievement) at a particular point in time, *with the intention of describing the nature of existing conditions that can be compared, or determining the relationships that exist between specific events* (Cohen and Mannion, 1995: 83).

As this study's focus was to describe the status of students' knowledge of science at a certain point in time, and to test some hypotheses related to it, the survey methodology is appropriate. In particular, the aim of the study was to attempt to ascertain the level of the students' content knowledge regarding physical science on their entry into the college and secondly to identify factors that influenced their achievement in physical science. To obtain this information, the students completed both a knowledge test and a biographical questionnaire. To understand the context of the learning environment that these students were entering into, a questionnaire was also administered to the course lecturers at the college. As the intention was to survey the content knowledge of the students soon after their entry into the college, the test was administered in the first half of the college year.

In this chapter, the design of the research project is described. Firstly the population that was investigated and the sampling is discussed in 3.2. Thereafter, the instruments that were designed and used for this study are

described in 3.3. In 3.4 the procedures that were carried out in the project are given in detail and finally, in 3.5, the Data analysis that was undertaken for this research is described and discussed.

3.2. POPULATION AND SAMPLE

The population in the study was first year physical science students at former African Colleges of Education who had taken physical science in their final year of schooling. The sample selected was a non-probability-type sample, which was selected using a purposive method (Cohen and Mannion, 1995). The sample had to include both rural and peri-urban Colleges of Education; Colleges offering primary and secondary teachers diplomas; that were spread across three provinces; that were considered typical of the former African teacher training system of the Department of Education and Training; and that were convenient in terms of their accessibility.

From these criteria, a sample of first year science students at six Colleges of Education was selected in the Gauteng, Northern and North West Provinces in South Africa. A minimum of one hundred students was considered to be a sufficient sample in terms of size and six Colleges provided enough variation in nature to be typical of the identified population group. The size of the sample tested was decided by the number of first year students, within each college, who took physical science as a major subject. A further determinant of the sample was that all the students to be tested had to have taken physical science for matric. In all, 175 students were tested, however, 26 students were found not to have taken physical science for matric and therefore were removed from the sample to be analysed. In total, the results of 149 students were analysed. The number of secondary teachers' diploma students tested in this study (n = 107) represented 14% of the first year intake

into Colleges of Education of science students in South Africa during 1996.

All the colleges were formerly Department of Education and Training colleges, meaning that they were Colleges of Education formerly intended for African students. By far the vast majority of Colleges of Education in South Africa fall into this category. The former DET colleges in general were identified (Howie and Wedepohl, 1993) as amongst those having the most difficulty in attracting good quality students

The six colleges selected for this study were in both urban (including peri-urban/township) and rural areas. From the information gathered it was initially believed that at least two of the colleges were based in rural areas, however on the day of testing it was clear that one college was situated on the edge of a township which was closer to the peri-urban description. In all, five colleges were located in peri-urban areas and only one college could be classified as a rural college.

3.3. RESEARCH INSTRUMENTS

To answer the research questions, a number of instruments were administered to the sample of students and to their lecturers. The following instruments were designed and utilized:

3.3.1. Physical science achievement test

This test sampled the physical science achievement of the students. The test covered four topics, two from physics (namely velocity and electrostatics) and two from chemistry (oxidation-reduction and the periodic table). These were

selected from the judgments of College of Education lecturers that these topics are for most of their students the most difficult or the easiest topics in physics and chemistry. The test consisted of 20 questions; some of these comprised more than one part. There were five questions for each topic. The tests contained both open-ended type of questions and multiple-choice questions. The reliability of the test was 0.86, using the KR 21 test. Unfortunately the reliabilities of the subtests per topic were too low to use them as separate test for a more refined description and analysis of the knowledge and skills of the students. The development, construction, administration and scoring of the test will be discussed in section 4.1 (see appendix 3 for the achievement test)

3.3.2. Student questionnaire

All students were asked to complete a background questionnaire (see appendix 4) containing 28 questions. These pertained to their personal details (age, gender, language, location of home and school, education of parents); activities (extra-mural), subjects and achievements at school; their attitudes and those of their parents towards science and teaching; and finally questions regarding their confidence of their content knowledge.

The questionnaire was designed after reviewing other survey-type questionnaires. It was intended to be as short as possible, whilst providing a number of variables that could be analysed in relation to the students' achievement on the science test. The questions were both open-ended and alternate choice types.

3.3.3. College of Education Lecturers questionnaire

The science lecturers of the science class tested completed a background questionnaire containing 13 questions (see appendix 5). This questionnaire comprised questions regarding their personal details (age, gender and language), teaching and lecturing experience and qualifications, information pertaining to first year students, the difficulty of science topics and those topics that had been taught to their students during that year.

3.4. PROCEDURE

The conduct of the study comprised different phases, which are presented in Figure 3.1. As the researcher is not an expert in physical science a group of experts in this field had to be involved in the instrument development, as well as in the provision of model answers for the test questions to ensure the content validity of the test. Their involvement included (see Figure 3.1 and Table 3.1):

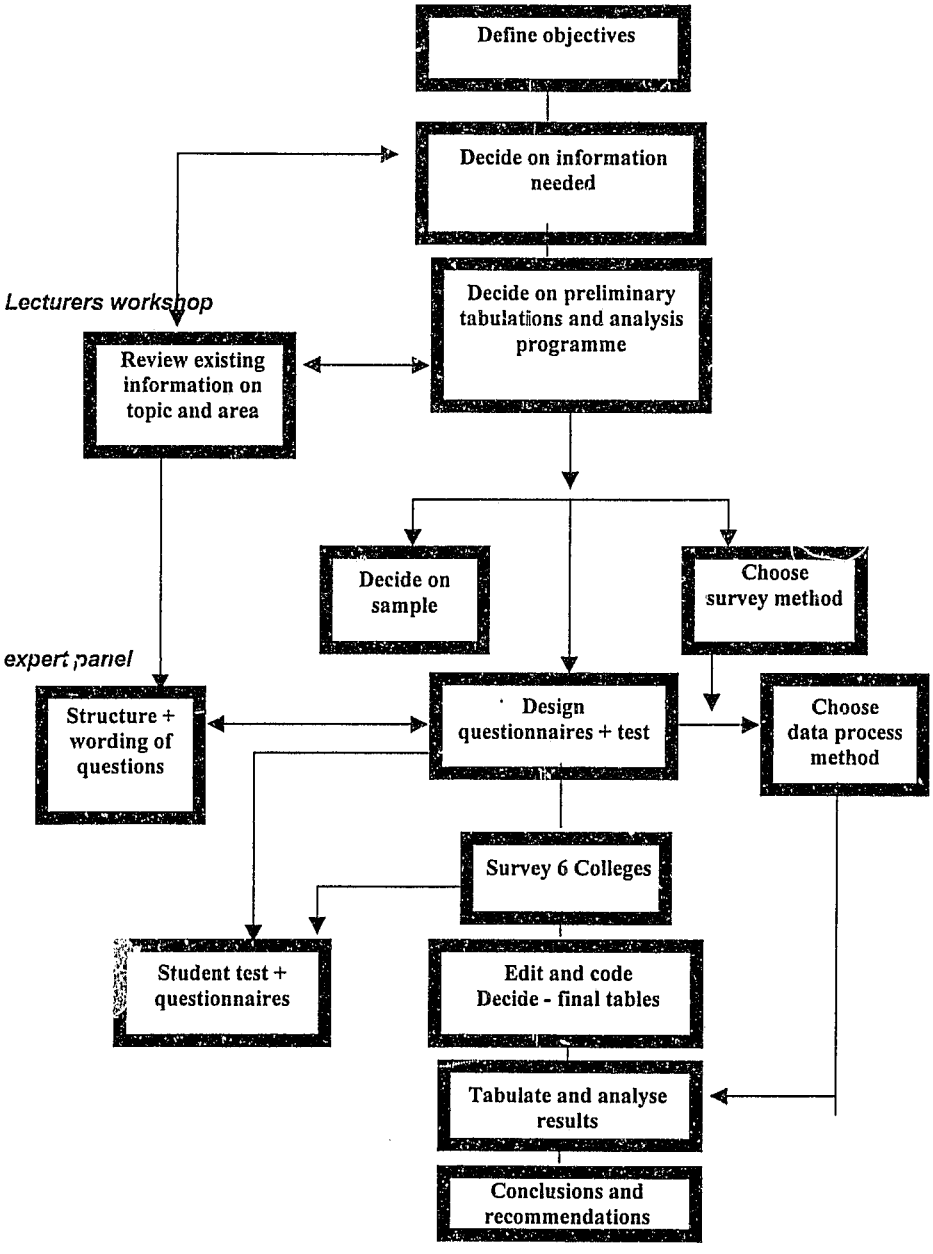
- judging the relevant difficulty of the physical science topics for the population
- consultation about the test items and their appropriateness.
- the answers to the test items to be used.

Table 3.1. The research process of the study and the involvement of experts

PHASE	SOURCE	DATES
Selection of Science topics	College of Education lecturers attending RADMASTE workshop	Jan 1996
Selection of test items	Std 10 final matriculation papers Expert panel (Panel 1)	March 1996
Construction of science test	Consolidation of expert panel's evaluation	Mar-Apr. 1996
Testing of students	Colleges of Education	May-Jul. 1996
Development of answers for test	Expert panel (Panel 2)	Aug. 1996 - Jan 1997
Data capturing	SPSS	Feb. - Jul. 1997
Analysis	SPSS package Consultations with statisticians	Aug. 1997 - Apr 1998
Write-up	Results, conclusions, recommendations from tests and questionnaires	Oct. 1997 - Jul. 1998

As with any survey, the research was designed in certain phases. These are represented in Figure 3.1, which gives an overview of these stages.

Figure 3.1. Stages in planning the survey of six Colleges of Education linked to framework of the dissertation



The instrument development will be discussed in detail in chapter 4. In this section, a description of the procedures that were followed in this study with regard to the fieldwork, testing and test administration will be given.

3.4.1. Fieldwork, testing and administration of questionnaires

The tests were conducted at the six identified Colleges of Education in May, June and July 1996. Arrangements with the Colleges included letters faxed to the institutions to ensure that the testing dates and times were as convenient as possible for the Colleges. First year class sizes were verified ahead of time to ensure enough materials for the students. Without exception, the Colleges' rectors, science lecturers and science students were very co-operative and the testing sessions went well. In a couple of cases, the lecturers or rectors spent some time after the test administration asking the researcher questions about the tests and the study and seemed genuinely concerned about the first year science students coming into the Colleges.

The researcher administered the tests. Testing in most cases was conducted in the afternoon rather than the morning to fit in with the college schedule. In all cases the lecturers were asked to be present initially in order to ensure that the instructions regarding the testing procedure, were understood by all the students. The background to the study was given to the students as well as a detailed instruction of how to answer the questionnaire and test paper.

The five questions for each identified topic were consolidated into one test paper. The students were allowed three hours to complete both the test and the questionnaire. They were encouraged to seek clarification of any

questions that they did not understand. Most of the students seemed to understand the instruction for the test well enough, although several students, it was discovered later, appeared not to be familiar with the concept of multiple choice items and how to answer these. In total 175 students were tested, although 26 test papers (mostly from one college) had to be discarded after testing as those students had not taken physical science for matric. All the students were able to complete the tests and questionnaires and no student was penalized due to a time constraint.

The background questionnaire was administered to the students at the same time as the test. Potentially complicated questions (for instance where students were asked to rank occupations in terms of the students' perceptions of the status of those careers in their communities) were read out in English and explained to the students. The students were assisted at various times during the course of the test administration, when there appeared to be problems with the language comprehension of certain questions, with the exception of students' questions regarding the science content.

The college lecturer's questionnaire was given to the lecturers at the time of the students' writing the test. Five of the six lecturers completed the questionnaire and returned it before the end of the testing process. Unfortunately, one lecturer did not return the questionnaire and left the college shortly after the students had been tested and this questionnaire could not be recovered.

3.4.2. Scoring and coding of the questions

Three science experts with extensive science teaching experience were approached for assistance with the grading of the answers. Each expert submitted a list of answers for each of the 20 items. These were then cross-checked before the marking process started. Every item was then marked by the researcher, the scores for the students were calculated for each topic and for the overall percentage for the test (see 4.1). These were coded as 1 = *correct*, 0 = *incorrect* or 3 = *not attempted*, for data capturing in Statistical Package for Social Scientists (SPSS). All the variables from the questionnaires were coded and entered (for instance the gender of the students was entered as 1 = male and 2 = female).

3.5. DATA-ANALYSIS

Inferential statistics deal with inferences about populations, based on the behavior of samples. They are concerned with determining how likely it is that results based on a sample are the same results that would have been obtained for the entire population. *Inferences concerning populations are only probability statements; the researcher is only probably correct when he or she makes an inference and concludes that there is a true difference, or true relationship, in the population* (Gay, 1987: 411).

At this point, a note must be made of the nature of the sample of this study in that it was a non-probability and purposively drawn sample. Therefore, although the statistical methods being used are inferential in nature, caution should be taken when inferring/ extrapolating the results of this study to the entire population of first year science students at all Colleges of Education in South Africa. On the other hand, given the characteristics of the six colleges,

there is reason to believe that they are reasonably representative of the former DET colleges in the country.

The data was analysed using several techniques that will be discussed in this section. For these analyses the Statistical Package for Social Scientists (SPSS) was used. SPSS is a comprehensive and flexible data management and statistical analysis system. SPSS can take data from almost any file and generate tabulated reports, charts and graphs of distributions and trends as well as generate complex statistical analyses. Therefore, it was felt that this would be an appropriate package to manage a fairly large and complex database, with more than 150 variables and 149 student files.

Frequencies of univariates were first drawn on all the variables and some of these have been included in the report as charts and graphs. Much time was spent on reviewing these frequency tables with data analysts and discussing the results with statisticians, concerning the most appropriate method of statistical analysis. Thereafter, variables were categorised (or re-categorised in some cases) in order to enable a second-order or more complex analysis (multivariate analyses) to be done.

The data were in form of a multivariate data set. The relationship between selected variables considered to be suitable, or alternatively thought possible, was explored using two-way contingency tables. In particular a number of students' background variables were selected to analyse whether these variables are independent or dependent. To *test the (in) dependency* between variables in a contingency table a chi-squared test (x^2) has been used. The chi-squared test is a nonparametric test of significance, appropriate when the data are in the form of frequency counts (nominal data) occurring in two or more mutually exclusive categories (Gay, 1987).

Correlational analysis is used to measure the strength of the association or covariation that exists between two quantitative variables. As this study comprised 149 students, the coefficient needed at a 95% confidence level is 0.19 (Gay, 1987:233) in order to conclude (in statistical terms) the existence of a relationship. Therefore, pairs of variables with correlation coefficients with an absolute value of 0.19 and higher are discussed, while variables with coefficients of absolute value lower than $r = 0.19$ were excluded from the discussion.

Significance levels for both the chi-squared test and the correlational analysis were set at 0.05 (critical $p = 0.05$). This was done in the nature of testing a hypothesis or relationships to indicate that the coefficient really reflects a true relationship and not a chance relationship.

CHAPTER 4 DESIGN AND DEVELOPMENT OF THE PHYSICAL SCIENCE ACHIEVEMENT TEST

As mentioned in chapter 3, a number of research instruments were developed for this study. This chapter elaborates on the design and development of the physical science achievement test and is important to set the scene for Chapter 6, when the test results are analysed and discussed, for an increased understanding of the methodology and the results of this research project.

The development of the physical science test followed a number of steps, such as the selection of the topics to be included, the selection of possible questions, the judgement of these questions and finally the final selection of questions. In all these phases a number of science education experts played a role.

4.1. ROLE OF SCIENCE EDUCATION EXPERTS

A panel of recognised physical science experts was identified and selected to assist in the development of the test. It was felt that not only their expertise was needed in the development process to obtain content validity, but their involvement would also contribute to the credibility of the test for the colleges and the colleges' science education lecturers.

The panel comprised three physical science Std 10 (grade 12) teachers, one College of Education science lecturer and one university lecturer with extensive science teaching/lecturing experience, who had also lectured at a

College of Education. Of the three teachers, two were African teachers who had taught physical science in schools for African students and were familiar with issues concerning English as a second language. The College lecturer was based at a College for African students and had also taught science at schools for African students. These teachers/lecturers were selected in particular for this experience, as there were serious concerns about testing the College of Education students who spoke English as a second language.

In the process of test development the panellists contributed to the following tasks:

- selection of candidate items from an item pool
- evaluating and prioritising candidate items for the final test.

Based on their input the researcher finalised the physical science test.

4.2. SELECTION OF PHYSICAL SCIENCE TOPICS

Early on in the study, it was felt that, due to time constraints during the data collection, an achievement test would have to be a great deal shorter than the traditional physical science matriculation examination (two exams of three hours each). An alternative method was needed to select the topics for which questions could be sought or developed. As this study involved College of Education students, it was felt that consultation with College lecturers would shed some light on the difficulties first-year students' experience in physical science at Colleges of Education. Based on this, a science achievement test would be developed

Therefore, a survey was conducted, by means of a questionnaire, amongst 36 College of Education science lecturers who were attending a RADMASTE

workshop (see appendix 1 for questionnaire) to collect data on the following topics:

- identifying the physical science topics that they, as lecturers, felt presented the first-year students with the greatest/least difficulty in learning at the Colleges;
- indicating the type of difficulties students have with these topics.

Also some background data of the respondents were collected.

The lecturers were asked to rank a list of 15 topics taught in physical science at Grade 11 and Grade 12, in order of difficulty (1 being the most difficult and 15 the least difficult). The lecturers' rankings of the topics in the questionnaires were analysed and an average score was calculated for each topic from these results, which are shown in Table 4.1.

In commenting on the difficulties, the lecturers were asked to indicate the perceived difficulty levels as well as what problems first year students have with the science content knowledge. A summary of these comments for the topics selected can be found in Appendix 2.

Table 4.1. Results from the Lecturers' questionnaires

Areas	Average score	Ranking
Electrostatics	7.3	9
The Electric current	6.8	6
Bodies in Motion	6.9	8
reaction rates and chemical equilibrium	5.6	2
Acids and bases	9.6	14
Oxidation reduction and electrochemical cells	5.1	1
Organic Chemistry	7.9	11
Vectors	6.8	6
Displacement-time , Velocity-time relationships	6.6	5
Light	7.5	10
The Atom	9.4	13
The periodic table	10.4	15
Chemical Bonding	8.3	12
The Kinetic model of matter and intermolecular forces	5.9	4
Inorganic chemistry	5.7	3

Generally, the chemistry topics were considered to be more difficult than the physics topics. In order for four topics to be selected, the topics considered most difficult and the easiest in both physics and chemistry were selected. In actual fact, the most difficult four topics were chemistry topics and the physics topic considered to be the most difficult, was only ranked fifth in order of difficulty. Similarly, the five easiest topics were chemistry topics. Thus, chemistry topics appeared to be considered as extremes in terms of their

difficulty by the lecturers. Velocity/displacement-time and electrostatics respectively, were considered the most difficult and second easiest topics in physics respectively. Light was actually considered easier than electrostatics as a topic, however it was decided to exclude light in favour of electrostatics as it is often not taught to Grade 12 students because it is not examined at matric level. Oxidation reduction/electrochemical cells and the periodic table respectively, were considered the most difficult and easiest topics in chemistry. These four topics were therefore selected as the content areas for inclusion in the science achievement test.

4.3. CONSTRUCTION OF THE TEST

At the start of the process, 80 provisional items were selected from past matriculation papers. The items were selected from physical science Std 10 (grade 12) papers (including higher grade and standard grade) used for the matriculation examinations between 1992 to 1994, from all the different departments of education that existed prior to 1995. For each topic (velocity/displacement time, electrostatics, oxidation reduction/ electrochemical cells) 20 questions were selected before the first elimination stage. The 20 questions based on the periodic table were selected from textbooks, as there were no suitable questions to be found in the matric papers.

These selected items were then sent to the expert panel (see 4.1.1) for comments and were submitted in a questionnaire format that had been specially prepared for this purpose (see Appendix 6).
The panel was asked to evaluate (using scales) the selected items in terms of the following:

- **Wording** - they were asked to state whether the specific items were simple, ambiguous, appropriate, difficult or incomprehensible. It was important that as far as possible there should not be unnecessary difficulties with the English language contained in the test items.
- **Difficulty** - the panel was asked to rate the items in terms whether the items were easy, fair or difficult for students at matric level.
- **Knowledge skills requirement** - they were asked to evaluate them in terms of Ebel's taxonomy of thinking skills and these were in the order from the simplest to the most complex:
- understanding of terminology
- understanding of fact and principle
- ability to explain/illustrate
- ability to calculate
- ability to predict
- ability to recommend appropriate action
- ability to make an evaluative judgement
- **Suitability** - they were asked to state whether or not the item was poor, satisfactory or good in terms of their suitability for the topic concerned.

All the items were reviewed independently, as far as possible by at least two members of the panel. Each expert was given 35 questions (from the original 80). These included a common cluster of 10 questions, which was circulated to all the members as a control. It happened that the College lecturers had consensus on this common set of questions. The panel members were also asked to complete an evaluation sheet with their response to each question. The comments of the panel members were collated (see appendix 7). All the items that any member of the panel considered ambiguous or incomprehensible in terms of their language content were immediately

excluded. Any items considered by members of the panel to be unsuitable for the intended topics were also eliminated.

Items considered appropriately worded (and preferably simple) and good in terms of their suitability were identified for the next phase of selection. Within each topic there had to be a balance of items evaluated in terms of the spectrum of Ebel's taxonomy of thinking skills, to allow different levels of cognitive skills to be assessed within each topic; as well as a balance of items considered to be easy, fair and difficult. For each topic, three questions which were considered fair, one question that was easy and one considered to be difficult, were selected so that the difficulty level of the test overall would be considered fair.

All these points discussed above (appropriate language content, suitability for the topic and a balance of items assessing levels of thinking skills) were used as the criteria for the final selection of the items. As an illustration of this process, the final selection of the items for 'oxidation-reduction' will be discussed (see Table 4.2). For instance, items O8, O14, O16, O20 were immediately eliminated from the list of candidate items due to the wording of the questions being considered difficult. There were enough items that were judged to be good in terms of their suitability for the topic and therefore items that were considered merely satisfactory were then not considered. This meant that O13 and O23 were eliminated. Of the remaining six items, preference was given to items where at least two judges were in consensus. Furthermore, of the five items to be selected, it was decided that where possible, three should be considered fair in terms of their difficulty levels, one should be considered difficult and one should be considered easy. Finally, the choice had to be made between O7 and O12 and the decision was made to select the items that addressed the thinking level of "explaining or illustration" tested by the item. Therefore, O12 was selected and O7 was

eliminated. In the end, the following items O1, O5, O11, O12 and O15 remained for the topic oxidation-reduction.

Finally, a test of 20 items comprising five questions (with a number of questions containing several parts to it) for each topic was compiled using these criteria. Unfortunately, the test development had to be based only on this expert judgement procedure, as there was no opportunity for pilot testing. Ultimately the quality of test appeared to be good, as its reliability coefficient was .86 (Kuder Richardson, KR21). The final physical science test is given in Appendix 3.

Table 4.2. Selection of Oxidation-reduction items

QUESTION CODE	EXPERTS INITIALS	EXPERT CODE	WORDING OF QUESTIONS a = simple b = ambiguous c = appropriate d = difficult e = incomprehensible					DIFFICULTY INDEX a = easy b = fair c = difficult			LEVEL OF THINKING TESTED BY THE QUESTION a = understanding of terminology b= understanding of act and principle c = ability to explain/illustrate d = ability to calculate e = ability to predict f = ability to recommend appropriate action g = ability to make an evaluative judgment							SUITABILITY OF QUESTION FOR TOPIC a = poor b = satisfactory c = good		
			a	b	c	d	e	a	b	c	a	b	c	d	e	f	g	a	b	c
O1	TZ,DM	E2			2				2			2			1					
O2	CQ	E3	1					1			1	1			1				1	
O5	TZ,DM	E2	1		1			2			1	1					1			2
O7	CQ	E3			1				1		1	1		1	1		1			1
O8	TZ,DM	E2			1	1		1		1	1						1		1	1
O11	TZ,DM	E2			2				2		1	1				1			1	1
O12	CQ	E3			1				1		1	1	1	1	1					1
O13	CQ	E3			1			1			1	1							1	
O14	JW,MR	E1			1M	M		M		1	M	1M	1						1M	
O15	TZ,DM	E2	1		1			1	1			2							1	1
O16	JW,MR	E1	1			M		M			M	1M					1		1	
O20	TZ,DM	E2				1	1		1	1					1	1	1		1	1
O23	CQ	E3			1			1			1	1		1					1	

CHAPTER 5. RESEARCH RESULTS FROM THE STUDENTS' BIOGRAPHICAL QUESTIONNAIRES

In the students' questionnaire, information was requested about the students' background, home environment, school environment, career choice, perceptions and attitudes towards science and teaching and their knowledge base in science. The intention was to identify background factors that could later be linked to students' achievement.

In Chapter 5 the findings from the students' questionnaire on their background and profile are discussed in order to set the context for the achievement results discussed in Chapter 6. The students' home background is discussed in 5.2 and their school environment and performance at school in 5.3. Section 5.4 concentrates on the reasons for the students entering into Colleges of Education and their attitudes towards teaching. Finally, the relationship between students' background variables is explored and analysed in 5.5.

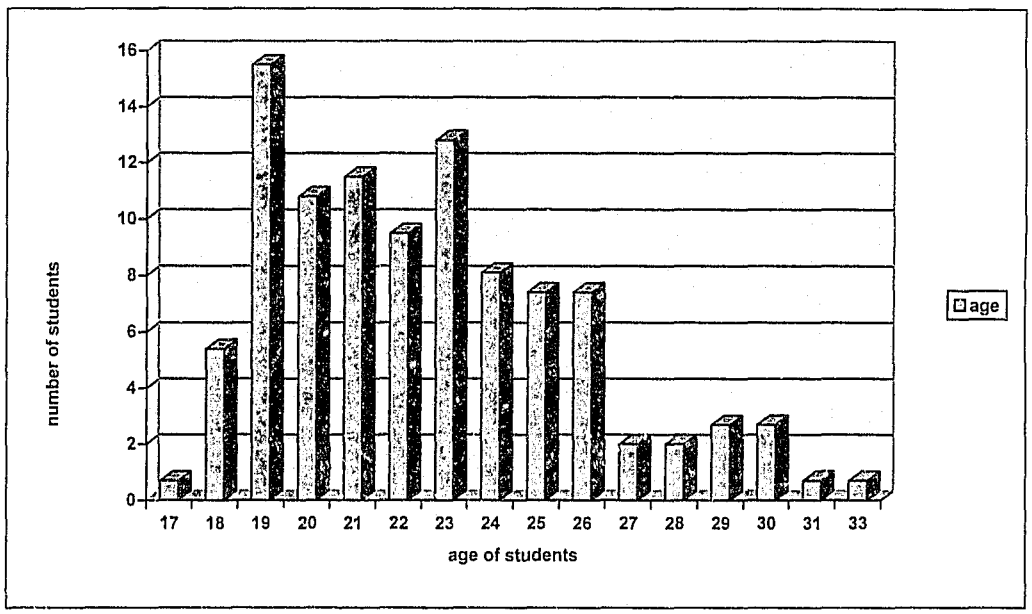
5.1 Student profile

The first section of the questionnaire concentrated on the students' background and interests. This biographical section was used to establish a profile of the students in terms of their age, gender, home language, where they had grown up and the kinds of activities in which they had participated in their matric year.

Age of the students

The youngest student tested was 17 years and the oldest was 33 years of age. Figure 5.1 shows the age distribution of the students. It can be seen that, although the average age was 22.5 years, the mode was in fact 19 years.

Figure 5.1 Age of the students when tested



As can be seen from Table 5.1, there was very little difference between the average ages of the male and female students (22.6 years: 22.4 years). Six of the students did not answer this question.

Table 5.1. Average age of students when tested and by gender

Students	Average age	Std dev	Number of students
Entire population	22.50	3.26	143
Female	22.43	3.46	81
Male	22.6	3.01	62

This relatively high average age would be in keeping with the large number of students in the sample completing matric prior to 1995. Furthermore, more than half of all black students in Grade 12, are 20 years and older (FRD, 1996). This means that on average, black students leave school two to three years later than students from other population groups. In many cases these students would also have repeated a school year at least once.

- The average age of the students also varied according to different **colleges.** College B was situated in rural area and the other colleges, A, C, D, E and F were situated in peri-urban/township areas.

Table 5.2 The average age of the students by college.

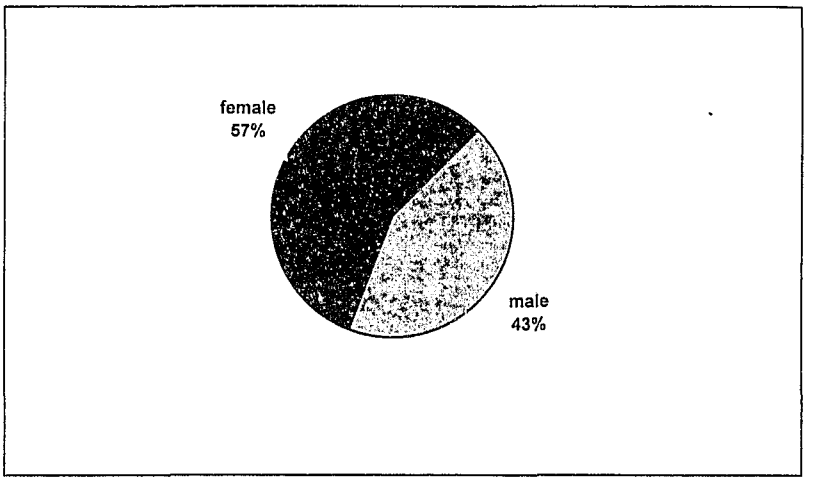
College	Average age	. Std dev	number of students
A	24.40	2.81	18
B	21.54	3.02	48
C	22.91	3.46	23
D	20.21	2.55	14
E	22.82	3.32	22
F	23.87	3.05	23

Students at College A had the oldest student cohort with an average age of 24.40 years, as can be seen from Table 5.2. This college offered primary teacher diploma courses and the entrance requirements for the course were lower at this college than others offering secondary teacher diplomas. The students from College D were on average younger (20.21 years) than those from other colleges. Most of the students from this college matriculated in 1995, the year before this sample of students was tested.

Gender

The majority of students tested were female, although the difference in the ratio of female students to male students was not as great as one might have expected (57%: 43%).

Figure 5.2 Gender of students



The majority of teachers in South Africa are women and almost twice as many black women teachers qualified from Colleges of Education in 1993 as men (30 485 women: 16 257 men) (FRD, 1996: 199). However the small difference in this case could be due to the fact the testing focused on science students, which traditionally is more of a male domain. The number of girls enrolling in physical science at matric level is increasing and 48% of matric students writing the physical science examination in 1995 were female compared to 45% in 1990 (Arnott et al, 1997: 12).

- There was a marked difference in the ratios of male to female students taking the senior primary teachers diploma course and those taking the secondary teachers diploma course, as can be seen in Table 5.3.

Table 5.3. The percentage of students taking diploma courses by gender

Course	Male	Female
Senior Primary Teachers Diploma	30.8 %	69.2 %
Secondary Teachers Diploma	48.1 %	51.9 %

Of the students taking the Senior Primary Teachers Diploma, almost 70% were female students. However, there was no real difference between the number of male and female students in the Secondary Teachers Diploma courses (48%:52%). However, these overall figures mask significant differences between colleges.

- There were significant differences in the gender composition between the first year science classes of different colleges.

Table 5 4. Information on male and female science students at different colleges

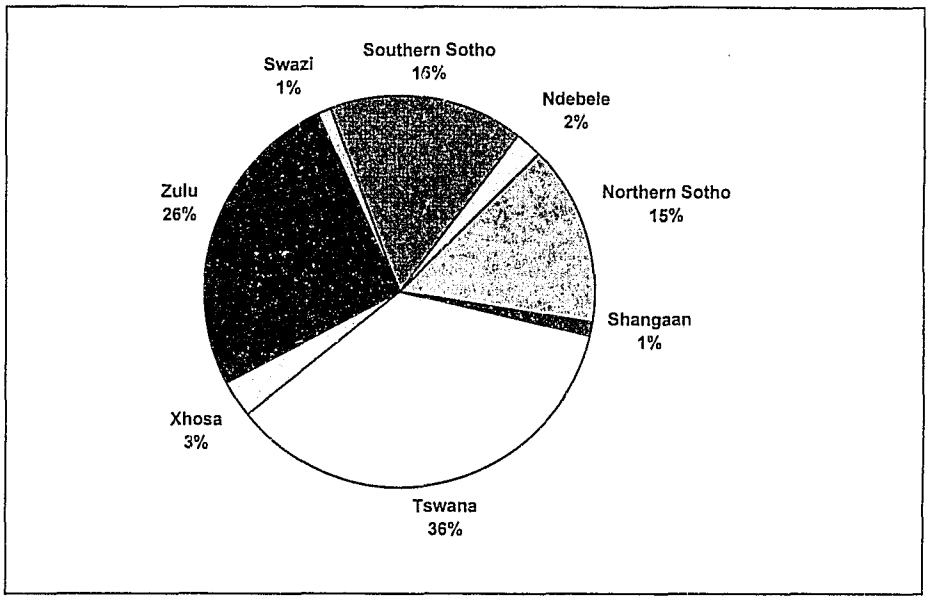
		SPTD		STD	
College	Number of students	Male %	Female %	Male %	Female %
A	18	38.9	61.1		
B	48			34.8	65.2
C	23			69.6	30.4
D	14			64.3	35.7
E	22			42.9	57.1
F	23	23.8	76.2		

As can be seen from Table 5.4, in 3 out of the six colleges (colleges A, B and F), there were significantly more female students than male students (61.1%, 65.2% and 76.2%). However, in two of the six colleges (colleges C and D), there were significantly more male students than female students (69.6% and 64.3%). In the case of Colleges A and F, this gender imbalance can be primarily explained by the fact that their colleges offered primary teachers' diplomas and as can be seen in Table 5.3, significantly more female students took this course. In general, male students appeared to be more prevalent in the STD courses than the primary courses which, explains some of the gender imbalances

Home Language of students

Eight of the official 11 languages were spoken by the students as their home languages. These were: Northern Sotho, Southern Sotho, Tswana, Zulu, Xhosa, Swazi, Ndebele and Shangaan.

Figure 5.3. Language of students tested



As can seen from Figure 5.3, more than two-thirds of the students were either Sotho or Tswana speaking. This can be explained primarily by the fact that the six colleges that were in the sample were situated in Gauteng, North West Province and Northern Province where these languages are predominantly spoken. Nearly a quarter of the sample spoke Zulu as a home language and this reflects the impact of the numbers of migrant Zulu labourers in the townships in and around Gauteng. It must be remembered that in all cases, the medium of instruction was English and none of these students were English first language speakers.

- In most of the six colleges, students from at least four language groups were found.

Table 5.5: Home-languages of students across the Colleges,

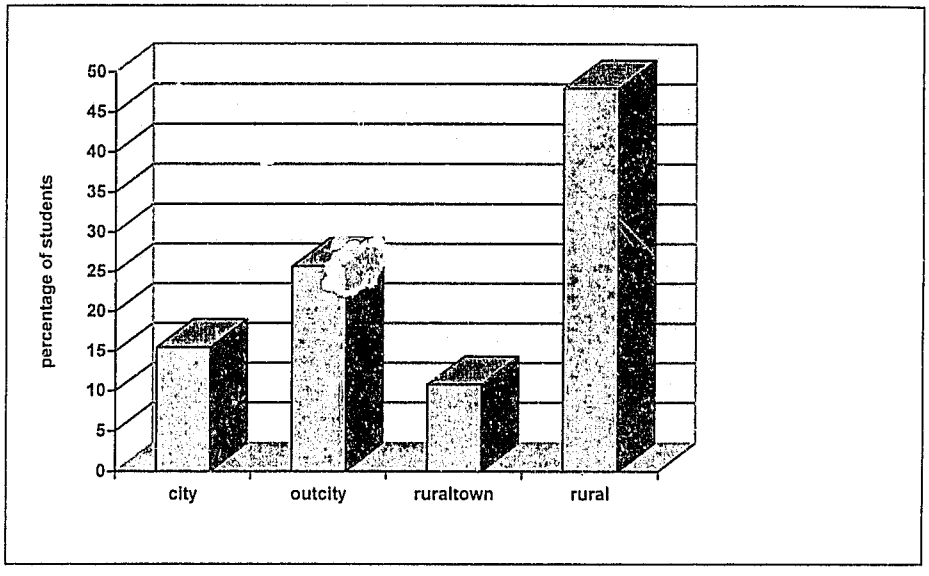
Home language	College A % of students (n= 18)	College B % of students (n=48)	Colleges C % of students (n=23)	College D % of students (n= 14)	College E % of students (n=22)	College F % of students (n= 23)
N.sotho	4.8	0.0	0.0	52.4	28.6	14.3
S.sotho	18.2	13.6	40.9	4.5	9.1	13.6
Tswana	2.0	87.8	2.0	0.0	0.0	8.2
Xhosa	28.6	7.1	35.7	0.0	28.6	0.0
Zulu	25.0	2.8	22.2	0.0	25.0	25.0
Swazi	0.0	0.0	0.0	0.0	50.0	50.0
Ndebele	0.0	0.0	0.0	33.3	0.0	66.7
Shangaan	0.0	0.0	0.0	50.0	0.0	50.0

As expected, in the peri-urban based colleges, a greater variety of languages were spoken by students at home, than in the rural based college. As can be seen in Table 5.5, in three of the peri-urban colleges (Colleges A, E, F) four or more (seven in College F) languages were found. This would increase the complexity of the lecturing and learning at such a college. In most of these colleges at least two dominant languages appeared. In the only rural college (College B), was there a clearly dominant language, Tswana (which 87.8% of the students spoke).

Area

Students were asked to indicate whether they had grown up in a city centre, on the outskirts of a city, in a rural town or in rural villages/isolated rural area.

Figure 5.4 Areas where students grew up



As can be seen from Figure 5.4, nearly two-thirds of the students in the sample had grown up in a rural environment. Of these, by far the majority had grown up in rural villages and isolated areas. Only 15% had grown up in the city.

Students' activities outside school hours

In looking at an overview of the students' activities outside school hours, a number of trends and differences between groups of students were observed.

Studying

Students claimed to have spent more time per week studying than on any other individual activity.

Table 5.6: Amount of time that students spent studying in their matric year

Number of hours spent studying per week	percentage of students
never	3.5
0-1 hours	9.9
1-2 hours	27.5
2-5 hours	39.0
more than 5 hours	19.9

As can be seen from Table 5.6, 59% of the students claimed to have studied more than two hours per week. Of these, 20% indicated that they studied more than five hours per week, which is more in line with what one would expect students to study during the matric year. On the whole, it would appear that most students did not spend a substantial amount of studying time on their own during this critical school year.

Most interesting was the difference in the studying behaviour of the urban and rural students. The greatest proportion of students (47%) who studied up to five hours per week, came from isolated rural areas, compared to 10.9%, 25.5%, 16.4% from other areas and 39% of those students studying more than five hours per week also came from isolated rural areas.

There was no significant difference between male and female students in terms of the amount of time they spent studying. Although, more female students indicated that they studied between 1-5 hours longer than male students did (59%:41%). However of those students studying more than 5 hours per day, 51.9% were male compared to 48.1% female.

Science homework

The amount of time spent on science homework also appeared to be on the low side.

Table 5.7. Time spent on science homework per week

Number of hours spent on science homework	percentage of students
never	3.5
0-1 hours	22.4
1-2 hours	42.7
2-5 hours	21.7
more than 5 hours	9.8

As can be seen from Table 5.7, most students appeared to spend between one and two hours per week on their science homework. Only 31.5% of students indicated that they spent more than two hours per week. Twenty-six percent of the students spent less than one hour per week or spent no time at all on science homework. These very low figures could be attributed to either the teacher giving insufficient homework, the students not doing the given homework or even possibly not taking the initiative to study physical science at home. This is a matter for concern for a demanding subject such as physical science and could also help to explain the low symbols achieved in matric for science which are discussed in 5.1.3.

There was no significant difference between the students from the urban and rural areas. However, a higher proportion of rural students (55.5:44.5%) claimed to do more than two hours of science homework per week. Students in isolated areas appeared to spend more time on their science homework than other students, as 45% spent more than two hours per week compared to 13%, 31% and 11% of students from other areas.

Generally male and female students spent the same amount of time on homework. However, of the students spending more than 5 hours per week on science homework, 64% were female students. This is in contrast to the general studying patterns of male and female students indicated earlier.

Paid Jobs

Generally, most South African school students do not spend much time doing paid jobs compared to their peers in countries like the United States of America, where 56% of Grade 12 students spend more than 5 hours per week on paid jobs (Mullis et al, 1998).

Table 5.8 Time spent on paid jobs per week

Number of hours spent on paid jobs per week	percentage of students
never	70.1
0-1 hours	6.3
1-2 hours	6.9
2-5 hours	8.3
more than 5 hours	8.3

As can be seen in Table 5.8 , 70.1% of the students claimed they had never worked in a paid job and only 8.3% said that they spent more than five hours per week working. Of the students who had never worked, 50% came from isolated rural areas. However, of the students working more than two hours per week, 42% also came from isolated rural areas compared to 16%, 25% and 17% from the city centre, outskirts of the city and rural towns respectively.

Generally, there was no significant gender difference between the students working, although of the students spending more than two hours per week working, 58% of these were male.

Chores/jobs around the house

Most students are expected to do a number of chores around the house, whether it be washing dishes, fetching water or looking after younger siblings.

Table 5.9 Time spent on chores around the house

Number of hours spent on chores	percentage of students
never	16.2
0-1 hours	27.2
1-2 hours	27.9
2-5 hours	17.6
more than 5 hours	11.0

Forty percent of the students spent less than one hour a day on average doing chores around the house. Only 11% of the students spent more than five hours per week.

As expected, rural students spent more time doing chores than urban students. Fifty percent of students spending more than two hours per week came from isolated rural areas.

Again, as expected, two-thirds of the students spending more than two hours per week were female. Girls often look after younger siblings, clean the house and cook in the absence of parents who come home late from their work.

Time spent on recreational activities outside school

Students generally had a wide range of activities, including spending time with friends, playing sport, watching television, going to movies and reading.

Table 5.10. Time spent on leisure activities per week

Amount of time	television	sport	movies	friends	reading
never	9.8	17.4	38.1	6.9	9.3
0-1 hours	32.9	27.8	18.7	30.6	47.1
1-2 hours	23.8	38.8	19.4	31.9	23.6
2-5 hours	23.1	11.1	19.4	16.0	12.9
more than 5 hours	10.5	4.2	4.3	14.6	7.1

- Students' most popular past-time seems to be watching television, closely followed by spending time with friends. A third of the students claimed that they watched two hours or more television per week and 10.5% of these claimed to watch more than five hours per week. In comparison, only 20% of students indicated that they read for more than two hours per week with only seven percent reading for more than five hours per week. This means that 93% of these students read for less than 43 minutes a day on average. This may be explained by the TIMSS findings that 60% of Grade 12 students had fewer than 26 books in their homes Howie and Hughes, 1998).

- Fifty-six percent of the students watching television for more than two hours per week came from urban areas. Sixty-five percent of students who watched television for less than one hour per week or who never watched television came from rural areas. More girls watched more television than boys (57%:43%)

- In general, it appears that students read too little. Those who do read, come from isolated rural areas. Of the students reading more than one hour per week, 52% come from isolated rural areas compared to 18%,

difference between boys and girls with regard to reading. Of those students reading for more than one hour per week, 52.5% are girls.

- Of the students who played more than one hour of sport per week 57% came from the rural areas and more boys than girls played sport (55%:45%).

In conclusion, the typical College of Education student in this study is as follows (with some differences between the profile of the typical male student and typical female student):

The student is on average 22 years old, comes from the rural areas and speaks either Sotho or Tswana. They do not study very much, on average about two hours a week and spend even less time on their science homework (fewer than two hours). Their favourite extra-mural activity is watching television, followed by visiting friends.

Differences between male and female students were found. The typical male student plays more sport, reads very little and is more likely to spend more time in his paid job, if he has one. The typical female student spends more than two hours a week helping around the house. She is more likely to spend more than five hours a week on her science homework. She also watches more television and reads slightly more than the male student.

5.2 STUDENTS' HOME ENVIRONMENT

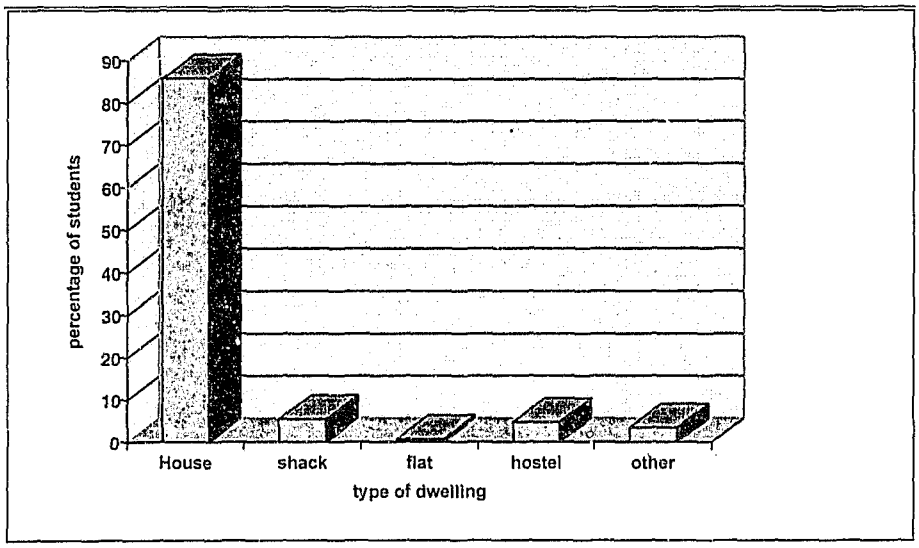
During the design of this study, it was felt that it was important to include questions concerning the students' home background. Several studies have reported on the influence of home background on achievement. Keeves (1992: 165), discussing the results of the Second International Science Study, stated that "*it is generally acknowledged that the effects of the home act through the attitudes and aspirations of the student to influence staying longer at school and the motivation to succeed*". It was shown previously that the home background plays an important role in developed countries as a predictor for students' achievement in physical science and mathematics. The influences of the home background factors on educational outcomes are so pervasive in such countries, that one cannot conduct analyses of the attitudes and gender of the students without considering the social class/socio-economic characteristics of the home (Keeves (1992:165-186). However, studies of developing countries by Heyneman and Loxley, 1982; Saha, 1983; Cohn and Rossmiller, 1987 have shown a relatively low importance of home factors.

In an attempt to study the effect of the home environment on the science achievement of this sample of students, a number of questions concerning the students' home environment were included in the questionnaire. These included the type of dwelling they lived in, whether or not students had a quiet place to study, their parents education, the students' mode of transport to school and the time it took them to get to school.

Where the students' lived during their matric year.

Students were asked to indicate where they had lived during their matric year. This was done to try to ascertain their probable living conditions. The choices were a house, an informal settlement, flat, school hostel and other. It was expected that many students would have come from somewhat impoverished backgrounds with little or no resources at home, although, to a certain extent, these students might have been considered slightly privileged in terms of the broader community because of the fact that their families (or the students themselves) were able to afford the additional costs (over and above what their bursaries cover) of supporting the students' studying at college.

Figure 5.5 Students' type of home during their matric year



As can be seen from Figure 5.5, the majority of students stated that they lived in houses. Very few students (4.7%) had lived in a boarding school

hostel when they were in matric. Only 5.4% of the students claimed to have lived in an informal settlement during their matric year although it is possible that students may not have wanted to volunteer this information.

Environment in which students' studied

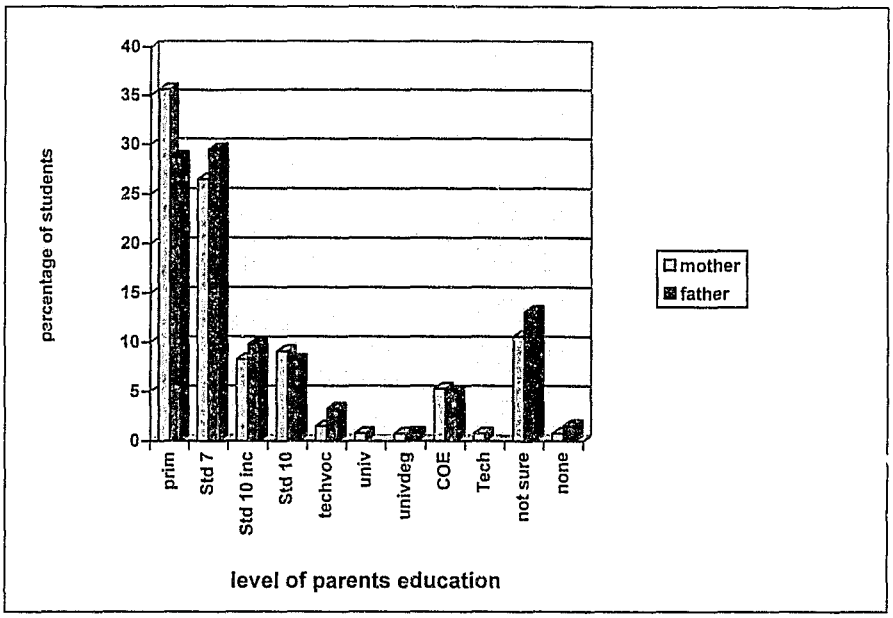
Not only do students need the opportunity to study, but it is also important for them to have an environment conductive to study. To establish whether or not the conditions were suitable for studying, students were asked to indicate whether or not they had a quiet place to study. Although 66.2% of students claimed that they had a suitably quiet place to study, 33.8% of the students indicated that they did not.

Parents' level of education

There is a general belief that the more literate the parents the higher the achievement of the students (Keeves, 1992). There is a further assumption that parents with more education have more books at home and therefore provide a richer environment that encourages their children in their learning.

It would appear that this sample of students is the first generation, in most cases, to finish school and to seek higher education. It stands to reason therefore that their parents' educational level is low. When students were asked to indicate the level of their parents' education a surprising number of students were not sure of the parents' educational level. One suspects that this could indicate a low level of education received by the parent.

Figure 5.6 Levels of education achieved by the students' parents



As can be seen from Figure 5.6, it would appear that the levels of the fathers' education are comparable to those of the mothers' education. Seventy percent of the students' mothers did not complete secondary school which is comparable to the figure for their fathers, 68% of whom did not complete secondary school. However, 36% of the mothers only completed primary school compared to 29% of the fathers.

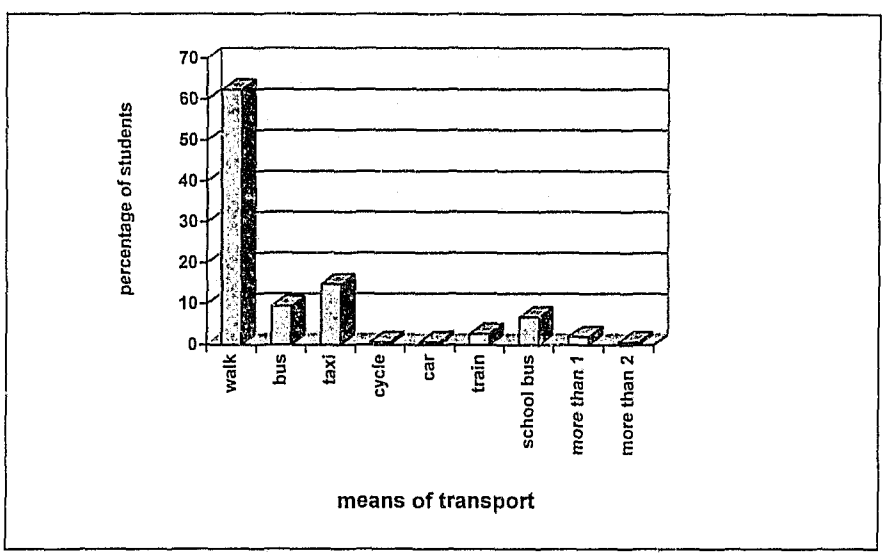
A very small percentage of the students' parents had attended or graduated from higher education institutions. The figure for their mothers in this regard was slightly higher than for their fathers, 7.7% compared to 5.7%. These figures nevertheless suggest that for the most part that these students were

in fact the first generation, not only to complete secondary school successfully, but also to attend an institution of higher learning.

Travelling to school

- The students were asked to select from a number of options to indicate their means of transport to school. These included walking, travelling by bus, taxi, bicycle, car, train or by school bus. When these answers were analysed, in some cases more than one form of transport was indicated and separate categories were identified for these students.

Figure 5.7 Students' means of transport to school

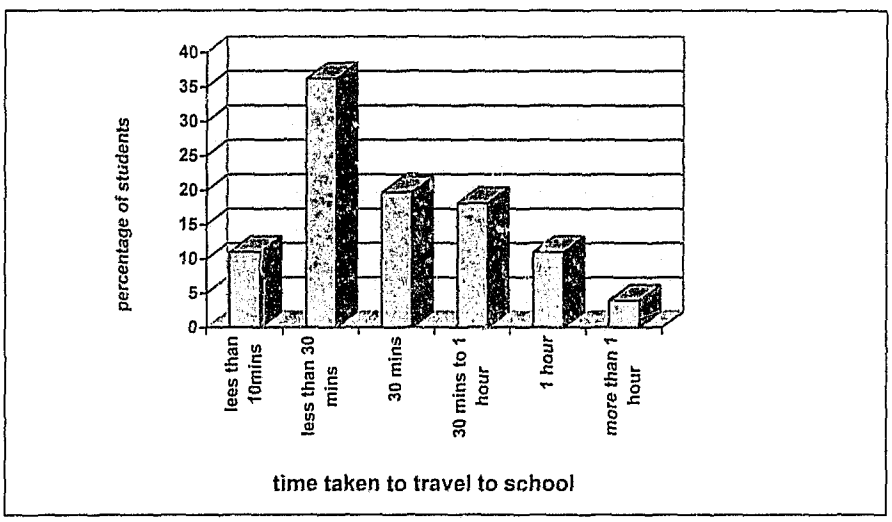


As can be seen from Figure 5.7 by far the most common means of transport was walking and 62% of the students walked to school. As so many of the students came from rural areas, this was not unexpected. Taxis were the next most popular, accounting for about 15% of the students, followed by the

bus which was used by nine percent of the students. The car and the bicycle, the more expensive means of transport, were the least common forms of transport accounting for less than two percent of the students.

- The students were also asked to state how long it took them to travel to school each day. Students were asked to choose from six options ranging from less than 10 minutes to more than one hour.

Figure 5.8 Time taken travelling to school



As can be seen from Figure 5.8 most students (67%) had travelled for 30 minutes or less every day. Only a very small percentage, 4% had travelled for more than one hour. More than 10% of the students did not answer this question.

The students' home profile **in conclusion** is as follows:
The typical college student in their matric year had lived in a house with a quiet place to study. However, their parents were not well educated and had

not completed secondary school. They (the student) lived within a half an hour's walking distance from the school and therefore had walked to school every day.

5.3 SCHOOL ENVIRONMENT AND STUDENTS' PERFORMANCE AT SCHOOL

In the USA, Stickney and Fitzpatrick (1987) found that family variables were more closely related to achievement than school variables. School variables were also related to achievement, but appeared to be more influential in the lower grades. These findings were further supported by Fyans and Maehr (1987) whose results suggested that school variables predicted the least variance in achievement.

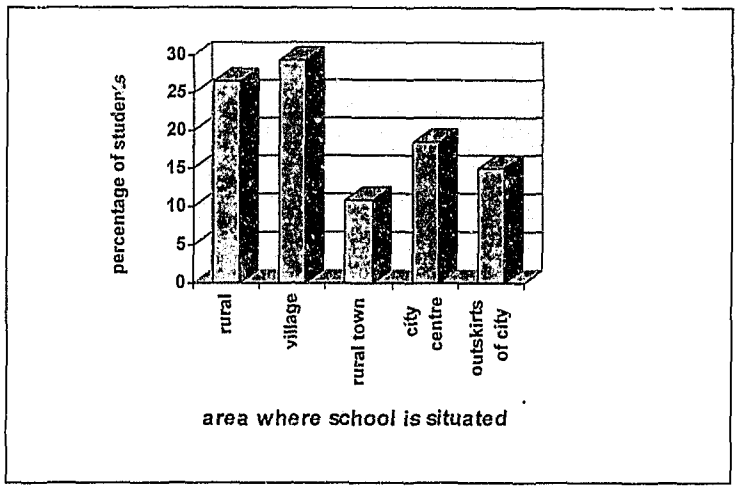
However, studies of developing countries by Heyneman and Loxley, 1982; Saha, 1983; Cohn and Rossmiller, 1987 showed the relatively low importance of home factors on achievement in science. In these studies, it was shown that the school environment has more impact on the achievement of students than the home.

In the context of the students in this study, the students school background was considered to be important. Students were asked to answer several questions pertaining to their school environment. Several different factors are discussed in this section which could be considered to be influential on achievement.

Location of school

The students were asked to indicate whether their school was situated in a rural area, in a village, a rural town, the centre of a city or the outskirts of a city.

Figure 5.9 Location of school



As seen in Figure 5.9, 66.7% of the students attended schools that were in rural and isolated areas. Only a third of the students attended schools in urban settings, of this third more than half of these students went to schools in the city centre. Colleges of Education often present rural students with the only accessible form of higher education coupled with the fact that in many rural areas, teachers are still held in high esteem by the communities, and this could explain the high percentage of rural students in the sample.

Facilities in the schools

From previous surveys conducted in South Africa, there is evidence that the majority of schools in this country have poor or non-existent facilities (HSRC, 1997). Students were asked about the existence of six different kinds of facilities that will be discussed in two parts: education-related facilities and recreation- type facilities. The questionnaire asked students to report on the availability of the facilities and they were not asked to comment on the state of these facilities nor their usage.

Education-related facilities:

- ***Computers***

Although computers are not common in African schools, there are already several schools that have computers. Nine percent of the students stated that their schools had computers. This figure is comparable to the figures quoted by the HSRC Schools needs based survey (HSRC, 1997) that just over nine percent of all schools in South Africa have computers. Considering the fact that one assumes that all of these students attended ex-Department of Education and Training schools, this percentage may even be considered high. However, in this study, the students were not asked whether or not the computers were available for teaching and student learning.

- ***Laboratories***

It is well-known that many African schools do not have science laboratories or have very poor science facilities (Manana, 1994: 66). There is a wider variation between provinces in the provision of laboratories. Provincial figures show that between 22% and 75% of the schools have laboratories, depending on the province (HSRC, 1997) A surprising number of students

(74%) claimed that their schools had laboratories. This could account for these students deciding to study science or it may be that most of the students came from provinces that had traditionally better facilities than others.

- ***Library***

Seventy-one percent of the students indicated that their schools had libraries and this is comparable to the national figure of 72% (HSRC, 1997). Students were not asked to specify if these libraries contained a certain number of books nor whether they had access to them. In many South African schools in rural areas there is a general shortage of books, good study materials and information in their libraries.

Recreation-type facilities:

Traditionally the recreational facilities at most African schools have been lacking or non-existent. As can be seen from table 5.11 the figures for these students' schools are very low as expected and fit the traditional model of a school in a deprived area.

Table 5.11 Recreation-type facilities

Availability of facilities	percentage of students' schools with pools	percentage of students' schools with courts	percentage of students' schools with fields
yes	1.5	33.6	74.5
no	98.5	66.4	25.5

Seventy-four percent of the students stated that their schools had playing fields. In most African schools this would tend to be soccer fields rather than hockey fields. The availability of this percentage of soccer fields would also explain the high numbers of male students who claimed to have played sport regularly. Thirty-three percent of students indicated that their schools had netball courts and only two students said that their school had a swimming pool.

Problems preventing students from attending school

In the past couple of decades in South Africa, there have been many disruptions in education. It seemed pertinent to try and ascertain what problems had existed in reality for these students.

Students were asked whether or not they had ever experienced any problems that prevented them from attending school. These were problems related to **transport**, the **weather**, **political** unrest, **pupil** strikes, **teacher** strikes and damaged **school** buildings. Students were asked to indicate to what degree these problems had affected their schooling and the time that was lost.

two months. This single factor far outweighed any other factor preventing students from attending school.

- Many schools also had their schooling disrupted by teachers' strikes. More than half of the students (57.5%) in this sample experienced some disruption of this nature, in their matric year. Two students had no schooling for up to five months because of teachers' strikes.

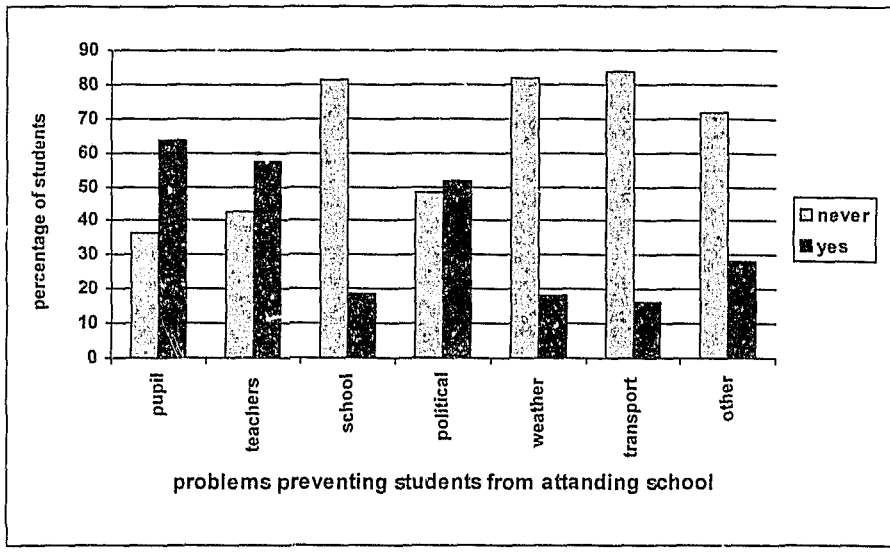
- Political violence raged through schools from the 1970's onwards, and 52.6% of the students had their schooling disrupted at some stage in their matric year due to **political unrest** (with one student losing a year's schooling in the process).

- At the height of political violence, some schools were burned down or damaged in some way. Whilst the majority (81%) of these students claimed never to have had any problems caused by **damaged school property**, the remaining 19% claimed to have had disruptions caused by this. Only three students had schooling disrupted for more than two weeks.

- During the years when most of these students were in their matric year, there were often problems with **transport** including strikes on trains and taxi clashes. However, because so many of these students walked to school, presumably in the rural areas and only a small proportion had to use transport, this was presumably the reason that only 16% of the students missed school. None claimed to have missed more than two weeks in their matric year because of this.

In summary, the students' schools situation was typically as follows:

Figure 5.10 Problems experienced by students at their school



From of the list of specific problems, those affecting the majority of students were **pupil strikes**, **teacher strikes** and **political unrest**. Damage to the school and problems relating to the weather and transport had a negligible affect on the students' attendance. Almost a third of the students however, indicated that they had had other problems preventing them from attending school as well.

- In the political climate of the 1980's and 1990's many schools became politicised and many pupils aligned themselves to (or were coerced to join) political factions. During clashes with other factions and with government forces, schooling was disrupted. Many students in this sample claimed to have had their schooling disrupted from anything between two weeks and six months. **Pupil strikes** affected more than 60% of the students. Of the 63.5% who had been affected, 30% said that the disruption had been two weeks or less. Only 3% of the students had been affected for longer than

they were mostly rural schools with laboratories and libraries, but no computer facilities. They had recreation facilities such as soccer fields and netball courts. Pupil strikes, teacher strikes and political violence were common, causing pupils to miss several weeks of schooling.

Matriculation results

Matriculation symbols are considered irrelevant as predictors for future careers and achievement by some circles in education. There are studies that have shown that this not the entirely the case (Louw, 1994; Saayman, 1991; Huggins, 1994) and there is merit in using them (sometimes in combination with other factors) as predictors of future academic success. Most universities and technikons in South Africa continue to use these symbols as part of a selection procedure to select students into courses, especially competitive courses such as medicine and engineering.

In this study, students were asked to indicate what subjects they had taken for matric, on what grade their examinations were written and what symbols they had achieved. The four science subjects, biology, geography, mathematics and physical science, were analysed more closely and are discussed here. In terms of the students selected, only students having written physical science at matric level were tested.

Grade level of science subjects

All of these students were selected based on the criteria that they had taken physical science as a subject for matric. More than half of the students (52%) stated that they took **physical science** on the HG for matric. In 1994

only 5 275 out of 40 345 (13%) African students who wrote physical science passed. No matriculation figures per ethnic group and per subject were released in 1995 and 1996. However, between 1991 - 1994, an average of 15% of African students passed physical science for matric, (FRD, 1996)

Ninety-seven percent of all the students in the sample took **mathematics** for matric. Forty-eight percent of these took mathematics on the HG. The figures for mathematics in 1994 were lower than for physical science, with 4558 out of 45 829 (10%) African students passing mathematics on higher grade. No matriculation figures per ethnic group and per subject were released in 1995 and 1996. However, between 1991 - 1994, an average of 12% of African students passed mathematics for matric, (FRD, 1996)

- Mathematics was the only subject where any students (n = 4) took a matric examination on the "functional " (lower) grade.

Table 5.12 Percentage of students taking science related subjects

grade	number of students taking biology for matric	number of students taking geography for matric	number of students taking maths for matric	number of students taking physical science for matric
higher	112	15	70	78
standard	31	6	72	70
lower	0	0	4	0
total	143	21	146	148

- Ninety-six percent of students took **biology** on the HG. Biology, is the most popular science subject (Howie and Hughes, 1998) and is considered by students to be one of the easier subjects, out of all the science-related subjects, to take on HG, and would have been an obvious choice for most students in order to qualify for a matric exemption to enter higher education. In total 75% of the students took biology on the HG.

- In contrast to biology, only 14% of students took **geography**. Geography is not a popular subject amongst South African students (Howie and Hughes, 1998) and it is not considered to be an easy subject for matric. Most students in this sample taking geography, took this subject on the HG.

Students' matric symbols in science subjects

There was a wide range of symbols for all subjects, except for geography where only a small number of students had taken this subject. It was unexpected to find symbols at the extreme ends of the range from A-symbols

to GG-symbols. Most students with A, B or even C-symbols go to university and it was surprising to find a few students with these marks at the colleges. It was also disturbing to find students with very low symbols such as F, FF, G and GG at the colleges. As these were to be found mainly amongst the results for physical science and mathematics, this could perhaps indicate the desperation of the colleges to find students with appropriate matric subjects for specialist training.

Table 5.13 Students' achievement in physical science, mathematics and biology across grades

SYMBOL ACHIEVED	PHYSICAL SCIENCE % of students		MATHEMATICS % of students			BIOLOGY % of students	
	HG	SG	HG	SG	FG	HG	SG
A	0	0	1	0	0	0	0
B	0	1.5		7	0	2	0
C	5	1.5	3	15	25	1	3
D	9	16	22	18	25	22	10
E	69	47	52	33	25	58	62
F	14	31	11	21	25	16	25
FF	0	1.5	0	0	0	0	0
G	0	0	4	3	0	1	0
GG	3	0	0	0	0	0	0
H	0	1.5	7	3	0	0	0

- The marks for **mathematics** were higher than for the other subjects. The marks ranged from A-symbols to H-symbols. It was surprising to find a student with A-symbol on the higher grade (HG) at a college of education, although there was only one with this symbol. Twenty-six percent of the

higher-grade students obtained a symbol D or higher. Fifty-two percent achieved an E-symbol. On the standard grade (SG), only 40% of the students achieved a D-symbol or higher. Once again, a large number (33%) of students had an E-symbol. However, it was interesting to find that colleges had admitted students with F-, G- and even H-symbols across both grades. In fact about a quarter of the students in this sample had these very low symbols, equivalent to less than 40% on their matriculation examination.

- The majority of these physical science students also had **biology** as a subject at school. Although, biology is regarded as the easiest science subject at school, only 25% of the HG students and a mere 14% of the SG students obtained a D-symbol or higher. More than 58% of HG and 62% of SG students had achieved an E-symbol. Alarming though was that so many students, 19% in total, who achieved lower than an E-symbol (17% HG and 24% SG) were still able to study general science at college (which includes biology).

- The marks for **physical science** in matric ranged from a B-symbol (on SG) to a H-symbol (also on SG). Only 14% of HG students and 19% of SG students had a D-symbol or higher compared to 26% (HG) and 40% (SG) of students for mathematics. Even though only 4% of the students had achieved C-symbols, it was encouraging to see that at least some students with C-symbols (in higher and SGs) in science are attending colleges of education. The majority of students, 69% of HG students and 47% of SG students had an E-symbol (40-49% for their matric examination). Twenty-five percent of the students (across both grades) had lower than an E-symbol (less than 40% for their matriculation examination).

Whilst it seems unbelievable that a student should be admitted to a science course inside a teacher training college with such very low symbols. This is not uncommon in colleges where there is pressure to find African students willing to do science courses and where there is a dire shortage of students. These findings are confirmed by comments of three colleges lecturers surveyed at the RADMASTE workshop earlier in the study who said that ***"My experience for the last 7 years is that those who register for physical science and maths courses at the college are coming with very poor symbols in those subjects in the matric G/SG exams. The ones with better marks get into universities and those rejected by the universities and technikons, get into the college."*** and ***Most students have only E or F on SG for matric*** and finally, ***The students I meet come with G and H and I have to start all over again."***

So, to summarise: all students took physical science; 97% took mathematics and 96% took biology for matric. The matriculation symbols are generally low for all three subjects.

- For physical science, the symbols for physical science range from a "C" to a "GG" on higher grade and from "B" to a "H" on standard grade. Most students had an "E" or an "F".

- For mathematics, the higher grade results varied from an "A" to a "H" and on standard grade from a "B" to a "H". Most students obtained an "E" symbol.

- The majority of students took biology on the higher grade and obtained mostly an E symbol.

Students' attitudes to science at school

It is thought that students' attitudes towards science may have an effect on students' interest, motivation and enrolment in science courses and other science-related activities (Morrell and Lederman, 1998). A number of studies have shown the importance of students having positive attitudes towards physical science and how motivated students produce better results than unmotivated students (Morrell and Lederman, 1998; Woolnough, 1997). Woolnough (1997a: 67) makes the point that "*unless students appreciate, enjoy and want to do science, it matters little what they know or can do*" and this is an important aspect often overlooked by policymakers as this human element is more difficult to change than physical factors such as textbooks or policy changes. In fact Woolnough, in particular, calls for teachers and lecturers *to "focus more on motivational factors in our science teaching*".

It is also important to note that Fraser (1982) (supported by Menis, 1989) found a weak relationship between attitudes and achievement and suggested to science educators wishing to improve their students' achievement to concentrate on the subject matter rather than on attitudes towards science.

In this study, students were asked to select from a list of options (not a scale), which terms described their attitudes towards science. The results of the students selection of the terms that best described their attitudes to physical science at school were found and are listed in table 5.14,

Table 5.14 Students' attitudes toward science at school

Descriptors selected by students	Percentage of students selecting the descriptor
Science was challenging	79.9%
Student enjoyed science	50.3%
Science was exciting	35.6%
Science was fun	16.8%
Science was difficult	15.4%
Science was easy	12.8%
Science was dull	4.7%
Science was boring	3.4%

On the whole the students' attitudes to physical science seemed to be positive. The most common descriptors used were "enjoy", "exciting" and "challenging". These positive attitudes amongst the students coincide with the findings of the TIMSS study in South Africa amongst a general sample of matric students (including those who did not take science) who exhibited positive attitudes to science. This was despite their poor performance in the general mathematics and science literacy test (Howie and Hughes, 1998). However, this and the TIMSS findings are in contrast to studies overseas, such as Morrell and Lederman, 1998 and Woolnough, 1997, amongst others which find a negative attitude amongst science students more generally. This could be due to the socially desirable perspective of completing such a questionnaire, in other words students perhaps seeking to answer in the manner that they perceive is desirable to those asking the questions rather than their own true feelings. This could also be attributed to the differences across cultures with respect to answering attitudinal questions.

Fifty percent claimed to have enjoyed science at school, however the reverse is also true - 50% did not select this descriptor, probably indicating that they had not enjoyed science at school. The other anomaly was that only 15.4% of the students claimed to have found science difficult and a mere 12.8% of the students found science easy and there appears to be no explanation for the remainder of the students. Although, 79.9% of the students did select the descriptor "challenging", which could also be a euphemism for finding science difficult, hence a possible total of 95.3% (79.9% + 15.4%) may find physical science difficult.

Students' opinions about doing well in science

Students were asked to give their opinion, as shown in Table 5.15 about what qualities were necessary for students to do well in science.

Table 5.15. Students' opinions about what is necessary for a student to do well in science

Qualities needed to do well in science	Percentage of students
Lots of studying	75%
natural ability	8.8%
lots of memorising	3.4%
luck	0%
studying and ability	8.8%
studying and memorising	4.1%

The results showed that students believe that hard work rather than ability, is necessary to do well in science. The majority of students seemed to think that lots of studying was required. This far outweighed any other single factor. In very few cases (8.8%) students thought that ability combined with studying was the answer to success.

Students' opinions on making science enjoyable at school

Students' opinions were solicited concerning what would make physical science more enjoyable at school.

Table 5.16 Factors contributing to the enjoyment of students of science at school

Factor	percentage of students
more practical work and experiments	37.4%
visits	0.7%
competitions	0.7%
teacher	4.1%
relevance of science topics	1.4%
videos	0.7%
exploration	2.7%
more than 1 factor	52.4%

As can be seen by Table 5.16, 52% of students felt that more than one factor contributed to making science enjoyable. Thirty-seven percent of the students felt that more practical work and experiments contributed to making science enjoyable. Very few students felt that visits, competitions, relevance

of the topics, videos, self-exploration on their own or teachers, made science enjoyable. This is an interesting finding as Woolnough's (1994) research indicates that teachers are by far the most important factor in making science enjoyable for students - does this say something about our teachers' competence/ performance in the classrooms?

Students' confidence in their understanding of science

The students were asked to indicate their level of confidence in their understanding of the science topics that according to the curriculum, they should have covered by the end of their matric year. Table 5.17 includes only the results of the topics that were tested.

Table 5.17 Students' confidence in their understanding of science

SCIENCE TOPICS	CONFIDENCE LEVELS percentage of students			
	not confident at all	*a little confident*	*confident*	*very confident*
Electrostatics	9.7%	35.4%	42.4%	12.5%
Oxidation Reduction	9.8%	38.5%	36.4%	15.4%
Displacement/Velocity	4.8%	24.0%	39.0%	32.2%
Periodic Table	3.4%	24.5%	38.8%	33.3%

The confidence levels tended to be higher than one would have expected considering the matric symbols obtained by the students. Students appeared

to be most confident in their understanding of the topics displacement/velocity and the periodic table where 71.2% and 72.1% respectively, were either confident or very confident about their understanding of these topics. Nevertheless, the confidence levels for electrostatics and oxidation-reduction were also relatively high with 54.9% and 51.8% of the students respectively, feeling confident or very confident about their understanding of these topics. These results are analysed in their relation to the students' performance in these topics in Chapter 6.

In summary, it seems that students' attitudes towards science are positive, despite the fact that they appear to find it difficult. Students believe that hard work will bring good results and that practical work is the single, most important factor in making physical science enjoyable at school. Finally, the students' confidence in their understanding and physical science knowledge does not seem to correspond with their matric performance in this subject.

5.4 STUDENTS' CHOICE OF CAREER

Parents' influence in students' career choice

It is believed that the influence of the parents, especially the mother, plays a role in students' choice of career. In this research project, students were asked to indicate the career path that their parents had wished them to follow after school.

Table 5.18 Career path advocated by parents

Parents wishes	Percentage of students advised by parents
job	10.2%
apprenticeship	2.0%
technikon	12.9%
university	39.5%
college of education	29.9%
technical college	0.7%
other	4.8%

As can be seen by Table 5.18, the majority of these students' parents wanted them to attend a university or college of education. Almost a third (29.9%) of the students' parents wanted the students to follow the career path of teaching. This could be due to the fact that they saw Colleges of Education as being a stepping stone for their children's advancement in life or the fact that the older generation still has a high regard for the teachers in their community. It is significant that 82.3% of the students' parents wanted

them to attend a tertiary institution after school, particularly in view of the nominal percentage of parents that had themselves attended higher education (see section 5.2). It is clear that the parents wanted their children to improve their standard of living in the future and saw education as a means to this.

Teachers' influence in students' career choice

Career counselling in the traditionally African schools is very seldom carried out (FRD, 1996). Therefore it seemed appropriate to ascertain whether or not these students, who would have been considered some of the higher achieving students at school (see 5.1.3), had received any advice from their teachers as to their career path.

Table 5.19 Teachers' advice to students about career paths

Teachers' advice	Percentage of students advised by teacher
technikon	24.0%
college of education	16.4%
job	7.5%
apprenticeship	2.1%
university	24.7%
technical college	0.7%
other	2.1%
did not advise	22.6%

Approximately 23% of the students did not receive any advice from the teachers. A quarter (24.7%) of the students were advised to go to university and a further 24% were advised to go to a technikon. Only 16.4% of the students' teachers advised them to attend a College of Education in comparison with 30% of the parents. Very few teachers advised their students to get a job, go into an apprenticeship or go to the technical college. This could be construed as teachers having little knowledge firstly about career options generally and secondly, about the needs of South Africa and its economy.

Students' own choice of career path

Students were asked whether or not teaching/attending a college of education was their first choice of career after school. Seventy-nine percent of students replied no to this question. The implications of this are alarming. This means that only 20% of the students went into the college, as their first choice, intending to teach from the outset. If it was not their first choice, this could influence their motivation for becoming teachers. This finding is supported by comments of lecturers surveyed at the college lecturers' RADMASTE workshop. An example of this was one lecturer who reported that: ***the ones (students) with better marks get into universities and those rejected by the universities and technikons, get into the college.***" There are also significant financial implications, as the Colleges then become very expensive bridging courses and will not necessarily prepare the students in the best way for their own hoped for future career.

When asked about their first choice, the majority of students indicated that they had wanted to go to university (again confirmed by the college lecturer's comment above). There were probably two main reasons why the students

did not go to university. These would have been that their matric marks were too low, thus disqualifying them from the limited number of places at university or secondly that they had financial constraints.

Table 5.20 Students' first choice of career path

FIRST CHOICE OF CAREER PATH if not College of Education	PERCENTAGE OF STUDENTS
technikon	27.8%
employment	3.5%
university	56.5%
apprenticeship	3.5%
technical training	2.6%
other	6.1%

After university, the next most common choice was that of the technikon and this is interesting to note. The population distribution within the technikons has changed drastically in the past few years as more and more African students are attending technikons. These enrolments have risen from 752 African students enrolled in 1985 to 41 133 in 1993 (FRD, 1996).

Students' selection of a particular College of Education

The majority of the students indicated that the reason for them selecting the college, was the reputation of the college. This reputation, though difficult to quantify, would mostly certainly have been the result of the perceptions of the community and the students' family. The next most popular reason was the advice from their parents. The influence of friends played a minor role in

students' selection of the college and the proximity to home played a surprisingly small role as well.

Table 5.21 Student's reasons for selecting Colleges

REASON FOR SELECTION	PERCENTAGE OF STUDENTS
reputation	44.1%
teachers	5.5%
parents	19.3%
friends	2.1%
closest to home	6.2%
more than one reason	7.6%
other	15.2%

Anticipated length of study at College

Seventy-seven percent of students indicated that they would finish their diploma in the minimum time, which at these Colleges of Education would be three years. Another 18.4% stated that they would take up to two extra years for their studies and a very small proportion (4.8%) of students said that they would take longer than five years.

Table 5.22 Students' anticipated length of study at Colleges

ANTICIPATED LENGTH OF STAY AT COLLEGE	PERCENTAGE OF STUDENTS
Minimum time - 3 years	76.9%
Minimum time plus 1 year	4.8%
Minimum time plus 2 years	13.6%
Longer	4.8%

The fact that about one-fifth of the students thought that they would need more than the minimum time already early in their first year of study is most alarming. It could be an indication of their low confidence levels in their performance at the College based on their previous weak performance at school.

Anticipated length of teaching career

The majority of students (55.7%) intended to teach 5 years or fewer. Only 27.5% of the students saw teaching as a long term career and intended to teach for more than 20 years. The fact that for the majority of the students (79%), teaching was not their first choice of career must be related to so many of these students intending to make teaching only a short-term career.

5.5 ANALYSES OF STUDENTS' BACKGROUND VARIABLES

Using the statistical procedures outlined in Chapter 4, analyses were conducted concerning the relationship between different types of students' background variables. On the whole, few relationships were found between variables previously described under the **Students' profile** and **students' home environment** (the frequencies of which were presented in 5.1 and 5.2). The greatest number of relationships were to be found amongst or between variables concerning the **students' school environment** and **students' performance** and the **students' career choice** (the frequencies of which were given in 5.3 and 5.4). The results of these analyses are discussed and are given in detail below. Only those relationships that are statistically significant are presented.

In order to conduct the analyses (using the chi-squared test) concerning the matriculation results, it was necessary to convert the matriculation examinations symbols first, into a combined point scale. The reason for this is that many of the students, as reported earlier, obtained symbols on different grade levels (e.g. higher grade versus standard grade, as indicated in 5.3). A point scale of 1-10 was chosen to convert the matriculation symbols as shown in Table 5.23.

Table 5.23 Matriculation symbol conversion Table

Symbol	Higher Grade	Standard Grade	Functional Grade
A	10	8	6
B	9	7	5
C	8	6	4
D	7	5	3
E	6	4	2
F	5	3	1
FF and lower	0	0	0

The scale used was a 10 point scale with 1 being awarded for the lowest symbol allowed here, an "F" Functional/lower grade symbol and the maximum being a 10 for an "A" higher grade symbol. So, students achieving 6 points on this scale could have an "A" symbol on the functional grade or a "C" symbol on the standard grade or an "E" symbol on the higher grade.

5.5.1 Factors relating to students' choice of teacher diploma course

- ***The majority of the STD students were less than 22 years of age.***

There was a significant association, ($p < 0.01$) between the course that the students were following (i.e.: Senior Primary Teachers Diploma (SPTD) or Secondary Teachers Diploma (STD)), and the age of the students. Of the 107 students electing to follow the STD course, 79 were under the age of 22 years of age (74%) compared to only 12 out of the 41 (29%) students following the SPTD course. This raises a number of interesting questions

about the reasons for this. One could speculate that this could be the result of the recent awareness campaigns regarding the importance of science subjects or perhaps some success in attracting eligible students via the government bursaries for science students at Colleges of Education.

- ***STD students had higher mathematics symbols in matric.***

An association (p = 0.16) was found between the students' diploma course (SPTD/STD), and their mathematics symbols for matric. No SPTD students obtained more than 7 points compared to 3% of STD students. Fifty-three percent of the STD students achieved 6 points or higher compared to 28% of SPTD students. The correlation could be due to the fact that a higher symbol for mathematics would have been required for the STD course than for the SPTD course.

- ***The STD students achieved higher matric physical science marks than the SPTD students.***

  A significant association (p < 0.001) was found between the students' course and the students' matric science symbols. Eight percent of the SPTD students achieved fewer than 3 points, in contrast to the 0% of STD students. Fifty-three percent of the STD students scored 6 points or higher compared to the 29% of the SPTD students. This finding is similar to that of the matric mathematics marks.

- ***The majority of STD students came from schools in rural areas***

  A significant association (p < 0.001) was found between their diploma course and the area where the students' school was located.

Table 5.24 Location of the school and students' course

School location	Senior Primary Teachers' Diploma course % of students	Secondary Teachers' Diploma course % of students
isolated rural areas	22	28
rural villages	20	34
rural town	0	15
city centres	36	11
outskirts of cities	22	12

As can be seen from Table 5. 24 the majority of students who attended school in rural areas are those following the STD course (77%:42%). More than a third (36%) of the students taking the SPTD course are those from city-centres.

- ***The majority of the STD students came from rural areas.***

An association ($p < 0.01$) was found between the students' course and the area where students had grown up.

Table 5.25 Area where students grew up and course

Area where students grew up	Senior Primary Teachers' Diploma course % of students on course	Secondary Teachers' Diploma course % of students on course
city centres	29	10.4
outskirts of cities	32	23.3
rural town	10	11.3
isolated rural areas	29	55

As can be seen from Table 5.25, the majority (66.3%) of the students who are taking the STD course grew up in rural areas. The majority of the students taking the SPTD course (61%) grew up in the urban areas.

5.5.2 Factors relating to the students' performance in mathematics in matric

- ***The students from rural areas achieved higher mathematics results in matric***

It appears from Table 5.26, that the performance of rural students is generally better than that of the urban students.

Table 5.26 The relationship between students' performance in mathematics and home areas of the students

Mathematics symbol converted to points	urban (n = 60)			rural (n = 84)		
	city centre *% of students (n = 23)*	outskirts - city *% of students (n = 37)*	mean % urban	towns *% of students (n = 15)*	isolated areas *% of students (n = 69)*	mean % rural
6 - 10	17	56	42	33	58	54
4-5	43	30	34	33	28	28
2-3	30	0	12	14	10	11
1 and lower	10	14	12	20	4	7

Fifty-four percent of the students from rural areas achieved 6 points and higher in mathematics, compared to 42% of those from urban areas. The highest performing single group of students came from the isolated rural areas. However, whilst the top-achieving students from this group are comparable percentage-wise to the urban students from the outskirts of the city, there are fewer rural students in the lowest two categories of points.

- ***Students from rural schools had achieved higher mathematics symbols in matric.***

There appears to be a relationship between the location of the students' school (e.g.: urban/rural) and the students' mathematics symbols in matric, as can be seen from Table 5.27.

Table 5.27 The relationship between students' performance in mathematics and the areas the students' schools were located in

Maths-points	urban (n = 48)			rural (n = 95)			
	city centre *% of students (n = 26)*	outskirts of city *% of students (n = 22)*	mean % urban	towns *% of students (n = 16)*	rural villages *% of students (n = 42)*	isolated areas *% of students (n = 37)*	mean % rural
8 - 10	0	0	0	0	2	5	3
6-7	35	45	40	37	52	54	51
4-5	31	41	35	44	31	19	28
0-3	34	14	25	19	15	22	18

The achievement of students attending rural schools is generally higher than that of the students attending urban schools. Fifty-four percent of the students from rural schools achieved 6 points and higher, compared to 40% of those from urban schools. The highest performing single group of students (59%) came from the schools in the isolated rural areas. This may be due to the fact that these students are more dedicated students who study more on their own and that they read more than their urban peers.

- ***The students' performance in mathematics was directly affected by the disruption of their schooling in matric.***

Table 5.28 Factors relating to the disruption of schooling and mathematics achievement

Mathematics marks converted to points	School Missed Political Unrest % of Students		School Missed Students' Strikes % of Students		School Missed Teachers' Strikes % of Students	
	never n = 57	yes n = 61	never n = 49	yes n = 86	never n = 56	yes n = 75
6-10 points	58	43	61	40	62	37
4-5 points	32	26	26	33	25	35
3 points	10	13	11	13	9	13
2 points and below	0	18	2	14	4	15

1. There was a significant association ($p < 0.01$) found between the mathematics marks and the number of weeks/months that the student was absent due to **political unrest** in the schools. As one can see from Table 5.28, 58% of students who had never missed schooling, due to this reason, achieved 6 points or higher for mathematics compared to 43% of students who had had disrupted education. Many more of the students who missed schooling also achieved lower results (3 points and fewer) than students who did not (31 % compared to 10% respectively).

2. As can be seen from Table 5.28, students who missed school, due to **strikes by students**, achieved lower mathematics results (on the whole) than students who never did. Sixty-one percent of those students who did

not miss school achieved 6 points and higher compared to 40% of those who had missed school and only 2% of the students who never missed school scored 2 points or fewer compared to 14% of the others.

3. The mathematics marks showed a highly significant association ($p < 0.001$) with the students' absence from school due to **strikes/stayaways by teachers**. As can be seen from Table 5.28, 63% of students who had not missed any schooling obtained 6 points and higher compared to only 37% of absent students. Only 13% of students not missing school obtained 3 points and lower compared to 28% of students who were absent.

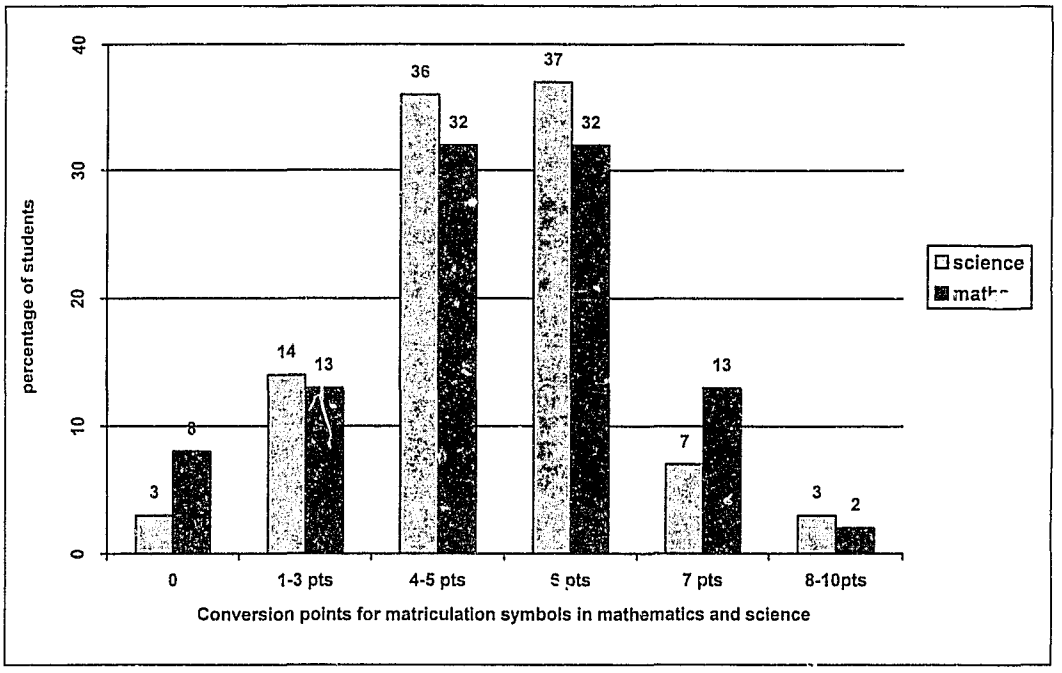
In analysing the absenteeism of students due to problems relating to political unrest, strikes by students and strikes by teachers, one can conclude that the students were disadvantaged by the disruptions. What is remarkable is that 40% of those students achieving more than 6 points had had attained these results despite a disrupted schooling. These findings highlight the apparent need for continuity in mathematics teaching and learning for the lower achieving students more especially, perhaps due to the sequential nature of mathematics.

5.5.3 Factors relating to the students' performance in Physical Science in matric

- ***Students performance in physical science was directly related to their performance in mathematics.***

Students' physical science matric results were found to have a highly significant association ($p < 0.001$) with their mathematics matric results.

Figure 5.11 The relationship between the mathematics and physical science points average obtained for matric



In Figure 5.11, the students' points average for their mathematics and physical science matriculation results is given. From the analysis, it is apparent that the students overall performance for mathematics is comparable to that of physical science. Forty-seven percent of the students' achieved between 6 and 10 points for both subjects.

- ***Students' performance in physical science in matric was linked to where students grew up.***

Table 5.29 The relationship between the students' area of origin and their performance in physical science.

Physical Science symbol	urban (n =59)			rural (n = 86)		
	city centre % of students (n = 23)	outskirts of city % of students (n = 36)	mean % urban	towns % of students (n = 16)	isolated areas % of students (n = 70)	mean % rural
7-8 points	4	11	8	12.5	10	10
5-6 points	35	44	41	75	53	57
3-4 points	57	39	46	12.5	36	31
fewer than 3 points	4	6	5	0	1	1

As can be seen from Table 5.29, generally students originating from rural towns appeared to perform better in the physical science matriculation exam than their counterparts in the other three areas. Overall, 67% of the rural students achieved between 5-8 points compared to 49% of the urban students. In particular, 87% of students from rural towns obtained between 5-8 points compared to the other groups (39%, 55% and 63%. However, students from the city centre performed poorly and 61% of the students obtained four points or fewer.

- ***Students' performance in physical science was linked to where their school had been located***

  As can be seen in Table 5.30, the top-achieving physical science students (obtaining between 7-8 points) came from schools in rural towns (13%), and schools in isolated rural areas (13%).

Table 5.30 The relationship between the students' school location and their physical science marks

Physical Science points	urban schools (n =48)			rural school (n = 96)			
	city centre *% of students (n = 27)*	outskirts of city *% of students (n = 21)*	mean % urban	towns *% of students (n = 16)*	rural villages % of students (n = 41)	isolated areas *% of students (n = 39)*	mean % rural
7-8 points	9	7.5	**8**	13	7	13	**11**
5-6 points	48	37	**42**	50	54	59	**55**
3-4 points	38	48	**44**	37	37	28	**33**
fewer than 3 points	5	7.5	**6**	0	2	0	**1**

Forty-three percent of students from schools in city centres and 55% of students from schools on the outskirts of cities obtained four points and fewer, compared to 37%, 39% and 28% of students from schools in the three rural groups. Overall, students who attended schools in the rural areas performed better than students attending schools in the urban areas as 66% of rural students achieved between 5-8 points compared to 50% of urban students.

- ***Students' performance in physical science in matric was affected by disrupted schooling in their matric year.***

  A relationship was found between the absence of students from school due to *political unrest*, *strikes by students* and *strikes by teachers* and the students' physical science matriculation symbols.

Table 5.31 Factors relating to the disruption of schooling and physical science achievement

Physical science symbol achieved for matric	Political Unrest % of Students (N = 119)		Students' Strikes % of Students (N = 134)		Teachers' Strikes % of Students (N = 131)	
	never (n = 58)	yes (n = 61)	never (n = 49)	yes (n= 85)	never (n=56)	yes (n= 75)
7-8 points	17	3	12	8	16	5
5-6 points	57	45	61	44	57	43
3-4 points	26	49	25	46	23	49
fewer than 3 points	0	3	2	2	4	3

1. in particular, there was a association ($p < 0.01$) found between the disruption of schooling, caused by **strikes carried out by students,** and the physical science average points obtained. As shown in the Table 5.31 above, students whose schooling was not disrupted performed better overall than those who had missed school. Seventy-three percent of students who never had their schooling disrupted achieved between 5-8 points compared to 52% of the students whose schooling was disrupted.

2. There was a relationship between the amount of school lost by students due to **political unrest** and their physical science results in matric. As can be seen in Table 5.31, 74% of students who had not had their schooling disrupted achieved between 5 - 8 points compared to only 48% of those students who had missed school. Of the students missing school, 49% obtained between 3-4 points compared to only 26% of those who had not.

3. There was a highly significant association ($p < 0.001$) found between schooling lost due to **teachers' strikes** and the physical science points average obtained by students. As can be seen in Table 5.31, 73% of the students who had not missed school achieved between 5-8 points compared to only 48% of students who had missed schooling. There was also a significant difference between the two groups of students scoring between 3-4 points and 49% of students who missed schooling attained this compared to 23% of students who did not miss schooling.

- Generally, those students who did not have their schooling disrupted achieved higher marks for physical science:
    - 12%-17% obtained 7-8 points compared to 3% - 8%
    - 57%-61% achieved 5-6 points compared to 43%-45%
    - 23% - 26% obtained 3-4 points compared to 46% - 49%

5.5.4. Factors relating to the schools' facilities and the achievement of students in mathematics and physical science in matric

The relationship between the schools' facilities in the students' matric year and their achievement in mathematics and physical science was also investigated. Whilst no relationship was found between the students' achievement and the presence of facilities/equipment, such as laboratories, libraries or computers, an association ($p = 0.02$) was found between the presence of **playing fields** and students' physical science matric results. The most probable reason for this is that the schools with these facilities might be those schools with better overall resources which would possibly attract better quality physical science teachers and contribute to better morale and a positive school ethos.

5.5.5. Factors relating to the year that students completed matric

Students' performance in physical science was directly related to the year that they matriculated.

The physical science points average for matric were found to have a significant association ($p < 0.001$) with the year that students matriculated in.

Table 5.32 Students' performance in physical science and their matric year

Points average for physical science	1982 - 1987 n = 5	1988-1993 n = 65	1994-1995 n = 69
8-10 points	1	1	2
6-7 points	2	26	33
4-5 points	2	25	23
0-3 points	0	13	11

Students matriculating in the years after 1993 had higher physical science marks on average than those matriculating prior to 1993. For instance, 51% of the students matriculating after 1993 achieved 8-10 points compared to 43% of students matriculating prior to 1994. Only 16% of the 1994/1995-matric students obtained 0-3 points compared to 19%.

- ***Students performance in mathematics was related to their matriculation year.***

The mathematics points average for matric were found have an association ($p < 0.01$) with the matric year of the students.

Table 5.33 Students' performance in mathematics and their matric year

Points average for mathematics	1982 - 1987 n = 5	1988-1993 n = 64	1994-1995 n = 69
8-10 points	1	2	0
6-7 points	2	27	33
4-5 points	1	19	24
0-3 points	1	16	12

Students matriculating in the years after 1993 had better overall mathematics points averages than those matriculating prior to 1993. The top performing students were comparable, and 48% of 1994/1995 matriculants achieved 6-10 points compared to 46%. However, only 17% of the 1994/1995 matriculants achieved 0-3 points compared to 25% of the 1982-1993 matriculants

- ***Students' enrolment at the Colleges was directly related to their matriculation year***

  There was a highly significant association ($p < 0.0001$) between the year that the students finished matric and the college they are presently studying at.

Table 5.33 Students' matric year and their College of Education

Year of matric	College A % of students	College B % of students	College C % of students	College D % of students	College E % of students	College F % of students
1982-1987	7	2	0	0	14	0
1988-1992	79	26	26	7	9	26
1993-1994	14	55	74	7	54	61
1995	0	17	0	86	23	13

As can be seen from Table 5. 33, only College D's cohort of students came primarily (86%) from the 1995 matric year and 14% from previous years. The majority (74%) of College C's students matriculated in either 1993 or 1994. Interestingly, 79% of College A's students matriculated between 1988 and 1992.

It is clear that students in this sample matriculating in the three years prior to their entry to the colleges were more likely to have better mathematics and science symbols than students matriculating earlier than 1993. Furthermore, this also appeared to have an influence on what college students enrolled at.

5.5.6 Factors relating to the length of time that students intended to study

- ***Students' commitment to teaching was linked to whether a College of Education was their first career choice.***

  A relationship was found between how long students intended to teach for and whether or not studying at a college of education was their first choice of career path.

Table 5.38 Relationship between choice of teaching career and intended teaching time

No. of years students intending to teach for	Teaching career - first choice % of students	Teaching career - not first choice % of students
fewer than 5 years	13	33
5-10 years	32	36
15 years	3	5
20 years and more	52	26

As can be seen from Table 5 38, those students who had entered into the college as their first choice of career were the students intending to make teaching their long-term career. Fifty-five percent of these students intended to teach for 15 years and longer compared to thirty-one percent of students who had had alternative career aspirations.

5.5.7 Factors influencing students' career choice

Parents played a significant role in students' choice of career

There was a significant relationship ($p < 0.01$) between the students' desire to go to the college of education as a first career option and what the parents had advised them to do. Thirty percent of the students' parents advised them to go to a College of Education. Thirty-nine percent of the students had followed their parents' advice by attending a College of Education, considering it their first career choice.

- There was a significant association ($p<0.001$) between the parents' advice on careers given to the students and the students' alternative choices of career. Students tended to indicate careers that generally related to the advice given by their parents (see Tables 5.18 and 5.20).

Teachers played a role in students' choice of career.

- A significant association ($p <0.01$) was found between the students' career choice and the advice given by teachers. It would seem that teachers appeared to be more influential than the students' parents when it comes to students choosing their career paths (see Table 5.19). Seventeen percent of the students' teachers advised them to go to Colleges of Education. Of the students given this advice by their teachers, 46% selected the colleges as their first choice of career.

- The students' aspirations for an alternative choice of career also had a significant association ($p < 0.001$) with the advice given by the teachers.

There was a difference between male and female students' career aspirations.

The gender of the students was found to influence students who had intended following an alternative career path. An association ($p = 0.04$) was found between the gender of the students and their alternative career choice.

Table 5.36 Students' gender and their career choice

First Career Choice	Male Students % of students selecting career	Female Students % of students selecting career
technikon	55	45
job	0	100
university	44	66
apprenticeship	75	25
technical college	33	67
other	0	100

As can be seen from Table 5.36, of those students wanting to study at university, 66% were female. Of the students wishing to study at the technikon, 55% were male. All the students wishing to find employment and seeking other career options, were female students. Most of the students wishing to go into apprenticeship training were male.

Table 5.37 Students' anticipated length of teaching career

ANTICIPATED LENGTH OF TEACHING CAREER	PERCENTAGE OF STUDENTS
1 year	4.7%
2-4 years	24.2%
5 years	26.8%
10 years	8.1%
15 years	4.7%
20 years	4.0%
more than 20 years	27.5%

In total, only 44% of the students intended making teaching a career and 56% would teach for five years and fewer. Most disturbing is the fact that Colleges of Education are not the first choice for the vast majority of students. In general, the typical College student was advised by parents and teachers alike to attend a university and failing that had heeded the advice, primarily given by the parents to attend a College of Education.

5.6. CONCLUSION

The students ages varied tremendously (see table 5.1) and across colleges (see table 5.2. Fifty-seven percent of the students were female and the gender of students varied from college to college (see 5.4). The composition of College F's cohort comprised 76% female students compared to only 30% females in College C. These percentages are significantly different to the sample overall where 57% were female students. Within the diploma courses, there were also differences regarding gender. In the Senior Primary

Teachers' diploma, 69% of students were female compared to 52% in the Secondary Teachers Diploma courses.

Two-thirds of the students came from rural areas (see table 5.4) and had attended schools in rural areas (see Figure 5.9). Students' parents generally had low levels of education (see figure 5.6) and less than 9% of parents had attended tertiary education institutions. In general therefore these students were first generation tertiary students.

The students' performance in physical science and mathematics in matric was poor. (see Table 5.13). The majority of students obtained an E- or F symbol (on both HG and SG) for physical science in matric. The students' performance for physical science was weaker than for mathematics. Several factors appeared to influence students' performance in physical science and mathematics at school. The students' whose schooling was least disrupted achieved higher results in their physical science matriculation exam. Students, who finished matric in 1994 and 1995 (in the years when the political situation began to normalise), on the whole achieved higher results than those in previous years (see Table 5.32). Finally, science students with higher matric symbols for mathematics achieved higher physical science symbols for matric.

The same factors were related to the students' mathematics achievement. However, in addition to the factors already mentioned above, the amount of time that students spent reading was related to the students' achievement in mathematics, which was not true for physical science.

An interesting difference was found between rural and urban students. Rural students generally spent more time on homework in their matric year (see 5.1.1). In particular, students coming from isolated rural areas studied more.

However, in general insufficient time was spent on physical science homework in matric (see Table 5.7). This is a matter of concern for a demanding subject such as physical science and may contribute to their low achievement in the physical science matriculation exam.
Most students (74%) claimed that their schools had science laboratories (see 5.1.3). This is a very high percentage when compared to the national percentage of schools with laboratories, where the best provisioned province has 72% of its schools equipped with laboratories and the worst province having 24% of its schools equipped.

On the whole, students attitudes to physical science were positive (see Table 5.14) and most described their feelings (towards physical science at school) as those of "enjoyment, excitement and had found the science challenging". The single factor identified by the students contributing to making physical science more enjoyable in matric, was practical work/science experiments. (Table 5.14). Students who believed that experiments/practical work contributed to the enjoyment of learning science also performed better than students identifying other factors. Students felt that studying, and not ability, results in success in physical science (see table 5.15).

Students were generally confident about their knowledge of physical science. Their confidence levels were higher than the results of the matriculation physical science examination suggested that they should be. In particular, more than 70% of the students were either confident or very confident in their content knowledge of Velocity (71%) and the Periodic Table (72%). Considering that 53% of the students had achieved fewer than 6 points for their matriculation physical science exam (see Figure 5.12), which is equivalent to less than an E-symbol on the higher grade and less than a C symbol on the standard grade, this confidence is even more surprising.

The Colleges of Education was not the first career choice for the majority of students. It is interesting to note that none of the students from College D (who had performed best overall in the test) had selected a College of Education as their first career choice. Furthermore, parents and teachers generally did not advocate Colleges of Education. The students negative attitude towards studying teaching was further illustrated by the fact that students were not committed to teaching as a career. More than half (56%) of the students did not intend to teach for longer than 5 years (see Table 5.23). The workshop college lecturers also reported students' lack of commitment towards teaching.

A disturbing finding was that almost a quarter of the students anticipated taking longer over their diploma than the prescribed time. Interestingly, College D's students were more committed to completing their study in the minimum time than others. This may be an indication of their wishing to complete their studies in order to move onto the institution of their choice – university.

Given this profile, the quality of these students as suitable, dedicated and motivated physical science teachers for the future is questionable and certainly highlights the difficulty of attracting high quality students into science courses at colleges of education.

CHAPTER 6 RESULTS FROM STUDENTS' SCIENCE ACHIEVEMENT TESTS

The achievement test consisted of 20 questions on the topics of oxidation-reduction/ electrochemical cells, displacement-time/velocity, electrostatics and the periodic table. The results are given in this section, 6. Firstly the overall results will be given in 6.1, followed by the results per content area in chemistry and in physics (6.2). Finally, within each content area, the analyses of the questions will be presented and discussed in 6.3.1 - 6.3.4

Before presenting and discussing the results, the concept of the reliability of a test is important. The reliability of the test was tested by the application of one of the Kuder-Richardson formulas - (KR-21). This KR-21 test determines the rationale equivalence reliability, which "determines how all items on a test relate to all other items and to the total test" The KR-21 formula results in an "estimate of reliability that is essentially equivalent to the average of the split-half reliabilities computed for all possible halves" (Gay, 1987:140). The reliability coefficient obtained from the KR-21 test applied to the overall test, with the 20 test items used in this study, was 0.97 . When the KR-21 test included each separate item within these 20 items (a total of 52 items in all) the reliability coefficient of 0.86 was obtained. A reliability coefficient of more than 0.90 is considered more than acceptable for any test (Gay, 1987: 141). In terms of an achievement test, the need for a high coefficient is considered to be more important than in other types of tests. Kehoe (1995) reports that tests containing more than 50 items should yield KR-20 values of 0.8 or higher. Therefore, it can be concluded, based on the results of these reliability tests, that the achievement test is reliable.

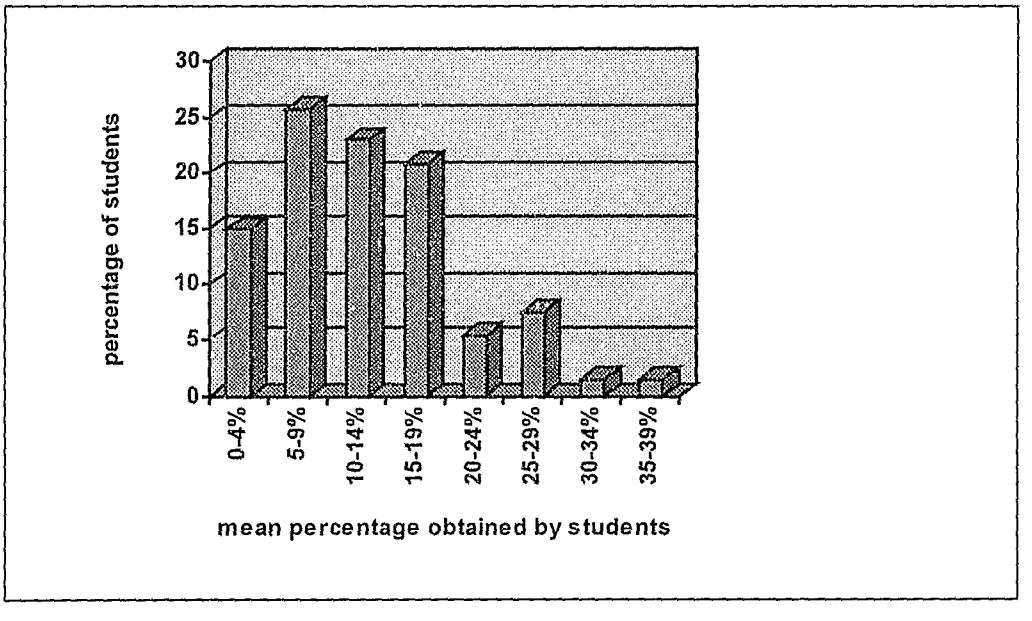
6.1. Students' overall achievement

The students overall achievement is presented and discussed in this section. The average percentages and the analyses are presented per college, diploma course, age of the students and gender of the students.

Overall students' average percentage

The overall average percentage of the students was 12.43% *(Standard Deviation (SD) = 7.82).* The percentages were categorised into eight groups and are presented in the following graph.

Figure 6.1. Students' overall average percentage obtained on the science test



As can be seen by Figure 6.1 and Table 6.1 the students performed very badly in general. Eighty-four percent of the students attained 19% or less on the test. Only 2.8% of the sample achieved more than 30% for this test. As can be seen the Standard deviation (SD = 7.82), indicates that the range of scores is large, with the maximum percentage achieved 37% and the minimum percentage of 0%.

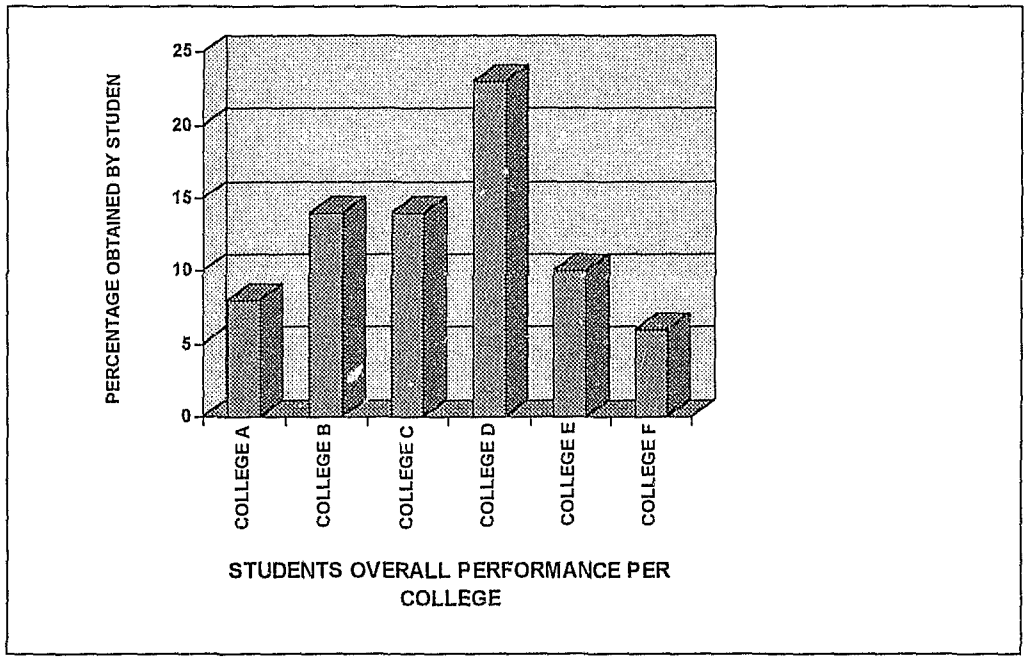
Table 6.1. Overall results of science achievement test

Ave %	Std Dev	Minimum %	Maximum %	Median	Std Error
12.43%	7.82	0%	37%	11%	0.64

- Figure 6.2 shows the **overall performance** of the students **by college**.

Whilst the overall performance of the college students in general was very poor, there were differences between the achievement of each colleges' students.

Figure 6.2 Students' overall performance by College



As can be seen from Figure 6.2, only three of the College means were above 10%. Students from College D (in the Northern Province) scored almost 10% more than students from other colleges. College B (from the North West Province) and College C (Gauteng Province) had similar overall results, nearly 10% below that of College D and Colleges A, E and F achieved 10% or less overall.

The performance of student cohorts from different colleges varied tremendously. There was a highly significant association ($p < 0.001$) between the **college** tested and the **percentage** achieved on the test.

Table 6.2 Percentages obtained by students by college

% obtained by students	College A % of students (n = 19)	College B % of students (n = 47)	College C % of students (n = 23)	College D % of students (n = 14)	College E % of students (n = 22)	College F % of students (n = 23)
0-4	11	11	9	0	4.5	52
5-9	58	11	17	0	54.5	26
10-14	26	32	26	0	23	13
15-19	5	34	31	29	9	4.5
20-24	0	6	9	14	4.5	0
25-29	0	4	4	50	0	4.5
30-34	0	0	0	7	4.5	0
35-39	0	2	4	0	0	0

As can be seen in Table 6.2, 69% and 78% students from Colleges A and College F respectively obtained only 9% or less on the science test. In contrast 71% of the students from College D achieved 20% and above on the test, compared to 0%, 12%, 17%, 9% and 4.5% of the students from the other colleges. No students from College A achieved more than 19%. No students from Colleges D, E or F, achieved more than 34%. The students who scored the highest percentages came from two colleges, College B and College C. In conclusion, the above table shows significant differences between different student cohorts.

- The **students' overall percentage** was analysed by the **teachers' diploma course**. The two groups were the Senior Primary Teachers Diploma (SPTD) and the Secondary Teachers Diploma (STD) students. The average percentage for the SPTD students (n = 42) was 7% compared to the STD students' (n = 106) average of 14%.

A highly significant association ($p < 0.001$) was found between the different diploma courses' cohorts of students and the percentage obtained by the students on the

test.

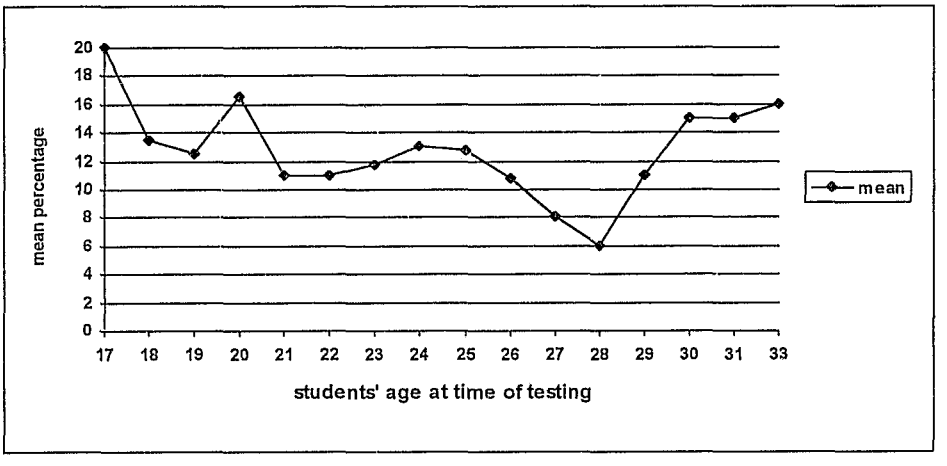
Table 6.3 Relationship between students' course and the percentage obtained

Percentage obtained	Senior Primary Teachers' Diploma % of students (n = 42)	Secondary Teachers' Diploma % of students (n= 106)
0-4	33	7.5
5-9	40.5	20
10-14-	19	24.5
15-19	5	27
20-24	0	7.5
25-29	2.5	9.5
30-34	0	2
35-39	0	2

As can be seen from Table 6.3, 73.5% of SPTD students attained 9% and less on the test compared to 27.5% of the STD students. Forty-eight percent of the STD students achieved 15% and more on the test compared to only 7.5% of the SPTD students.

- The **students' performance** also varied according to **age** and the overall average percentage is represented in Figure 6.3.

Figure 6.3 Students' overall percentage by age



There was no relationship between the students' age and the percentage obtained in the science test. However, from Figure 6.3, it appears that students in the top-performing age group were 17 years of age, followed by those students of 20 years of age. The lowest achieving students were 28 years old. The graph follows an interesting pattern as the performance improves again with students of 30-33 years of age, (n = 6) who achieve the similar scores to the 20 year old students (n = 16).

This pattern of younger teacher trainees was also found in England where a correlation was found between low science achievement and mature entry into the Primary Postgraduate Certificate of Education teachers' course (Huggins, 1994).

- An analysis was conducted on the 142 students who answered the question on gender. The average percentage for the male students was 5% above that of the female students. Male students (n = 62) scored 15.36% compared to female (n =

80) students who achieved 10.49%.

There was a significant association ($p < 0.01$) between students' **gender** and the students' **percentage** obtained on the test.

Table 6.4 Relationship between gender and the students' performance

Percentage obtained	Male % of students (n= 62)	Female % of students (n= 80)
0-4	8	19
5-9	16	33
10-14-	21	25
15-19	27	16
20-24	11	1
25-29	13	4
30-34	2	1
35-39	2	1

As can be seen in Table 6.4, the male students' performance was generally better than the female students. Seventy-seven percent of female students scored 14% and less on the test compared to 45% of the male students. Twenty-eight percent of male students scored more than 20% compared to 7% of the female students.

Several international studies have shown the relationship between gender and achievement in science. According to Levin, Sabar and Libman (1991),

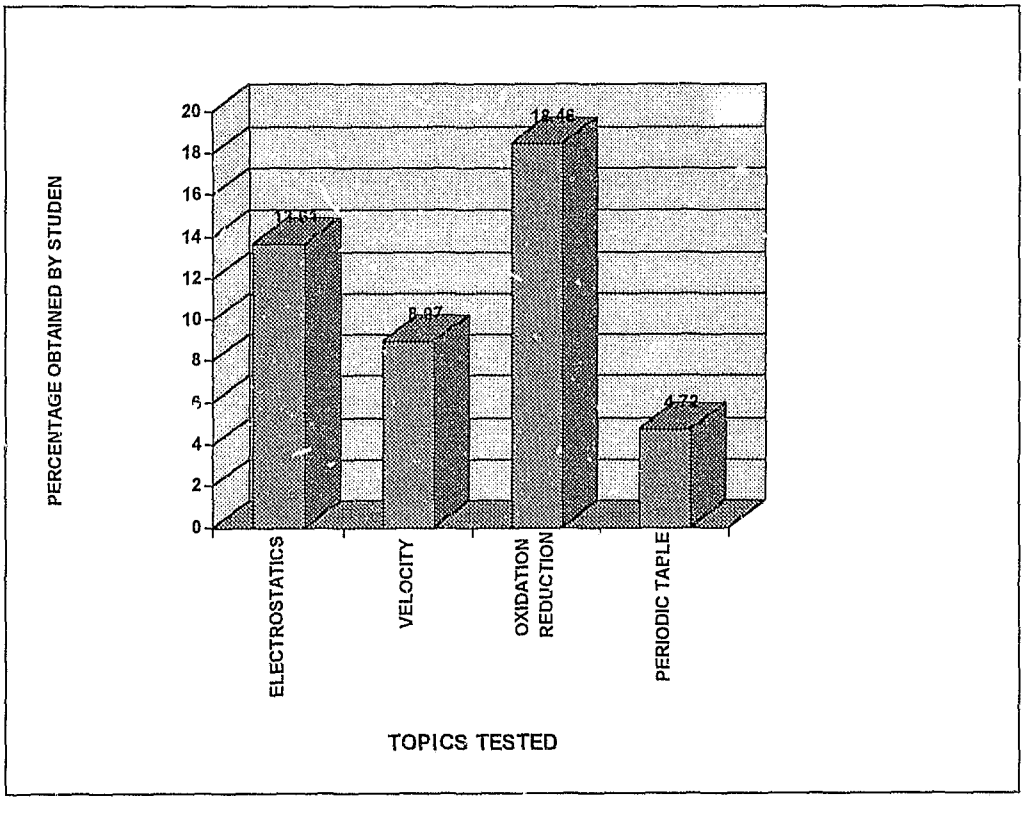
boys, with very few exceptions have been found to outperform girls in science achievement measurements. They were reporting on the Second International Science Study as well as the studies by Walberg, 1967; Fleming and Malone, 1983; and Erikson and Erikson, 1984. These studies showed an interesting trend of male pupils outperforming the female pupils especially at the lower age groups and these differences decreasing in the older age groups. In the Third International Mathematics and Science Study, there was no statistically significant difference between the achievement of South African boys and girls in Grades 7 and 8 (Howie, 1997). South Africa was one of only a few countries with this finding. It is therefore, particularly interesting that this trend is observed in this study amongst this older group of preservice education students.

6.2 Students' overall performance per topic in chemistry and physics

In this section the results on each section are presented and in section 6.4 these results are related to other findings (see section 6.4).

The overall performance of the students in physics (11.29%,) was comparable to their performance in chemistry (11.59%). Within the fields of physics and chemistry, four topics were selected and incorporated into the test for the students. The overall results per topic are shown in Figure 6.4.

6.4 *Students' overall performance by physics and chemistry topic*



As can be seen from Figure 6.4 and Table 6.5, the students' performance in all four topics was poor. However, the students performed best overall in oxidation-reduction, obtaining a average percentage of 18.46% (*SD* = *12.63*) with a wide range of scores (0% - 54%). Electrostatics was next best with an average of 13.61% (*SD* = *13.29*) and the students' performance in this topic ranged from 0% to 54%, the same as Oxidation-reduction. Students' achievement in Velocity was lower than the other physics topic. The students' average was 8.97% (*SD* = *9.97*) and there was also a wide range of scores' (0% to 42%). The students' performance on the questions in the periodic table topic was particularly poor for all students. The average

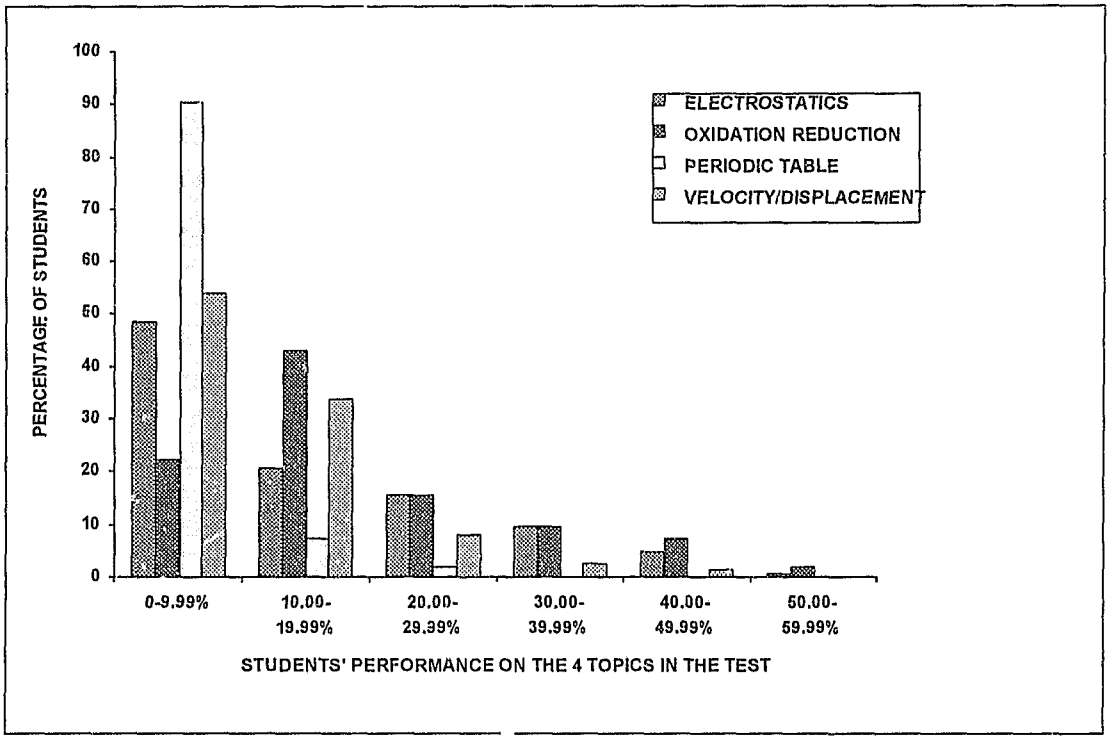
percentage was an extremely low, 4.72 (*SD* = 5.33) and the range of scores (0% - 23%) was much narrower, indicating that the students' achievement was generally very low.

Table 6.5 Results of the achievement test by topic

Topics	Average	Standard Deviation	Minimum	Maximum	Median	Std Error
Electrostatics	13.61	13.29	0	54.0	10.0	1.1
Velocity	8.97	9.97	0	42.0	8.0	0.82
Oxidation-reduction	18.46	12.63	0	54.0	16.0	16.0
Periodic Table	4.72	5.33	0	23.0	4.5	0.44

The distribution of the students' overall results per topic is presented in Figure 6.5.

Figure 6.5 Distribution of students' overall performance by topic



More than half of the students obtained less than 10% for two topics (periodic table and velocity/displacement). No student achieved more than 29% for the periodic table questions. Less than 20% of the students managed to obtain more than 30% for any of the other three topics. Only three percent of the students managed to achieve more than 50% for the topics, Electrostatics and Oxidation-reduction.

The analyses for the students' performance and their confidence in their understanding and knowledge will be discussed separately under each topic.

6.3 STUDENTS' ACHIEVEMENT IN THE DIFFERENT SCIENCE TOPICS

In this section (6.3), the students' performance in each of the four topics is analysed using the chi-squared test. The students overall performance is discussed, followed by an analysis of the students' performance by college, diploma course and gender. Furthermore, the confidence of the students in each topic is related to their performance in that topic and the students' performance is then briefly reviewed at question level.

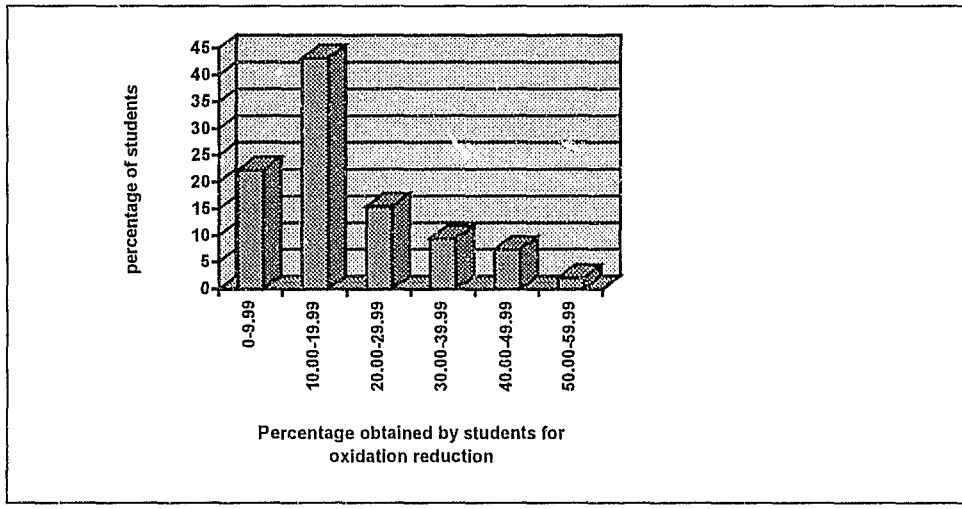
6.3.1 Students' performance on oxidation-reduction and electrochemical cells

A number of studies have focused on students' understanding of oxidation-reduction and/or electrochemistry (Ahtee and Varjola, 1998; Boo, 1998; Garnett and Treagust, 1992a; Garnett and Treagust, 1992b; Hesse, 1992; Lee and Fensham, 1996 and Zoller, 1990). Garnett and Treagust (1992b) identified several misconceptions relating to the inappropriate use of definitions of oxidation and reduction. They also found that many students experienced problems in identifying oxidation-reduction equations.

- **Students overall performance on oxidation-reduction and electrochemical cells**

The results for the questions on oxidation-reduction and electrochemical cells were better than for any other topic, even though the performance was low. Figure 6.6 shows the distribution of the results across the six percentage categories.

Figure 6.6 Students' overall performance on oxidation-reduction and electrochemical cells



As can be seen from Figure 6.6, 65.5% of the students obtained less than 20% for this topic. Nonetheless, 9.4% of the students achieved more than 40% and of this, 2% (n = 3) achieved more than 50% for this topic.

The difficulty that South African teacher trainees have with this topic was confirmed by College lecturers who reported on the problems students have generally with chemistry, saying for instance "*Some topics I presume become very difficult because students never got a chance of doing them at school. The sort of response I get from students is that they usually do not get time to cover the chemistry section at school.*" and one other lecturer reported that "*I think as the teachers are "afraid" of chemicals, some sort of centralised laboratories must be constructed. Because generally the students view chemistry as being more difficult than physics. In short, I would like to point out that the problems in general is LACK*

OF EXPERIMENTATIONS (sic)."

- ***Students' overall results for oxidation-reduction and electrochemical cells by college***

Within the overall poor results, the performance of the students in oxidation-reduction and electrochemical cells varied greatly across colleges. Table 6.6 represents the relationship of the students' performance by college.

Table 6.6 Students' performance on the topic by college

% obtained by students	College A % of students (n = 19)	College B % of students (n = 47)	College C % of students (n = 23)	College D % of students (n = 14)	College E % of students (n = 22)	College F % of students (n = 23)
0-9.99	10.5	9	26	7	36	52
10-19.99	89.5	45	26	14.3	45	35
20-29.99	0	21	26	14.3	9	13
30-39.99	0	17	9	21.4	5	0
40-49.99	0	6	13	29	5	0
50-59.99	0	2	0	14	0	0

There is a highly significant association ($p < 0.0001$) between the students' results in this topic and the colleges they attended. As can be seen from Table 6.6, the students from College D performed best overall in oxidation-reduction and electrochemical cells which is not unexpected as College D's students achieved the highest mean percentage for the test (Figure 6.2). Sixty-four percent of College D' s students achieved more than 30% on this topic compared to 0%, 25%, 22%, 10% and 0% of the other colleges' students. Only 21.3% of College D's students obtained less than 20% for the test compared to 100%, 54%, 52%, 81% and 87% of the other

colleges' students. Finally, two students from College D managed to achieve more than 50% for this topic.

- ***Students' overall results for oxidation-reduction and electrochemical cells by course***

There is a highly significant association ($p < 0.001$) between the students' performance and the course the students are enrolled for

Table 6.7 Relationship between students' course and the students' mean percentage for oxidation-reduction and electrochemical cells

Percentage obtained	Senior Primary Teachers' Diploma % of students (n = 42)	Secondary Teachers' Diploma % of students (n= 106)
0-9.99	33	18
10-19.99	60	37
20-29.99	7	19
30-39.99	0	13
40-49.99	0	10
50-59.99	0	3

Overall the STD students performed better than the SPTD students. Forty-five percent of STD students obtained more than 20% compared to 7% of SPTD students. No SPTD students achieved more than 29% for this topic compared to 26% of STD students. Three percent of STD students achieved more than 50% for

this topic. The superior performance of the STD students was not entirely unexpected as this corresponds with the students' performance in their physical science matriculation examination.

The superior performance of the STD students is also confirmed by College lecturers who commented on the relative poor performance of SPTD students generally, for example "*Most of the difficulties experiences by this students (PTD1) are compounded by the fact that they are from schools which are ill-equipped or have no laboratories at all and because of teachers having lower qualifications*" and.*"STD students are better achievers than PTD students"* reports another.

.

- ***Students' overall results for oxidation-reduction and electrochemical cells by gender***

There was a significant association ($p < 0.01$) between the gender of the students and the students' mean percentage obtained on oxidation-reduction and electrochemical cells. As discussed earlier, male students have been found elsewhere in other studies to outperform female students.

Table 6.8 Relationship between gender and the students' performance

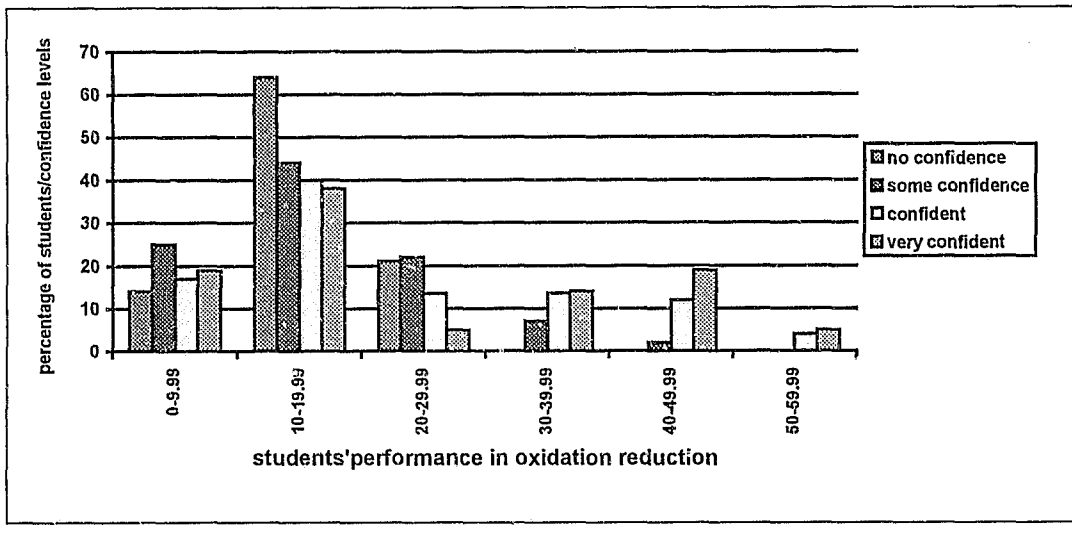
Percentage obtained	Male % of students (n= 62)	Female % of students (n= 80)
0-9.99	23	23
10-19.99	32	51
20-29.99	18	13
30-39.99	8	11
40-49.99	16	1
50-59.99	3	1

As can be seen in Table 6.8, the male students' performance was generally better than the female students. Seventy-four percent of female students scored less than 20% for the topic compared to 55% of the male students. Nineteen percent of male students scored more than 40 % compared to 2 % of the female students.

- **The relationship between the students' perceptions of their understanding of oxidation-reduction and electrochemical cells and their performance**

Prior to writing the test, the students were asked to complete a questionnaire in which they had to indicate their confidence in relation to their understanding of the topics in their Grade 11 and Grade 12 science syllabi. They were asked to indicate whether they were very confident, confident, a little confident or not confident (see Table 5.17). The findings of the confidence levels for oxidation-reduction and electrochemical cells are related to the students' performance. These are presented in Figure 6.7.

Figure 6.7 The relationship between the students' confidence and their performance in the topic



There was a relationship between the students' confidence of their understanding of oxidation-reduction and electrochemical cells and their achievement in that topic. As can be seen from Figure 6.7, students with no confidence performed poorly and did not attain more than 30%. Students who stated that they were confident or very confident performed significantly better and amongst them were the students who achieved more than 50% for this topic. However, it is also important to note that amongst this group, almost 40% scored between 10-20% for this topic. Nevertheless, the results show that there is some link between the student attitudes and their achievement in this topic.

- **Analyses of oxidation-reduction and electrochemical cells questions**

In order to analyse the topic further, it is necessary to look at the individual questions and their results for this topic.

Question 1

A zinc spoon is used to stir a copper sulphate solution for a long time.

A. Does the temperature of solution increase, decrease or remain the same?

B. Give a reason for your answer in a)

C. Name the precipitate which forms.

D. Describe the colour change taking place in the solution.

E. Why can the reaction taking place be considered to be a redox reaction?

F. Which substance acts as an oxidising agent in the reaction?

G. What happens to the mass of the spoon?

Question 2

A copper-zinc electrochemical cell is set up and an ammeter connected in the external circuit shows that the cell is delivering current.

A. Write down the equation for the half-reaction which occurs at the cathode.

B. In which direction do electrons move in the external circuit?

C. Will the mass of the copper plate increase or decrease?

D. Name a suitable salt solution which could be used in the zinc half-cell.

E. How does the concentration of the solution in the zinc half cell change?

Question 3

The net reaction for a zinc-lead electrochemical cell is $Zn + Pb^{2+} - Zn^{2+} + Pb$

Answer the following questions:

A. Is this reaction spontaneous?

B. Give a reason for the answer.)

C Write down the anode half-cell reaction.

Question 4

An electrochemical cell has the following cell notation:
$Al(s) / Al^{3+}(aq) // M^{2+}(aq) / M(s)$

If the E.M.F. of the cell under standard conditions is 2,00V,

A. determine, using the REDOX tables provided, what element M is. (Clearly show how you determine this element).

B. Give the correct half reactions and the complete overall reaction when the cell delivers current.

C. A salt bridge is an essential component of any cell. Briefly explain the purpose of the salt bridge.

D. Propane belongs to a homologous series and it is highly flammable.
Name the homologous series to which propane belongs.

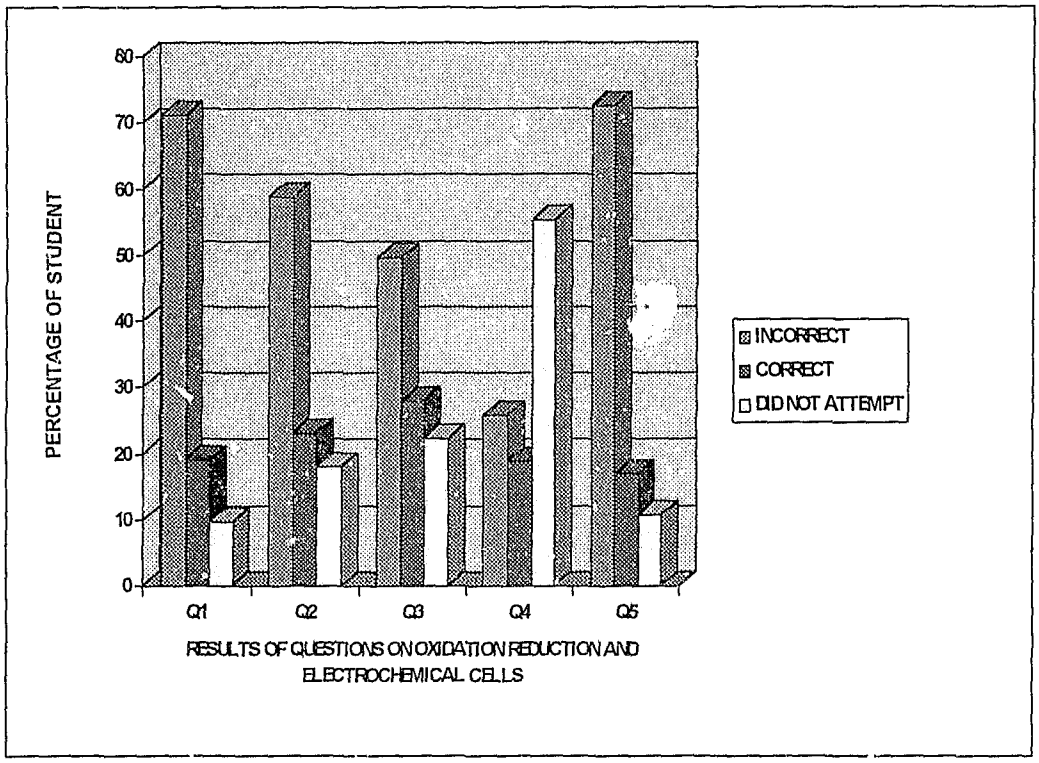
Question 5

In which reaction is Fe^{2+} being oxidised?

A. Fe ⟶ $Fe^{2+} + 2e^-$
B. $Fe^{2+} + 2e^-$ ⟶ Fe
C. Fe^{2+} ⟶ $Fe^{3+} + e^-$
D. $Fe^{3+} + e^-$ ⟶ Fe^{2-}

Figure 6.8 presents the results of each of the oxidation-reduction and electrochemical cells questions. In cases where questions had several parts to it, such as Question 1, 2, 3 and 4, the mean was calculated for all parts together and presented as an overall percentage for the question.

Figure 6.8 Students' results on oxidation-reduction and electrochemical cells



As can be seen in Figure 6.8, most students attempted all the questions in this topic. Of the five questions, question three had the highest number of correct answers and 28% of the students answered the question correctly. Questions one and five proved to be difficult for students as only 19% and 16.8% of the students respectively answered it correctly. Question four seemed to be the most problematic as 55% of the students did not even attempt to answer it, despite having been given the redox tables. Students did not perform well on the whole on any questions where the answers had to be worked out or calculated and perhaps the complexity of the question negatively influenced them. In most cases, students attempted part C and

part D (64% and 53% respectively attempted the questions) where students were required to remember facts as opposed to the parts A and B (20% and 30% respectively attempted the questions) where they need to use the redox tables.

The results for the questions, including their separate parts, are shown below in Table 6.9.

Table 6.9 Results for individual questions

Oxidation-reduction and electrochemical cells			
question	**% incorrect**	**% correct**	**% not attempted**
1A	40.3	53.7	6.0
1B	87.1	2.7	10.2
1C	83.8	5.4	10.8
1D	81.2	8.1	10.7
1E	81.0	2.7	16.3
1F	73.6	20.9	5.4
1G	51.4	39.9	8.8
2A	68.5	18.1	13.4
2B	74.3	12.2	13.5
2C	44.3	45.6	10.1
2D	51.4	32.4	16.2
2E	55.7	7.4	36.9
3A	16.1	67.1	16.8
3B	67.1	2.0	30.9
3C	65.5	14.9	19.6
4A	12.1	18.1	69.8
4B	9.4	20.8	69.8
4C	58.4	6.0	35.6
4D	23.5	30.2	46.3
5	72.5	16.8	10.7

Several parts of different questions were answered relatively well such as Questions 1A, 2C and 3A. Question 4 seemed to be problematic as a high proportion of students did not attempt three out of the four parts and parts 1 and 2 seemed to pose the most problems.

- ***Thinking/Difficulty levels of oxidation-reduction and electrochemical questions***

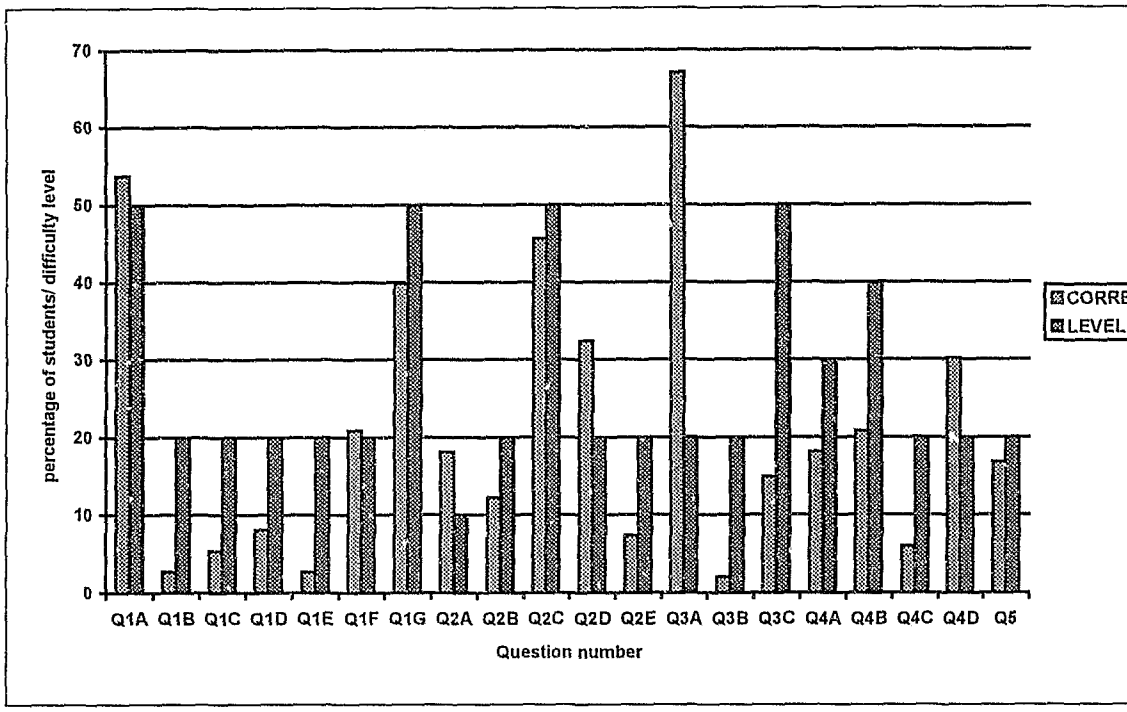
Results are presented in Figure 6.9 as detailed average percentages for each question and parts of items. Furthermore the level of thinking required, can be interpreted in terms of the difficulty level of the question ("understanding of terminology" being the simplest level and the "ability to make an evaluative judgement" the most complex level of thinking required. The thinking level (categorised according to Ebel, 1972), of each question was identified by an expert panel as explained in Chapter 3.

These levels have been coded and are represented graphically below as follows:

- 10 = understanding of terminology
- 20 = understanding of fact and principle
- 30 = *ability to explain or illustrate*
- 40 = ability to calculate (numerical problems)
- 50 = ability to predict
- 60 = ability to recommend appropriate action
- 70 = *ability to make an evaluative judgement*

In Figure 6.9, the percentage of students obtaining the correct answer for each question, as well as the identified thinking level expected for each question is presented together.

Figure 6.9 The relationship between the number of students answering the question correctly and the thinking level of the questions



As can be seen from Figure 6.9, questions 1A, 1G, 2C, 3 C and 4 B required the highest levels of thinking (50 = ability to predict) and students answered 1A, 1G and 2C relatively well. The reason that question 1A was answered relatively well was that in fact students had to select between three possible answers "Does the temperature of the solution increase, decrease or stay the same?". Not only did the students not have to create their own answer, but it also gave them a chance of one in three of guessing the correct answer.

In question 1G, a similar pattern is found where students were asked "what happens to the mass of the spoon?" Despite the relatively high thinking level required (ability to predict), only a limited number of options were available (increase, decrease or stay the same), thus helping the students to find the answer more easily. Similarly, in the context of question 2C, students were asked "Will the mass of the copper plate increase or decrease?", students had a 50% chance of guessing the answer to the question (and less than this guessed correctly). So, although all three of these questions called for a prediction, the options for answering were limited to two or three thus making the question easier for the students and also allowed them to be able to guess the correct answer.

Where students were asked for facts or basic principles they tended to answer them very poorly. In questions 1B, 1C, 1D, 1 E, 3B and 4C where less than 10% of students answered them correctly, students were asked for some basic fact or principle. Question 3B was answered particularly poorly. The question called for the students to "Give a reason for the answer in Question 3A" and whilst students scored very highly on question 3A (almost 70% answered correctly) which called for a yes/no answer, only 2% students could substantiate their answer.

The question with the fewest correct answers was a multiple-choice question (question 5). Students' answers were below the chance factor and only 16.8% of the students answered it correctly.

Generally, the students' results from this topic confirm the level of the difficulty of this topic earlier reported by the College lecturers from the RADMASTE workshop, who felt that this was the most difficult chemistry topic in the matric syllabus. What is less clear is the reason for the results of

this topic being better than the others.

The difficulty of this topic is further confirmed by recent surveys world-wide, which have addressed the difficulties with students' understanding of electrochemistry and oxidation-reduction. For instance, Butts and Smith (1987) from Australia, examined the difficulty of 50 chemistry concepts and found that the connection between cell voltage and the relative strength of the oxidant and reactant was ranked by students as the most difficult concept.

Furthermore, in North America, Finley, Stewart and Yarroch (1982) found that chemistry teachers ranked oxidation and reduction along with chemical equilibrium, the mole and reaction chemistry as topics that cause learners most difficulty. Garnett and Treagust (1992a) also say that because the understanding of oxidation-reduction is a prerequisite for understanding cells, *it is likely that electrochemical and electrolytic cells are topics that pose considerable conceptual difficulty for chemistry students.*

In conclusion, it would seem that the problems with oxidation-reduction and electrochemistry are not unique to South African students. However, it would appear that few South African students had an idea about the correct answers to the questions, even for the multiple-choice questions. Most worrying is the fact that students were unable to answer questions requiring the basic facts/principles for this topic.

6.3.2 Students' performance on the Periodic Table

The prevalence of misconceptions of basic chemical concepts e.g. the periodic table, amongst pupils, students and teachers has been reported in several studies (Menis, 1989; Altun and Kaya, 1996; and Garnett and Treagust, 1992a), but few studies have been conducted amongst preservice education students.

- **Students overall performance on the periodic table**

The results for the questions on the periodic table were the worst out of all the topics and this must be kept in mind when discussing the results in this section. The very poor results are of major concern as the periodic table plays the central role in the learning of chemistry. Ironically, given the poor results, this was the topic that the workshop College lecturers indicated was the easiest of all the topics, but having said that, lecturers did report that these basic concepts were problematic and that students learned that section by rote learning. For instance, one very experienced lecturer said that "*Understanding of atomic structure and implications of organisation of the periodic table poorly understood - rote learning a problem. This obviously has implications for an understanding of reactions in organic chemistry. Chemical equilibrium - kinetic theory - not understood - rote learning without understanding.*"

Figure 6.10 Students' overall performance on the periodic table

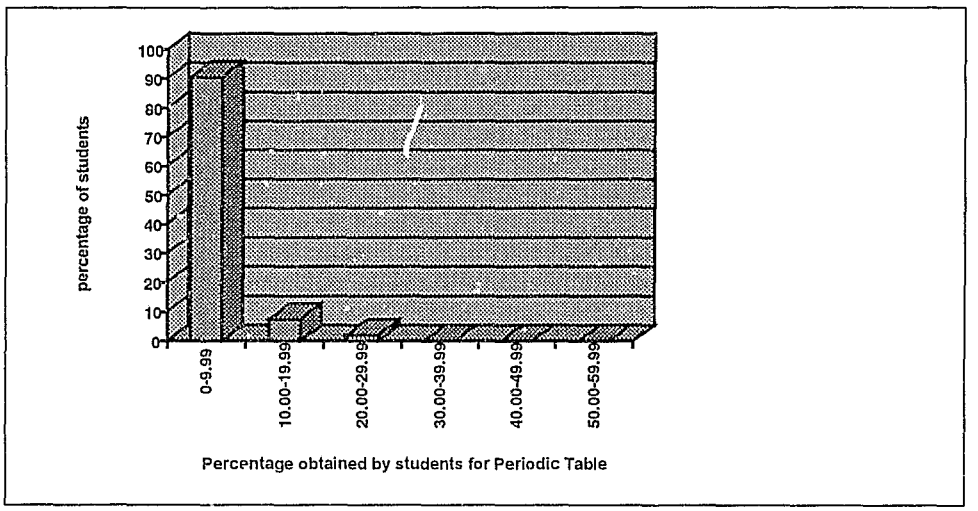


Figure 6.10 shows the distribution of the results across the six percentage categories. As can be seen from this figure, the students' performance on this topic was very poor. Ninety percent of the students achieved less than 10% for this topic. Only two percent of the students managed to achieve above 20% for this section of the test.

- ***Students' overall results for the periodic table by college***

The performance of the students in the periodic table did not vary greatly across colleges. Table 6.10 represents the relationship of the students' performance by college.

Table 6.10 Students performance on the topic by college

% obtained by students	College A % of students (n = 19)	College B % of students (n = 47)	College C % of students (n = 23)	College D % of students (n = 14)	College E % of students (n = 22)	College F % of students (n = 23)
0-9.99	100	83	97	86	90	97
10-19.99	0	13	3	14	5	3
20-29.99	0	4	0	0	5	0

Unlike the findings on oxidation-reduction/electrochemical cells, no significant difference was found between the students' results in this topic and the colleges they attended. However, as can be seen from Table 6.10, there were a few students from College B (4%) and College E (5%) who managed to achieve above 20%. Students from College A performed particularly poorly on this topic with no student achieving above 10%.

- ***Students' overall results for the periodic table by course***

The students' performance is presented in Table 6.11 by the students' course.

Table 6.11 Relationship between students' course and the students' mean percentage for the periodic table

Percentage obtained	Senior Primary Teachers' Diploma % of students (n = 42)	Secondary Teachers' Diploma % of students (n= 106)
0-9.99	98	88
10-19.99	2	9
20-29.99	0	3

Again in contrast to oxidation-reduction/electrochemical cells, no significant association was found between the students' performance and the course that the students are following. However, a higher proportion of STD students achieved more than 10% (12%: 2%) compared to the SPTD students.

- ***Students' overall results for the periodic table by gender***

The relationship between gender and the students' results for the Periodic Table is presented in Table 6.12

Table 6.12 Relationship between gender and the students' performance

Percentage obtained	Male % of students (n= 62)	Female % of students (n= 80)
0-9.99	90	93
10-19.99	8	6
20-29.99	2	1

Once again, in contrast to oxidation-reduction/electrochemical cells, there was no significant association between the results for this topic and the gender of the students. As can be seen in Table 6.12, there is little difference in the performance of the male and female students.

- **The relationship between the students' perceptions of their understanding of the periodic table and their performance**

As can be seen in Table 6.13, there was no relationship between the students' confidence levels in their understanding of the periodic table, and their achievement in that topic (a mean of 4.72%).

Table 6.13 The relationship between the students' perceptions and their performance in the topic

Confidence level	Not at all Confident	A little confident	Confident	Very confident
Percentage of students	3.4%	24.5%	38.8%	33.3%

It is clear that the students' confidence levels were much higher than their actual performance in this topic.

- **Analyses of the periodic table questions**

Due to the fact that the students all performed very badly in this topic, it was decided against further detailed analysis on this topic's questions. Question 5 was attempted by the majority of students, whilst question 2 (which had the highest difficulty index) was not attempted by 50.3% of students and question 3 was not attempted by 80.5% of students. No student answered question 2 or 3 correctly.

The trend exhibited by students above with these questions 1 to 4, was also observed by Abraham et al's research on school pupils regarding chemistry concepts. They found that there were few misconceptions with the periodicity concepts, however, they also found that students either could show understanding or they had no idea. It would appear that these South African preservice students were in the latter group.

The probable reason why question 5 was attempted by so many of the

students in contrast to the other questions, was that students had to select between a number of possible answers and did not have to create their own answer. A similar trend was also found between the students' performance in oxidation reduction/electrochemical cells and their perceptions. All the other questions were open-ended questions that required basic knowledge and understanding of principles.

Concepts concerning the periodic table are central to any student's initial learning of chemistry. Chemistry is dependent on the atomic model and concepts associated with atoms and their actions are used for all explanations or in chemical phenomena. Yet, it appears that students suffer from a lack of understanding of the atomic model and the fact that the literature is filled with examples of this (Ben-Zvi and Genut, 1998; Andersson, 1986; and Novick and Nussbaum, 1981), indicates the degree to which this is a general problem.

The result of this lack of understanding is an uncertainty that students may feel when explaining concepts related to the atomic model. This may manifest itself when students avoid using the terms *atoms* and *molecules* to explain chemical phenomena or processes, thus making scientifically satisfactory explanations very difficult. A cursory look at the students who attempted questions 1 to 4 reveals that this was indeed the case for these South African students.

An important point made by Ben-Zvi and Genut (1998: 353) directly applicable to the South African situation, is that *whenever students are studying the Periodic Table, students are naturally much influenced by their textbooks and thus tend to uncritically to accept and use the Periodic Table in the form presented.* In the South African context this comment may apply as well to the teachers

in the majority of schools as much as to the students. This comment also comes back to the point made at the beginning of this section by the College lecturer who talked about the problems with the periodic table and rote learning. In a country which is so dependent on the textbook (and often only one) for much of its teaching and learning, it is hardly surprising the students' understanding of the basic concepts is so poor.

Question 1

Explain the difference between the covalent radius and Van der Waal's radius.

Question 2

Point out briefly why positive ions are always smaller and negative ions are always greater than the corresponding atom.
Is energy absorbed or liberated during the formation of these ions?
Name the kind of energy in each case.

Question 3

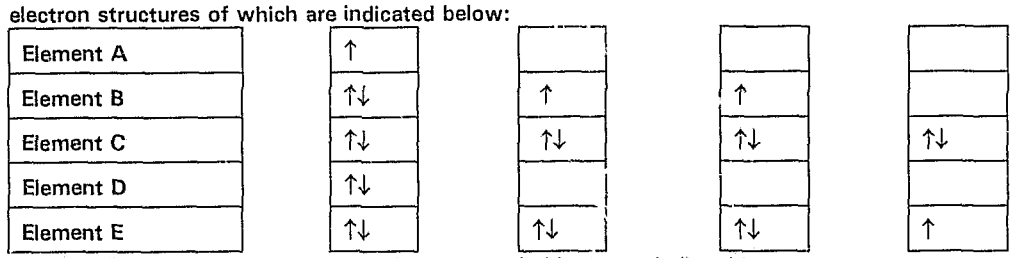
The first kind of ionisation energy of magnesium is 734 $kJ.mol^{-1}$. Calculate the energy of an electron found in the 3s-orbital of the magnesium atom.

Question 4

Compare the first ionisation energy of metals and non-metals.
Use the concepts of atomic radius and nuclear charge to explain the difference.

Question 5

The following seven questions refer to the elements marked A, B, C, D, E, the valence electron structures of which are indicated below:



(NOTE: All these elements appear in the same period in the periodic table.

a) Which element will definitely be a gas at room temperature?

b) Which element will be found in Group IV of the periodic table?

c) Which element(s) will most probably be metal(s)?

d) The negative ion of which element will have the same electron structure as element C?

e) The negative ion of which element will have the same electron structure as element A?

f) Which element(s) appear(s) in the s-block of elements in the periodic table?

g) Which element(s) appear(s) in the p-block of elements in the periodic table?

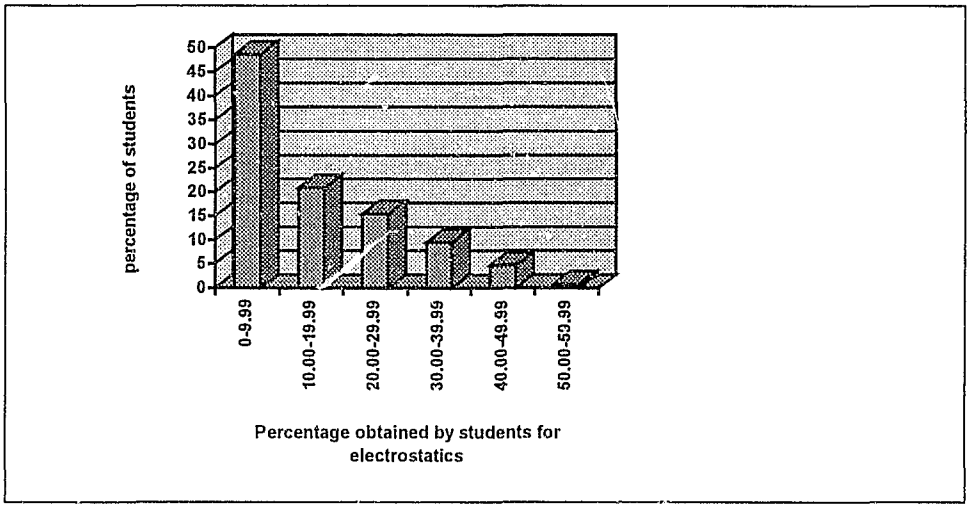
6.3.3 Students' performance on Electrostatics

"The same alternative conceptions in physics are reported to exist across many countries, within a variety of cultural and environmental contexts" (Thijs and van den Berg, 1995:317) and Solomon (1983:49) reported that *most student ideas are fragmented and not logically integrated*". Interestingly, Thijs and van den Berg (1995:331) reported that "*culture does not seem to be responsible for the formation of strong physics preconceptions as such, since students seem to distinguish well between school science and other domains*".

- ***Students overall performance on Electrostatics***

The results for the section on Electrostatics were the second best of all the topics and Figure 6.10 shows the distribution of the results across the six percentage categories. Although in the context of this study, the students did relatively well, these results were nonetheless poor. This can be partly explained by a comment from one of the workshop lecturers who said "*The year one students I have to teach for the past four years seems to be able in chemistry than physics. With most physics concepts they know what they are but cannot apply them."*

Figure 6.11 Students' overall performance on Electrostatics



As can be seen from Figure 6.11, 15% of the students achieved more than 30% for this topic. Of these 5% of the students achieved more than 40% and one student even achieved more than 50%.

- ***Students' overall results for Electrostatics by college***

The performance of the students in Electrostatics varied greatly across colleges. Table 6.14 represents the relationship of the students' performance by college.

Table 6.14 Students performance on the topic by college

% obtained by students	College A % of students (n = 19)	College B % of students (n = 47)	College C % of students (n = 23)	College D % of students (n = 14)	College E % of students (n = 22)	College F % of students (n = 23)
0-9.99	68	38	35	0	64	83
10-19.99	21	28	35	21	14	0
20-29.99	11	21	17	14	9	13
30-39.99	0	9	13	43	4	0
40-49.99	0	4	0	14	9	14
50-59.99	0	0	0	8	0	0

A highly significant association ($p < 0.0001$) was found between the students' results in this topic and the colleges they attended. As can be seen from Table 6.14, the students from College D performed best overall in Electrostatics. Sixty-five percent of College D's students achieved more than 30 % on this topic compared to 0%, 13%, 13%, 13 % and 14% of the other colleges' students. This is consistent with College A's students' performance in oxidation-reduction and their overall performance where they achieved higher scores on average. College D' s students achieved the lowest scores with 89% of their students obtaining less than 20%.

Students' overall results for Electrostatics by course

There is an association ($p < 0.01$) between the students' performance and the course the students are following.

Table 6.15 Relationship between students' course and the students' average percentage for Electrostatics

Percentage obtained	Senior Primary Teachers' Diploma % of students (n = 42)	Secondary Teachers' Diploma % of students (n= 106)
0-9.99	76	38
10-19.99	10	25
20-29.99	12	17
30-39.99	0	13
40-49.99	2	6
50-59.99	0	1

Overall the STD students performed significantly better than the SPTD students. Twenty percent of STD students obtained more than 30% compared to 2% of SPTD students. Only 38% of STD students achieved less than 10% for this topic compared to 76% of SPTD students. The superior performance of the STD students was not entirely unexpected as this corresponds with the students' performance in their physical science matriculation examination. This is probably the reason why the students from College D also performed better as they were all STD students and the majority of them were male.

- ***Students' overall results for Electrostatics by gender***

The achievement of the students in Electrostatics was dependent on their gender. There was a significant association ($p < 0.01$) between gender and the students' average score for Electrostatics.

Table 6.16 Relationship between gender and the students' performance

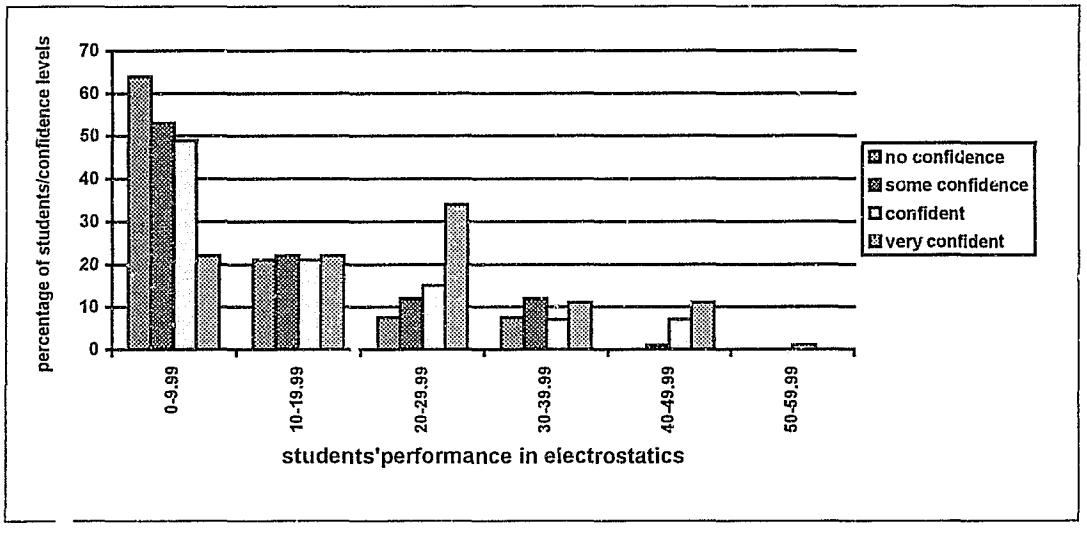
Percentage obtained	Male % of students (n= 62)	Female % of students (n= 80)
0-9.99	29	61
10-19.99	29	16
20-29.99	19	13
30-39.99	16	5
40-49.99	7	4
50-59.99	0	1

As can be seen in Table 6.16, the male students' performance was generally better than the female students. Seventy-seven percent of female students scored 19% and less on the topic compared to 58% of the male students. Twenty-three percent of male students scored more than 30 % compared to 10 % of the female students. However, it was a female student who scored the highest marks on this topic.

- **The relationship between the students' perceptions of their understanding of Electrostatics and their performance**

The students' confidence levels for Electrostatics are linked to the students' performance and are presented in Figure 6.12.

Figure 6.12 The relationship between the students' confidence levels and their performance in the topic



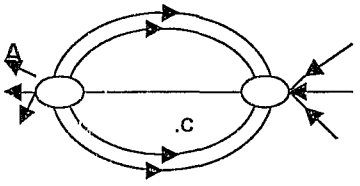
As can be seen from Figure 6.12, students with no confidence performed poorly and more than 60% of them attained less than 10%. Furthermore, it is important to note that more than 20% of the students that were very confident on this topic scored less than 10%. Students who stated that they were confident or very confident performed significantly better overall and amongst them were the students who achieved more than 40% for this topic.

- **Analyses of Electrostatics questions**

In order to analyse the topic further, it is necessary to look at the individual question/item results.

Question 1

The diagram shows the electric field between two point charges A and B.

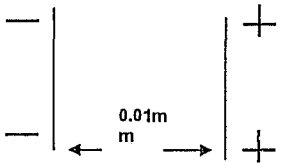


A. State the nature of the charges carried by A and B.

B. In what direction will a positive test charge placed at point C move?

Question 2

A potential of 1000V exists between two parallel vertical metal plates 0,01m apart in a vacuum.



A. Sketch the electric field pattern between the plates.

B. Calculate the work done by the electric field on a positive charge of $8x10^{-19}C$ that moves from the positive plate to the negative plate

C. Determine the magnitude of the electric force acting on the positive charge.

Question 3

When two identical positively charged point charges are a certain distance apart they repel each other with a force of $1x10^{-3}$N.

A. Make a free hand sketch to show the pattern of the electric field formed by the two charges.

B. The point charges are now moved 3 mm closer to each other and this time repel each other with a force of $4x10^{-3}$N. How far apart were the charges originally?

C. What was the magnitude of each charge?

Question 4

A small sphere with a charge of $+5x10^{-9}$C experiences an electrostatic force of $2x10^{-8}$N to the right when placed at a point in a uniform electric field.

A. Calculate the magnitude of the electric field strength at this point.)

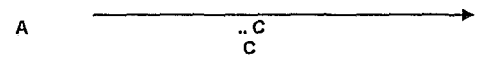
B. What is the direction of this electric field?

C. *If an electron is placed in the same field, will the electrostatic force on this electron be greater or less* than the electrostatic force on the sphere?

D. In which direction will the electron move?

Question 5

A and B in the diagram represent two positive point charges of the same magnitude.



A. Draw a neat pencil sketch of the electric field due to the point charges A and B.

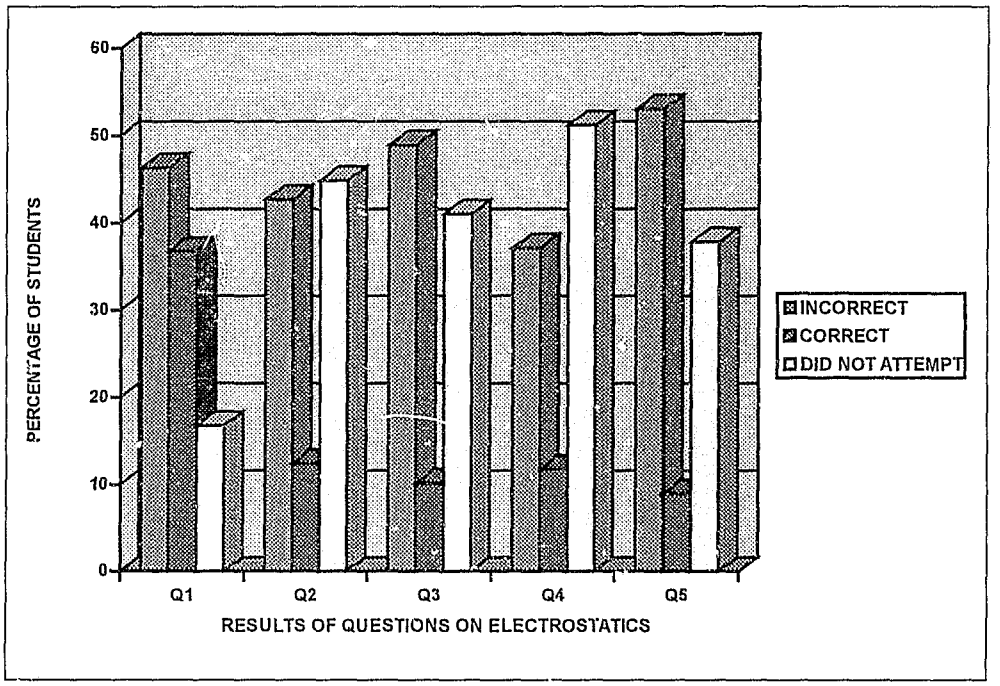
B. If A= +6nC and B = .6nC and the distance AB = 20mm, calculate the magnitude of the force A exerts on B.

C. A positive point charge lies midway between A and B. Explain whether it would experience any resultant force.

Figure 6.13 presents the results of each of the Electrostatics questions. Due

to the fact that each question had many parts, such as Question 1, 2, 3 and 4, the average was calculated for all parts together and presented as an overall percentage for the question

Figure 6.13 Students' results on Electrostatics



Approximately half of the students attempted all the questions in this topic. Of the five questions, question 1 had the highest number of correct answers with 37% of the students answering the question correctly. Question 5 had the lowest percentage of students answering it correctly (9%). Question 4 seemed to be the most problematic overall, as 51% of the students did not even attempt to answer it. Students performed very badly in questions, 2, 3, 4, and 5, all of which contained parts requiring calculations, on average only

10% of the students answered them correctly.

The questions with their separate parts are shown in Table 6.17 together with the results for each part.

Table 6.17 Results for individual questions

question	% incorrect	% correct	% not attempted
1A	51.7	30.9	17.4
1B	40.9	43	16.1
2A	51.7	21.5	26.8
2B	43.6	10.7	45.6
2C	32.9	4.7	62.4
3A	48.0	29.1	23.0
3B	53.7	0.7	45.6
3C	45.0	0.7	54.4
4A	38.3	6.0	55.7
4B	35.6	13.4	51.0
4C	31.5	18.1	50.3
4D	43.0	9.4	47.7
5A	59.7	10.1	30.2
5B	61.1	0.7	38.3
5C	38.9	16.1	45.0

Two parts of different questions were answered relatively well such as Questions 1A, and 1B. Questions 3B, 3C and 5B seemed to be problematic to students as only one student in each case managed to answer these questions correctly.

- ***Difficulty levels of Electrostatics questions***

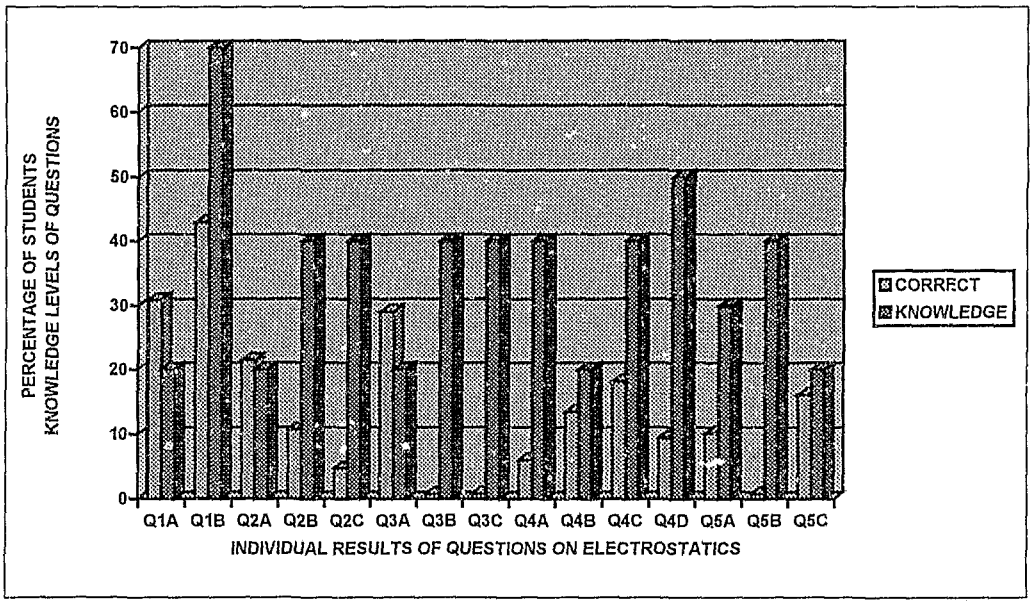
Results are presented in Figure 6.13, as detailed average percentages together with the level of thinking skills required answering each of these

questions. As stated previously, these thinking skills levels can also be interpreted to represent the level of the difficulty of each question. They are described in full in Chapter 3.

These levels represented below have been coded in the following way:

- 10 = understanding of terminology
- 20 = understanding of fact and principle
- 30 = ability to explain or illustrate
- 40 = ability to calculate (numerical problems)
- 50 = ability to predict
- 60 = ability to recommend appropriate action
- 70 = ability to make an evaluative judgement

Figure 6.14 The relationship between the number of students answering the questions correctly and the knowledge level of the questions



As can be seen from Figure 6.14, questions 1B and 4 D required the highest knowledge levels and yet students answered 1 B better than any other question in this topic. The reason that question 1B was answered relatively well was that students had to select between two possible answers and had a 50% chance of guessing the right answer. So, although this question called for a prediction/ an evaluative judgement, the options for answering were limited to two making the question easier for the students and also allowed them to be able to guess the correct answer. In contrast, students clearly had no idea what question 4D required (indicated by a high non-response rate) and could not even guess the correct answr even though there were only possible answers.

Students generally performed badly on questions that required them to do calculations, such as questions 2B, 2C, 3B, 3 C, 4A and 5B. Even if students had answered these questions satisfactorily, which they clearly had not, there are other problems in physics. Clement (1981) showed that students who are adept at using mathematics equations in the solution of physics problems are not necessarily able to demonstrate understanding of the underlying physics concepts not provide a physical interpretations of the solution. The main point that Walsh et al, 1993; Clement, 1981; Lindner and Erikson , 1989; all make, is that their research has shown that although students' understanding of mathematical procedures is necessary to learn physics, it is not sufficient.

In conclusion, it would appear that these preservice science students in this study had serious problems with the calculations required in these electrostatics problems. Furthermore, it is also likely that they would be unable to demonstrate their understanding of the underlying physics concepts, given their poor performance and understanding illustrated in the test so far.

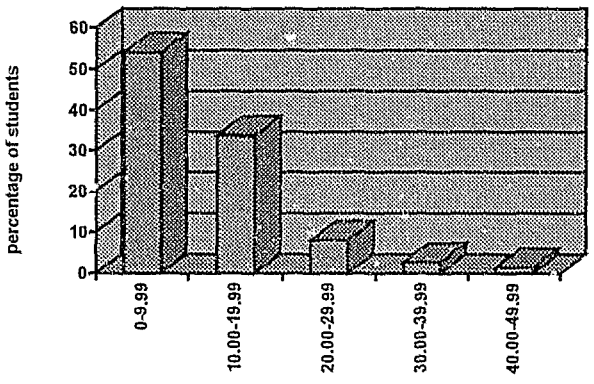
6.3.4 Students' performance on velocity and displacement-time

There are many international studies that have found extensive conceptual difficulties across physics including the concepts velocity and displacement, (Peters, 1992; Champagne et al, 1980; and Trowbridge and McDermott, 1981).

- **Students overall performance on velocity and displacement-time**

The results for the questions on velocity and displacement-time were once again generally poor and Figure 6.15 shows the distribution of the results across the five percentage categories.

Figure 6.15 Students' overall performance on velocity and displacement-time



As can be seen from Figure 6.15, 88% of the students obtained less than 20% for this topic and only 1.4% of the students achieved between 40% and 50% for this topic.

- ***Students' overall results for velocity and displacement-time by college***

The performance of the students in velocity and displacement-time varied across colleges. Table 6.18 represents the relationship of the students'

performance by college.

Table 6.18 Students performance on the topic by college

% obtained by students	College A % of students (n = 19)	College B % of students (n = 47)	College C % of students (n = 23)	College D % of students (n = 14)	College E % of students (n = 22)	College F % of students (n = 23)
0-9.99	58	51	39	43	59	74
10-19.99	37	32	43	43	32	22
20-29.99	5	11	8	14	4.5	4
30-39.99	0	4	5	0	4.5	0
40-49.99	0	2	5	0	0	0

Unlike Electrostatics, no association was found between the students' results in this topic and the colleges they attended. However, as shown in Table 6.18, the students from College C performed best overall in velocity and displacement-time, with 18% of their students achieving more than 20% on this topic compared to 5%, 17%, 14%, 9% and 4% of the other colleges' students. Furthermore, 5% of College C's students achieved more than 40% with the only one other college's students, College B (2%), achieving more than 40%.

- ***Students' overall results for velocity and displacement-time by course***

The students' performance in this topic was linked to the course the students were following. This was consistent with the finding on the other Physics topic (Electrostatics) and was also found in the students overall performance.

Table 6.19 Relationship between students' course and the students' means percentage for velocity and displacement-time

Percentage obtained	Senior Primary Teachers' Diploma % of students (n = 42)	Secondary Teachers' Diploma % of students (n= 106)
0-9.99	67	49
10-19.99	29	36
20-29.99	4	9
30-39.99	0	4
40-49.99	0	2

Overall the STD students performed better than the SPTD students. Fifteen percent of STD students obtained more than 20% compared to 4% of SPTD students. No SPTD students achieved more than 29% for this topic compared to 6% of STD students. The superior performance of the STD students was not entirely unexpected as this corresponds with the students' performance in their physical science matriculation examination.

- ***Students' overall results for velocity and displacement-time by gender***

There was relationship between the students' gender and the mean score obtained on velocity and displacement-time. A similar finding was made on the overall performance of the male students and in the other Physics topic.

Table 6.20 Relationship between gender and the students' performance

Percentage obtained	Male % of students (n= 62)	Female % of students (n= 80)
0-9.99	45	58
10-19.99	35	35
20-29.99	13	5
30-39.99	5	1
40-49.99	2	1

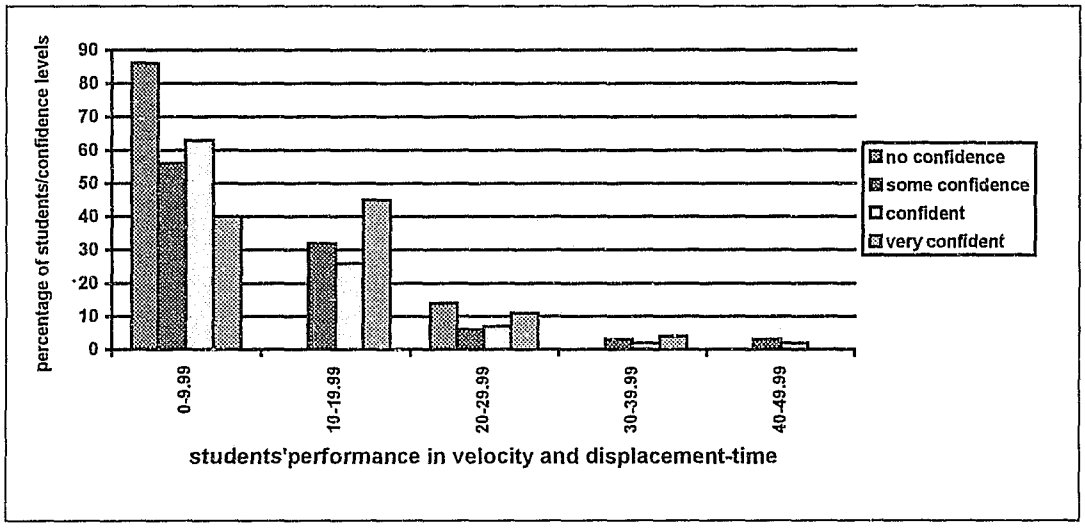
As can be seen in Table 6.20, the male students' performance was generally better than the female students. Fifty-eight percent of female students scored less than 10% compared to 45% of the male students. Furthermore, 20% of male students scored more than 20 % compared to 7 % of the female students.

- **The relationship between the students' perceptions of their understanding of velocity and displacement-time and their performance**

No statistical association was found between the students' results and their

degree of confidence in their understanding of the topic.

Figure 6.16 The relationship between the students' perceptions and their performance in the topic



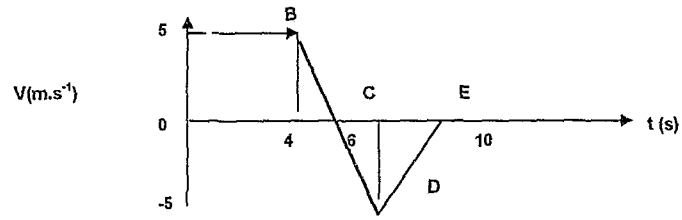
As shown in Figure 6.15, students with some degree of confidence performed better than those students with no confidence, although this was not statistically significant. For instance, 86% of the students without any confidence achieved less than 10% for this topic. However, only 40% of the students that were very confident on this topic achieved less than 10%

- **Analyses of velocity and displacement-time questions**

In order to analyse the topic further; it is necessary to look at the individual question/item results.

Question 1

The graph represents the velocity of a body moving horizontally towards the east.



Calculate the magnitude and direction of the displacement of the body after it has been in motion for 10s.
(Use the graph. Do not use the equations of motion.)

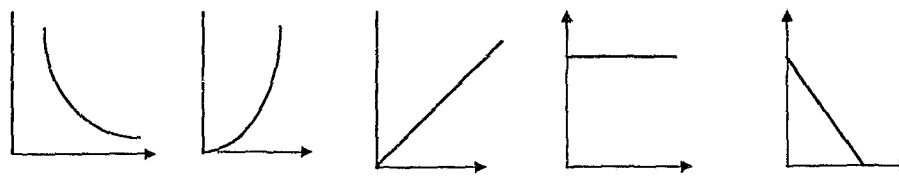
Question 2

A car of mass M is moving along a straight level road at a certain velocity. The driver then applies the brakes and the car decelerates uniformly coming to a stop after travelling a distance S. A second car of mass 2M is moving under similar conditions at the same velocity. If the second car brakes with the same retarding force as the first car in what distance will the second car stop?

A. 4S B. 2S C. S
D. 1/2S E. 1/4S

Question 3

A steel ball rolls down an incline of constant slope. Which one of the following graphs describes the relationship between the displacement (s) and the time (t) correctly? (Friction is negligible.



Question 4

A traffic patrol car stops at a red robot along a straight road. A truck, maintaining a constant velocity of 9 $m.s^{-1}$ passes the patrol car and goes through the red robot. The robot only turns greens 10 seconds later and at this instant the patrol car accelerates uniformly at 2 $m.s^{-2}$ and chases the truck.

A. Calculate the time the patrol car took, from the moment it left the robot, to overtake the truck. [HINT: at the moment of overtaking both vehicles have travelled the same distance from the robot.]

B. Calculate how far both vehicles were from the robot at the moment of overtaking.

Question 5

Which one the following statements are false?

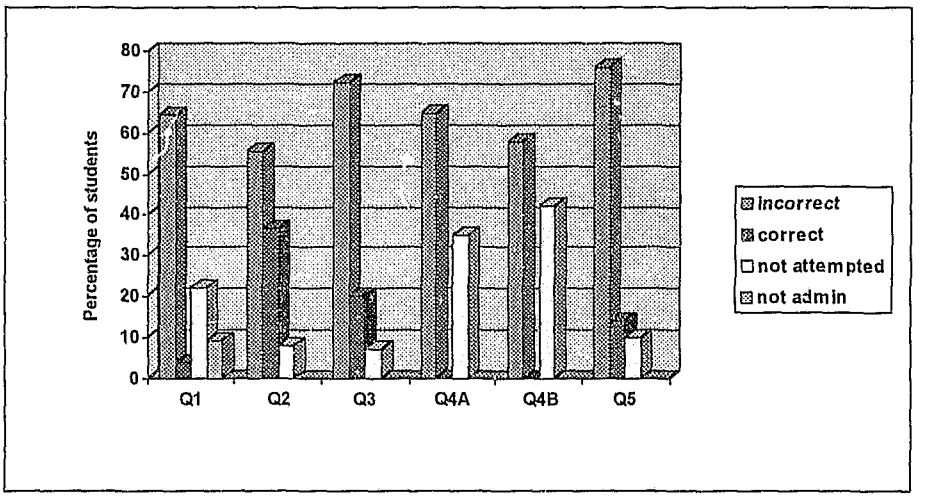
An object can have, at some stage of its motion:

A. constant speed, even though its velocity is changing,
B. constant acceleration, even though its velocity is changing,
C. constant velocity, even though its speed is changing,
D. zero velocity, even though its acceleration is not zero.

In cases where questions had several parts to it, such as Question 1, 2, 3 and 4, the mean was calculated for all parts together and presented as an overall percentage for the question.

The results for each question are illustrated in Figure 6.17. The percentage of questions answered: correctly, incorrectly, were not attempted (or as in question 1 in a few cases, was not administered) by the students present.

Figure 6.17 Students' results on the Velocity and Displacement-time questions



As can be seen by Figure 6.17, most students attempted all the questions in this topic. Of the five questions, question two had the highest number of correct answers and 36.5% of the students answered the question correctly. Question 4 proved to be difficult for students as no students answered this question correctly. Question four seemed to be the most problematic on appearance to the students, as 38% of the students did not attempt to answer it. The questions with their separate parts are shown below in Table 6.21 together with the results for each part.

Table 6.21 Results for individual questions

Question	incorrect	correct	not attempted
1	64.4	4.0	22.1
2	55.4	36.5	8.1
3	72.5	20.1	7.4
4A	64.9	0	35.1
4B	57.7	0	42.3
5	75.8	14.1	10.1

As can be seen from Table 6.21, on average, 65% of the students answered the questions on this topic incorrectly. In particular, Questions 4A and 4B seemed to be problematic as no students answered the questions correctly and 35% and 42% of the students respectively did not even attempt the question. Question 1 was also answered poorly, although 78% of the students did attempt to answer the question. The high attempt rates of questions 2, 3 and 5 can be explained by the fact that all three of these questions were multiple-choice questions.

- ***Thinking levels required by oxidation reduction and electrochemical questions***

Questions 1, 2, 4A and 4B required the highest level of thinking and thus would have been considered the most difficult. Of these, questions 1, 4A and 4B were answered very badly. The probable reason for this poor performance is that they required the students to perform calculations, which as with the Electrostatics problems, students had difficulty in performing.

Question 2 also called for a calculation, but it was in form of a multiple-choice question, so students could also guess the answer, thus

explaining the relatively better performance. Question 3 was also a multiple choice question as was question 5 both allowing students to guess the answer which may explain the slightly better performance in these questions and is also consistent with the findings of the other three topics.

These poor results are corroborated by a pilot study involving South African preservice students (Govender, 1998) which revealed that many students have a poor understanding of concepts such as speed, velocity and acceleration. Furthermore, it was shown that sign conventions, an understanding of signs and definitions had been memorised without understanding for examination purposes. This learning for assessment purposes is also highlighted by Walsh et al (1993:1134) who stated that " *if methods of assessment preferentially focus on the reproduction of facts, formulas and mathematical procedures rather than on understanding of the underlying concepts and principles, it is not surprising that students who successfully pass examinations may display a limited understanding of key concepts and principles*" within physics. Govender makes the same point and has furthermore found that the rote learning of these definitions (and formulas) resulted in them being forgotten almost immediately after the matriculation examinations.

The poor results of the students seem to correlate with the statements above, as several of the questions included calculations. However the poor performance on questions 3 and 5 is not explained quite as simply and indicates the absence of knowledge of basic facts and principles in this topic. Since a great deal of time is normally spent on mechanics and Newtonian physics in the last years at schools, this is surprising.

6.3.5 Students' achievement across the science topics

This section explores the similarities and differences in the students' achievement, as well as the relationships found across the topics in terms of their achievement.

Similarities and differences between students' achievement across topics

- Associations were found between the students' performance in two (Electrostatics and Oxidation-Reduction) out of the four topics and the **college** that the student was enrolled at. In both these topics, students from College D performed significantly better than those from other colleges. Secondly, a significant association was found between the students' achievement in those topics and the **course** they were enrolled in. In both these topics, STD students performed significantly better than SPTD students. Finally, a significant association was also found between the students' achievement in those topics and their **gender** with male students performing significantly better than female students.

- A weak relationship, but no statistical association, was found between the **students' confidence** across three of the four topics (the exception being the periodic table). In these topics, the more confident students attained the higher percentages for those topics and conversely a similar trend was observed amongst the less confident students who achieved lower percentages generally.

- In these analyses of the questions, common problems were observed across the topics. Students had problems with open-ended questions and fewer students attempted these questions across all four topics. This has also been observed in other studies (Thijs and van den Berg, 1995; Howie, 1997; and Howie and Hughes, 1998) and appears to be symptomatic of both the lack of basic understanding required by the questions and an inability to communicate or express themselves. This is particularly relevant in this study as all students were second or third language speakers. Thijs and van den Berg (1995:319) stated that "*if students lacked an articulation of their alternative conceptions, it might mean that either the conceptions are rather weak or that the conceptions are there, but students are not fully aware and do not have yet the terminology to express them.*" In the South African context it appears that both explanations are valid, with the additional complication of a second language.

- Students even did poorly in the multiple-choice questions across three of the four topics (with the exception of electrostatics) and most often achieved results below the chance level. For instance if four alternative answers were offered, the student had one in four chance of guessing the right answer. However, in many cases, less than 25% of the students guessed the correct answer, perhaps indicating the presence of strong misconceptions.

Relationship between the students' achievement across topics

The relationship between the students' achievement across the four science topics was explored using the Chi-squared test. A number of significant

relationships were found and are described below per science topic included in the students' test.

- There was a highly significant association ($p < 0.001$) between the students' performance in the **Oxidation reduction and electrochemical cells topic** and their performance in the **velocity-time and displacement time topic.** Students who tended to perform poorly in oxidation-reduction also performed poorly in Velocity time and displacement time. For instance of the students achieving more than 10% and/or less than 20%, 94% achieved between 10 and 20% for Velocity time and displacement time relationship questions.

- A significant association ($p < 0.01$) was found between the students performance in the **electrostatics topic** and their performance in the **velocity-time and displacement time topic.** The students who performed poorly in electrostatics also performed poorly in velocity-time and displacement time. For instance of the students who achieved less than 10% for electrostatics, 94% achieved less than 20% for the velocity-time and displacement time topic.

Although the following relationships were not associated statistically by the chi-squared test, the following observations were made:

- There was relationship between the students' performance in the **electrostatics topic** and their performance in the **oxidation reduction and electrochemical cells topic**. Students who scored the higher marks for electrostatics also scored the higher marks for oxidation-reduction. Of the students who scored between 30%-60% for electrostatics, 41% scored between 30%-60% for oxidation-reduction.

- There was a relationship between the students' performance in the **Oxidation reduction and electrochemical cells topic** and their performance in the **periodic table topic**. Students who performed very poorly in oxidation-reduction also performed very poorly in the periodic table. Of the students who achieved less than 10% for oxidation-reduction, 97% also achieved less than 10% for the periodic table.

No relationship was found between the students' performance in the topics **electrostatics** and the **periodic table**; and **velocity-time and displacement time topic** and the **periodic table.**

Note: The results are surprisingly consistent and reflect that the students are very weak across all topics.

6.4 THE RELATIONSHIP BETWEEN THE STUDENTS' OVERALL PERFORMANCE ON THE SCIENCE TEST AND THEIR BACKGROUND VARIABLES

In an attempt to uncover the possible reasons for the students lack of achievement in the science test, the relationship between the students' performance in this test and their backgrounds was analysed. Whilst one realises that the relationship between these variables may not be causal, it is nevertheless important to try to ascertain possible or probable factors contributing to the students' poor overall performance. An analysis was conducted, using the chi-squared test and correlational analysis, where appropriate, and the variables, which were found to be significant, are discussed below

As reported in 6.1, associations or relationships were found between the students overall percentage on the test and the students' college, their teachers' diploma course and their gender. In this section, the associations and relationships found with the area where they grew up; the year they matriculated; and the students' opinions about science are analysed and discussed below.

- A highly significant association ($p < 0.001$) was found (using the chi-square test) between the students' **overall performance** and the **students' *opinion* about what makes physical science enjoyable**. Students who felt that either experiments, or more than one factor (such as experiments plus teachers), made physical science enjoyable at school appeared to achieve higher results overall. Of the students who achieved a mean percentage of more than 15%, 40% felt that experiments were the most important factor and 53% felt that more than one factor made science enjoyable and these together represented 93% of the students achieving above 15%. Whilst there are diverse opinions about the relationship between students' attitudes and achievement in science as discussed in Chapter 2, the results from this study reveal a close link between the two.

- A highly significant association ($p < 0.001$) was found between the students' **overall performance** and the **year of matriculation**. Students who achieved higher overall results, matriculated just prior to 1996 (i.e.: 1995/1994). Of the students who achieved a mean percentage of more than 15% ($n = 54$), 52% matriculated in either 1995 or 1994. Of the students achieving above 25% ($n = 15$), 13 matriculated in 1995 or 1994. Thus those students who matriculated earlier were therefore older,

performed worse than more recent matriculants. This finding is supported by Huggins (1994) who had also found this relationship between low achievement and mature entry.

- There was a relationship between the students' **overall performance** and the **area where the students grew up**. Students who achieved higher results overall, generally came from the rural areas. Of the students who achieved a mean percentage of more than 15% (n = 54), 66% of the students came from rural areas compared to only 33% from urban areas. Of the students achieving above 25% (n = 15), 53% (n = 8) came from rural areas compared to 47% (n = 7) from urban areas. In particular, students from isolated areas appeared to do better (n = 71) and 59% of these students achieved more than 15% compared to 7%, 28% and 6% from rural towns, outskirts of cities and city centres respectively. This is one of the more interesting relationships found, as it dispels some myths about rural students achievement in physical science.

6.5 SIMILARITIES AND DIFFERENCES BETWEEN THE STUDENTS FROM DIFFERENT COLLEGES OF EDUCATION

The Colleges of Education selected for the study were a mixture of rurally-based and urban-based with some offering primary and others offering either primary or secondary or both courses, across three provinces. It was expected that there would be differences between the colleges and in particular that the students that these colleges attracted would also perform differently in the science test.

A large number of variables were analysed (by means of a chi-squared test)

for differences or similarities between the colleges and only those found to be significant when correlated were included for discussion below.

- There was significant relationship ($p < 0.001$) between the colleges and the **physical science marks** obtained by the students in their matriculation examination. Two colleges in particular appeared to have a greater number of students with significantly better physical science matriculation marks than the other four colleges. All of College D's students had achieved six points and more for physical science, whilst 61% of College B's students had achieved this. This is in comparison with 26%, 18%, 14% and 30% of the other colleges' students. Neither of these colleges had students with fewer than 4 points for their physical science matric exam. It is also significant to note that both of these colleges were rurally based and offered only secondary teachers' diplomas.

- Similarly, there was an association ($p < 0.01$) between the **colleges** and the **mathematics results** for the matriculation examination. The same two colleges (as with the physical science) in particular appeared to have a greater number of students with significantly better mathematics matriculation marks than the other four colleges. In this case 72% of College B' students and 71% of College D's students achieved above six points for their exams in contrast to 33%, 23%, 45% and 23% of the other colleges' students. Most disturbing was that 59% of students from College F achieved fewer than 4 points for their mathematics matriculation examination.

- A significant association ($p = 0.017$) was found between the colleges and the **gender** of their students. More than 50% of the students in four out of

the six colleges were female. Seventy-six percent of College F's students were female in contrast to College C who had the lowest percentage of female students (36%). The students in College F and College A, who also had a high percentage of female students (61%), were studying primary teachers diploma courses and as such may have been expected to have had a larger percentage of female teacher trainees. This could also explain why Colleges A and F did so poorly as female students and Primary teacher's diploma students performed worse.

- A significant association ($p < 0.01$) was found between the colleges and length of time that their students anticipated **studying** at the college. The students from College C, with 91%, and College D, with 100%, were the most confident of finishing their diploma courses within the minimum time of three years. The students at College D were also the youngest students the majority of whom had matriculated the year before entering the college. Interestingly Colleges C and D were also the colleges with the highest percentage of male students, 70% and 64% respectively. The students from College F, with 41%, were the least confident of completing in the minimum time and once again this was the college with the highest percentage of female students.

- There was a relationship between the colleges and the students' intended length of **teaching** career. Students from different colleges intended to teach for varying lengths of time. Students from College D, who had the highest performing students in the test, also had the largest percentage of students for whom a teaching career was a short-term aim (less than 5 years). Only 57% of the students intended to teach for more than 5 years. In contrast 68% of College A's students intended to teach as a long term career (more than 10 years). Fifty-three percent of College F's

students envisaged teaching as a medium-term (5- 10 years) career and had the smallest percentage of students (13%) intending to teach in the long-term.

6.6 RESULTS FROM THE LECTURERS' QUESTIONNAIRES

At the time of the study in 1996, there were more than 100 colleges of education all offering teachers' training courses up to 1995. Colleges of Education in South Africa have always played a Cinderella role in the hierarchy of tertiary education as confirmed by the is the National Teacher Education Audit (1995) and most recently by the national survey concerning mathematics and science teachers (Arnott et al, 1997). Both of these surveys concluded that the quality of pre-service training (with particular reference to Colleges of Education) was generally poor and that there were huge disparities across institutions. As three-quarters of South Africa's secondary school science and mathematics teachers graduate from Colleges of Education, this is an important sector of the science education system.

In order to gather some background information to explain possible variables in the student data, questionnaires were administered to all (six in total) the lecturers of the classes containing the first year science students sampled and tested. As mentioned previously these questionnaires included background information about the college as well as information about the sampled class. Five out of the six questionnaires
were analysed (unfortunately, the questionnaire from College D was not returned) and the results are discussed in this section.

6.6.1 Profile of the lecturers

The age of the lecturers ranged from 29 to 51, the median being 37 years of age. Three male lecturers and two female lecturers completed the

questionnaires.

Language of instruction in physical science is an important issue in South Africa, with many problems arising at school level amongst second language speakers (Arnott et al, 1997). Arnott et al, (1997:18) reported that several college lecturers have also reported that English as a second language often "*presented problems in the understanding and communicating of certain concepts in (mathematics and) physical science*". The national survey reported that most lecturers in historically black colleges do not have English as their mother tongue either and further suggests that "*the possibilities for ambiguity, misunderstanding, confusion and a complete lack of understanding are profound*". Although the report does not call for the language of instruction to revert to the vernacular, it strongly suggests the need for language development and sensitivity to language on the part of the colleges. However, reverting to the vernacular, if one takes the debate that far, would be difficult. As revealed in 5.1, when as many as nine languages are spoken by the college students in one college, which language would be used in those colleges?

With this debate in mind, the lecturers were asked to indicate their home language in this study. These languages varied, with two lecturers speaking English and each of the other three speaking Xhosa, Zulu and Afrikaans. If the national survey (Arnott et al, 1997) is correct, then this group was not representative of the broader population of Colleges of Education lecturers, in term of language groups.

Arnott et al reported on the qualifications of lecturers saying that there had been an improvement in academic qualifications and relatively few lecturers in mathematics and science did not have degrees. Four of the five lecturers

surveyed held degrees from universities with two of them having BSc Honours degrees plus teaching diplomas and the other two having BSc degrees with teaching diplomas. Only one lecturer had a teaching diploma from a College of Education.

Arnott et al reported that at several colleges, staff had little or no experience. This study's findings indicated just the opposite with the lecturers having between 5 years and 23 years school teaching experience and on average this amounted to 9 years of school teaching experience. However, it should be said that the amount of lecturing experience at Colleges of Education of all the lecturers was relatively little - between one year and five years, with 3 out of the lecturers having 5 years experience.

6.6.2 Information pertaining to the students tested

The number of students studying science in the first year at the colleges varied tremendously. The size of the first year class ranged from 19 to 53 students and always formed a small percentage of the total first year cohort in the colleges. The exception was College B as science was compulsory for all first year students. The average class size across the five colleges was 36. The average first year intake was 142, although it ranged from 70 students to 180 and therefore the science students on average represented about 25% of the first year cohort of the colleges tested.

As the testing of the students took place between May and the first week of July, it was thought important to ascertain which topics they had been taught since the beginning of the year. Lecturers were asked to indicate which of the fifteen topics, that were included, had already been taught to the

students.

Table 6.22 Topics taught to first year students tested

College lecturers	Oxidation reduction taught yes/no	Periodic Table taught yes/no	Electrostatics taught yes/no	Velocity time taught yes/no
A	No	No	Yes	Yes
B	No	Yes	*	*
C	No	Yes	No	No
E	No	Yes	No	No
F	No	Yes	Yes	No

As can be seen from Table 6.22, the only topic that had been taught (taught includes - the topic partly taught, a large part of the topic taught and topic completed) at all to most of the students was the Periodic Table, in which the students performed the wor t overall. Oxidation-reduction had not been taught to any of the students and despite this the students performed the best in this topic out of the four topics.

It should be noted that although the Colleges had opened officially in February, student strikes had resulted in lectures in some Colleges only starting in April. However, despite this, the fact that students had received some tuition in this topic and given the particularly poor results of the periodic table, this is a matter of concern.

Like the workshop lecturers mentioned in chapter 4, these lecturers were

also asked to rank the physical science topics in order of difficulty. The answers varied from one lecturer to another and are displayed in Table 6.23

Table 6.23. Lecturers ranking of topics tested, in order of difficulty

College lecturers	Years of Lecturing experience	Oxidation-reduction	Periodic Table	Electrostatics	Velocity
A	1	10	11	8	11
B	5	1	6	*	*
C	5	2	14	11	7
D	*	*	*	*	*
E	3	1	14	8	2
F	5	6	14	1	10
average ranking		**4**	**11.8**	**7**	**7.5**
workshop average ranking		**4.9**	**9.7**	**8.5**	**6.3**

The topics that are the most difficult are marked 1 and the topics the lecturers found the easiest are marked with a 15. Unfortunately, the lecturer from College B was unable to comment on the Physics topics as he taught chemistry only and the physics lecturer was on long leave at the time of testing.

On average the lecturers agreed that oxidation reduction/ electrochemical

cells was a difficult topic. Only one lecturer put this topic in the easy range. Four out of the five lecturers considered the periodic table the easiest topic. Electrostatics appeared to be the topic causing the most dissension as one lecturer considered it the most difficult topic whilst another considered it one of the easier topics. Like electrostatics, velocity-time also had divergent rankings from 2 to 11. These two topics were considered, on average, equally difficult.

The ranking by the students' lecturers generally corresponds with the rankings assigned by the lecturers in the initial workshop mentioned in Chapter 4. In both instances, the lecturers ranked oxidation-reduction as the most difficult and the periodic table as the easiest topics. However, there was a very slight discrepancy between the ranking of electrostatics and velocity/displacement. The lecturers from the workshop ranked electrostatics as being easier than velocity/displacement which was exactly the opposite to the students' lecturers' rankings.

Whilst the lecturers agreed on the whole on the ranking of the topics, the students' performance in these topics contradicted the perceptions of the lecturers. In fact the students appeared to find the periodic table, which the lecturers ranked as the easiest, the most difficult and performed best in the oxidation-reduction/ electrochemical cells topics, in contrast to the lecturers ranking it the most difficult on average. This is an interesting finding that will be expanded upon later in the Chapter 7.

In conclusion, the lecturers were found to have a reasonable amount of school teaching experience on average, but were fairly new to the Colleges. Only two of the lecturers were native English speakers and the other three lecturers represented three other language groups. The qualifications of the

lecturers were lower than one might have hoped for lecturers teaching at institutions of higher learning, but appeared to fit the national profile reported on by Arnott et all (1997).

The number of students of each college represented a quarter of the yearly intake at the colleges. The start of the academic year had been delayed due to student action and therefore little progress had been in the classes. However, students who had covered topics that were included in the test had no advantage over those who had not, as no difference could be found in the results of the tests. Finally, the Lecturers' rankings of the difficulty of the topics also coincided with those given by the workshop lecturers, although the students results did not reflect these rankings given by both sets of lecturers.

6.7. CONCLUSION

The students' performance in the physical science test was very poor. The overall average of the students' results in the test was 12.43% (With the standard deviation being 7.82). The performance of the student in both chemistry and physics (discussed in 5.2.2) was equally poor. (11.59%: 10.84% respectively). Of the four topics tested, the students' achievement was the highest in Oxidation Reduction/electrochemical cells (18.46%) and the lowest in the Periodic Table (4.72%) (see 5.2.3). Thus, the evidence from these test results shows that the students' knowledge of topics in physical science appears to be very limited.

The performance of the students differed between colleges. Students from Colleges A and College F achieved particularly low scores and the averages

of these colleges were less than 10% and contributed to the low overall average percentage of the students (see Figure 5.16). In contrast College D's students obtained an average percentage of more than 20%. (which although this was the highest score in this study it is cause for grave concern in students are hoping to teach science)

Primary teaching diploma students' results were lower than the secondary teaching diploma students and they obtained an average percentage of 7% compared to 14%. The college lecturers from the workshop also remarked on the weaker performance of PTD students. Female students achieved lower results than the male students with an average percentage of 10.49 %, compared to 15.63% see Table 6.4. The fact that the female students performed worse and that the majority of primary teaching students were female, partly explains the much lower results of the students studying primary teaching.

Students had more difficulty in responding to questions requiring written answers (open-ended questions). The inability of the students to respond to some of the open-ended questions, specifically where there was a very high percentage of students not attempting this type of question, could suggest a lack of knowledge. Typical examples of questions where significant percentages of students did not attempt them are Oxidation Reduction question 4A, 4B (69%), Periodic Table question 3 (80.5%), Electrostatics question 5C (62%) and Velocity question 4B (42%).

Students had considerable difficulty answering questions requiring calculations to be performed. This resulted in the students' low achievement in these questions, as can be seen in the low percentages of students answering the following questions correctly: Oxidation-Reduction question

4B (9%), Electrostatics question 5B (1%); Velocity question 4B (0%). In some cases it was obvious that students could not remember specific formulas or, in instances where students did remember the formula, they made substantial errors in the application of these formulas.

Students' performance on questions with alternate answers or multiple-choice answers was also poor. Students' achievement on the multiple-choice questions, requiring students to select their answers, was so low that, in some instances, this fell even below the chance level. By this it is meant that, if students had to choose between four answers, they had a 25% chance of getting the answer correct by simply guessing. Despite this, the students achieving the correct answers was less than 25% on the following questions for example: Oxidation-Reduction 5 (17%), Periodic Table questions 5C (2%), 5G (6%) and Velocity questions 5 (14%).

Students had difficulty with the questions requiring knowledge of basic scientific facts and principles with a high percentage achieving low percentages on such questions. High percentages of students incorrectly answered questions requiring basic scientific knowledge, as seen in Oxidation-Reduction questions, 1B (87%), 1C (84%), 1D (81%), Velocity question 5 (76%); Electrostatics question 2A (52%). These results suggest an inadequate grounding in physical science at the very basic level, as well as indicating the presence of misconceptions or alternative conceptions in physical science. It is furthermore important to note that these questions were generally considered to require a low cognitive level (see 6.3).

Students were also unable to substantiate their answers. This often occurred where students were asked to explain their answer to the previous question, having correctly answered the first part of a question offering alternate

answers (i.e.: yes/no or a choice of two other answers). This clearly indicates that students resorted to guessing the answer in the first question or lacked the understanding of the knowledge required in the question, or the ability to express it, to substantiate their answer. A good example of this was found in Question 3A in Oxidation Reduction where 67% of the students answered the first part of the question correctly, but then 98% (of 67%) of them could not substantiate it, meaning that only 2% answered the second part correctly.

Confident students did better in specific topics of the science test. Students who were more confident of their knowledge in two topics (Oxidation-Reduction and Electrostatics) achieved better results than those with lower confidence levels in those topics. What is most interesting however, is the students dismal performance in the Periodic Table, despite the fact that the students generally were the most confident in this topic out of the four. Male students exhibited more confidence than the female students.

Students, who matriculated in 1994/1995 prior to entering the colleges, achieved higher results than those who had left school earlier. The most obvious reason is that the knowledge of these students is more recent and therefore easier to recall than students who had matriculated in years before. Secondly, students who matriculated in 1994 and 1995 had less disrupted schooling (see Table 5.28) and therefore more contact learning time

Students who had grown up in rural areas achieved higher scores overall in the test than those who were brought up in urban areas (see 6.1). A higher percentage of rural students were found to study more, watch less television, read more and had less disrupted schooling in their matric year than the urban students (see 5.1.1). Thus, their schooling being less disrupted and

their greater dedication to their studies may explain the rural students' performance. Furthermore, rural students may have fewer distractions than urban students and the fact that they watch less television illustrates this.

There were significant differences in the achievement of students from the different Colleges of Education. Students from College D achieved higher results on the test than any other cohort of students. The majority of College D's students finished school in 1995 (86%); were mostly male students (64%); and were all secondary teacher's diploma students. All of these factors are related to achievement. In contrast, most of College A's students, who achieved the lowest overall average percentage, matriculated between 1988 and 1992 (79%); were female (61%); and were all studying the primary teachers diploma course.

Students, who had been taught certain science topics, at their Colleges of Education, did not achieve significantly higher scores for those topics (see 5.2.3 and 5.5). The Periodic Table was taught to students at four colleges who performed no better than the students of the remaining college. Furthermore, students achieved the lowest results on this topic. Students achieved the highest results for the topic, Oxidation-Reduction, which was not taught to students at any of the colleges.

As is evident in the poor results, the students found the test very difficult. As the reliability of the test was high and the questions that were selected had been judged fair and without ambiguous and complex language; it can be concluded that the students who wrote the test were not up to the standard required to enter into the college courses. In fact, their physical science content knowledge appeared to be far below the minimum requirements for students entering into science teaching courses.

CHAPTER 7 KEY FINDINGS AND RECOMMENDATIONS

To highlight the key findings, it is essential to put these in the context of the study and the central research problem statements which were:

To investigate the content knowledge and performance in physical science of first year science students' at historically black Colleges of Education in South Africa;

To determine some of the factors that may impact on their content knowledge and performance in physical science.

These statements should also be seen (and have been presented in this dissertation) against the background of the performance of students in science and mathematics over the past decade. The problem statements concern African matriculants especially with particular reference to the former DET preservice student cohort of teacher trainees. There has been discussion within education circles and Colleges of Education as well as some anecdotal evidence (see for instance Howie and Wedepohl, 1993) regarding the problems of students with insufficient science content knowledge. This study is an attempt to quantify the extent of this problem within the Colleges of Education sector.

The key research questions (as discussed in 1.4) steered the design of the study, in terms of the design and implementation of the test instruments and questionnaires.

These were:

1. How do the students perform in physical science?
2. What is the extent of the students' physical science content knowledge?
3. How do the students perceive the level of their knowledge of physical science and how confident are they in their science knowledge base?
4. What are their attitudes towards physical science
5. What is the profile of the students entering into first year science courses at Colleges of Education?
6. What are some of the factors that may impact on, or influence, the students' achievement in physical science?
7. What are the factors that influenced the students' choice of teaching as a career?
8. What is the extent of the students' commitment to teaching?
9. Based on the students' performance and their profile, what recommendations can be made for **preservice science education** at Colleges of Education in South Africa?

To facilitate the formulation and discussion of the key findings in this chapter and to address the focus of the study, the research questions will be taken as the point of departure for the discussion. For each of the research questions, the relevant findings from this study will be formulated and discussed. This will be followed by a number of recommendations, which have been drawn up following the nature of the key findings, bearing in mind the limited nature of the study.

7.1. STUDENTS' PERFORMANCE IN THE PHYSICAL SCIENCE TEST

The key findings for the first two research questions concerning the students' performance in the test and their content knowledge of physical science are discussed in this section.

7.1.1 The students' performance in the physical science test was very poor.

The overall average of the students' results in the test was 12.43% (with the standard deviation being 7.82). The average performance of the student in both chemistry and physics (discussed in 5.2.2) was equally poor (11.59%: 10.84% respectively). Of the four topics tested, the students' achievement was the highest in Oxidation Reduction/electrochemical cells (18.46%) and the lowest in the Periodic Table (4.72%) (see 5.2.3). Thus, the evidence from these test results shows that the students' knowledge of topics in physical science appears to be very limited. The poor quality of science students is confirmed by Arnott et al (1997) who referred to it throughout their report.

The performance of the students varied according to the students' **gender,** the **college** they were enrolled at and what **course** they were studying. **Female students achieved lower results** than male students with an average percentage of 10.49 % compared to 15.63 % (see Table 6.4). The finding that male students achieved higher average percentages than the female students has also been reported in other studies (see for example Adams, 1996). **Students from Colleges A and College F achieved particularly low scores** and the averages of these colleges were less than 10% and contributed to the low overall average percentage of the students (see Figure 5.16). In contrast College D's students obtained an average percentage of more than 20% (which although this was the highest score in

this study it is cause for grave concern in students who are hoping to teach science). **Primary teaching diploma students' results were lower** than the secondary teachers' diploma students and they obtained an average percentage of 7% compared to 14%. The fact that students, who had enrolled for secondary teachers' diploma courses, achieved better results may be partly attributed to the higher/stricter admission requirements for secondary teachers diploma courses and that the higher matric results correlated with better test results. A college lecturer from the workshop also remarked on the weaker performance of the PTD students. These findings help to explain why Colleges A and F achieved the poorest results. They both offered primary diplomas and the majority of their students were female.

7.1.2 Students had more difficulty in responding to questions requiring written answers (open-ended questions)

- **Students had difficulty in answering open-ended questions satisfactorily.** The inability of the students to respond to some of the open-ended questions, specifically where there was a very high percentage of students not attempting this type of question, could suggest a lack of knowledge. Typical examples of questions where significant percentages of students did not attempt them are Oxidation Reduction question 4A, 4B (69%), Periodic Table question 3 (80.5%), Electrostatics question 5C (62%) and Velocity question 4B (42%). This may also be related to the fact that students could have experienced a language and communication problem, remembering that all the students wrote the test in English and not their home language.

Several studies confirm students' problems in articulating answers (Thijs and van den Berg, 1995, amongst others) and others highlight the issue of second language and science (Ogunniyi, 1996 and Arnott et al, 1997)

- **Students had considerable difficulty answering questions requiring calculations to be performed.** This resulted in the students' low achievement in these questions. In some cases it was obvious that students could not remember specific formulas or, in instances where students did remember the formula, they made substantial errors in the application of these formulas.

- **Students' performance on questions with alternate answers or multiple-choice answers was also poor.** Students' achievement on the multiple-choice questions, requiring students to select their answers, was so low that, in some instances, this fell even below the chance level.

7.1.3 Students had difficulty with the questions requiring knowledge of basic scientific facts and principles.

- **A high percentage of students achieved low percentages on questions requiring knowledge of basic scientific facts and principles.** High percentages of students answered questions requiring the basic scientific knowledge incorrectly. This suggests an inadequate grounding in physical science at the very basic level, as well as indicating the presence of misconceptions or alternative conceptions in physical science. It is furthermore important to note that these questions were generally considered to require a low cognitive level (see 6.3). The difficulty of students in their understanding of basic scientific facts and principles has been reported in the literature extensively as discussed in Chapter 2 and Chapter 5.

- **Students were unable to substantiate their answers.** This often occurred where students were asked to explain their answer to the

previous question, having correctly answered the first part of a question offering alternate answers (i.e.: yes/no or a choice of two other answers). This clearly indicates that students resorted to guessing the answer in the first question or lacked the understanding of the knowledge required in the question, or the ability to express it, or to substantiate their answer (or a combination of these). The inability of students to substantiate their answers has been reported widely by Garnett and Treagust; 1992b; Walsh et al, 1993; and Thijs and van den Berg, 1995 among others.

7.2 STUDENTS CONFIDENCE IN THEIR CONTENT KNOWLEDGE OF PHYSICAL SCIENCE

The key findings on the students' level of confidence in their own content knowledge of the physical science topics covered in matric and included in the science test are discussed below.

7.2.1 The confidence levels were higher than the results of the matriculation physical science examination suggested.

- **Students were generally confident about their knowledge of physical science.** Considering that 53% of the students had achieved fewer than 6 points for their matriculation physical science exam (see Figure 5.12), which is equivalent to less than an E-symbol on the higher grade and less than a C symbol on the standard grade, this confidence is even more surprising.

7.2.2 Confident students did better in specific topics of the science test

Students who were more confident of their knowledge in two topics (Oxidation-Reduction and Electrostatics) achieved better results than those with lower confidence levels in those topics. What is most interesting however, is the students dismal performance in the Periodic Table, despite the fact that the students generally were the most confident in this topic out of the four. Male students exhibited more confidence than the female students, which concurs with the findings of other studies (Adams (1996) amongst others).

7.3 STUDENTS ATTITUDES TOWARDS PHYSICAL SCIENCE

- **Students had positive attitudes towards physical science and felt that studying, and not ability, results in success in physical science.**
  On the whole, students' attitudes to physical science were positive. Furthermore, the majority of the students felt that hard work is necessary to do well in physical science. Both these findings were also found in the TIMSS findings concerning grade 12 pupils in South Africa (Howie and Hughes, 1998).

- **Practical work makes physical science more enjoyable for students**
  The single factor identified by the students that would contribute to making physical science more enjoyable in matric, was practical work/science experiments. Students who believed that experiments/practical work contributed to the enjoyment of learning science performed better than students identifying other factors. It is believed that students feel this way as it assists them in understanding the more difficult or abstract concepts and lessens their feeling of alienation from the subject. There is extensive

literature supporting the finding that students' attitudes influence students' performance. Woolnough, (1995 and 1997) is a strong proponent of practical work at school level and has also noted the influence of students' attitudes on their performance in physical science.

7.4 THE PROFILE OF THE STUDENTS IN THE STUDY

7.4.1 Findings related to the students' biographical profile

- **The students' ages varied considerably .** The average age of students also varied from college to college (see table 5.2) with College D's students being on average 20 years of age in contrast to College A's where the students' mean age was 24 years. The FRD (1996) also reported on the mature age of African candidates leaving school.

- **The ratio of male to female students enrolled differed across the colleges and courses.** Just over half of the students were female, however College F's cohort comprised 76% female students and College C's only 30% female students'. Within the diploma courses, there were also differences regarding gender. The majority of the Senior Primary Teachers' diploma, were female students in contrast to the Secondary Teachers Diploma courses where only half of the students were female.

- **Students' parents generally had low levels of education**
  Most of the parents of the students did not complete secondary school and less than 9% had attended tertiary education institutions. In general these students were first generation tertiary students. A similar finding was included in the TIMSS report that reported only 9% of fathers and 6% of mothers had attended tertiary education (Howie and Hughes, 1998: 40).

- **Most students in the Colleges came from rural areas**
  Two-thirds of the students in the colleges came from rural area (see table 5.4) and had attended schools in rural areas (see Figure 5.9). This is high considering that only 50% of South Africa's population live in non-urban areas (CSS, 1997:8)

7.4.2 Findings related to students' activities and performance in their matric year.

- **The students' performance in physical science and mathematics in matric was poor.** Generally, the students' achievement in physical science was low and the majority of students obtained an E- or F symbol (on both HG and SG) for matric. The students' performance for physical science was weaker than for mathematics. The report by Arnott et al reported that although certain minimum requirements for Colleges of Education existed for physical science (and mathematics) at Grade 12 level, these were frequently relaxed to ensure that more candidates could be enrolled in their science courses.

- **Several factors related to students' performance in physical science and mathematics at school.** The students' whose **schooling was least disrupted** achieved higher results in their physical science matriculation exam. Students, who **finished matric after 1993**, on the whole achieved higher results than those in other years. Finally, science students with higher matric symbols for **mathematics** also achieved higher physical science symbols for matric.

The same factors were related to the students' **mathematics** achievement. However, in addition to the factors already mentioned above, the amount of

time that students spent **reading** was related to the students' achievement in mathematics, which was not true for physical science.

- **Rural students generally spent more time on homework in matric.** Rural students spent more time on their homework in their matric year and those students coming from isolated rural areas in particular studied more.

- **Insufficient time was spent on physical science homework in matric.** Sixty-eight percent of the students spent two hours or less on physical science during their matric year. This is a matter of concern for a demanding subject such as physical science and may contribute to their low achievement in the physical science matriculation exam.

- **Most students' schools had science laboratories.** Of the schools attended by these students, 74% had laboratories. This is a very high percentage when compared to the national percentage of schools with laboratories, where the best provisioned province has 72% of its schools equipped with laboratories and the worst province having 24% of its schools equipped (HSRC, 1997). This fact could play a role in the students' decision to firstly, take physical science for matric and secondly, what has influenced them to choose science as a course at the Colleges. It would also partly explain their inclination of selecting practical work as a factor that enhances students' enjoyment of science.

7.5 FACTORS RELATED TO STUDENTS' ACHIEVEMENT IN PHYSICAL SCIENCE.

A number of key findings were made in terms of factors that were directly related to and are believed to have influenced the students' achievement. A number of these have been discussed previously in earlier paragraphs

including the relationship between students' achievement and their gender, attitudes, and confidence in their science content knowledge; and how students' performance differed depending on the College and the course they were enrolled in.

7.5.1 Students' achievement in the test was related to their studies/background in matric

- **Matriculants from 1994 and 1995 performed better** and achieved higher results than those who had left school earlier. The most obvious reason is that the knowledge of these students is more recent and therefore easier to recall than the students who had matriculated years before. Secondly, students who matriculated in 1994 and 1995 had less disrupted schooling (see Table 5.28) and therefore more contact learning time. This finding was also been observed by Huggins (1994).

- **Rural students achieved higher scores** than those who have brought up in urban areas (see 6.1). A higher percentage of rural students were found to study more, watch less television, read more and had less disrupted schooling in their matric year than the urban students (see 5.1.1). Thus, their schooling being less disrupted and their greater dedication to their studies may explain the rural students' performance. Furthermore, rural students may have fewer distractions away from urban areas and the fact that they watch less television illustrates this.

7.5.2 Students achievement was related to differences between student cohorts

- **Students achievement differed significantly between Colleges.** Students from College D achieved higher results on the test than any other cohort. The majority of College D's students finished school in 1995 (86%); were mostly male students (64%); and were all secondary teachers diploma students. All of these factors are related to achievement. In contrast, most of College A's students, who achieved the lowest overall average percentage, matriculated between 1988 and 1992 (79%); were female (61%); and were all studying the primary teachers diploma course.

- **Colleges' intervention in topics had no impact on students' results.** Students, who had been taught certain science topics, at their Colleges of Education, did not achieve significantly higher scores for those topics (see 5.2.3 and 5.5). The Periodic Table was taught to students at four colleges who performed no better than the students of the remaining college. Furthermore, students achieved the lowest results on this topic. Students achieved the highest results for the topic, Oxidation-Reduction, which was not taught to students at any of the colleges.

7.6 FACTORS INFLUENCING THE STUDENTS CHOICE OF TEACHING AS A CAREER

Sixty-seven percent of the students indicated that they had wanted to attend a university or technikon and not a College of Education.

- **The Colleges of Education was not the first career choice for the majority of students.** Furthermore, it is interesting to note that none of the students from College D (who had performed best overall in the test) had originally selected a College of Education as their first career choice. According to Arnott et al, the intake of quality African students into the colleges is negatively affected by the science and engineering programmes of universities and technikons competing for the same small pool of students. They further claim that a career in science and mathematics teaching is seen as a last resort by the relatively few students with science and mathematics at matric level. This is further supported by the survey conducted by Howie and Wedepohl (1993).

- **Parents and teachers generally did not advocate Colleges of Education.** Both parents and teachers advised most of the students to enrol at universities. Similar aspirations were also highlighted in the TIMSS report (Howie and Hughes, 1998: 36) where 75% of South African students wanted to attend universities on completing school, which was the highest percentage out of 22 countries surveyed.

7.7 THE STUDENTS COMMITMENT TO TEACHING

- **Students were not committed to teaching as a career.** More than half of the students did not intend to teach for longer than 5 years (see Table 5.23). Forty-three percent of College D's students (the top performing students) intended to teach for less than five years. The lack of commitment was also reported by the workshop college lecturers. Arnott et al also reported on this and stated that although this was not the case universally, students in many colleges of the education seemed to have little commitment to teaching as a career and stated that this was also corroborated by the National Teachers Audit.

- **Almost a quarter of the students anticipated taking longer over their diploma than the prescribed time.** A quarter of the students anticipated finishing outside the prescribed time for their diploma course (see Table 5.22). Interestingly, College D's students were more committed to completing their study in the minimum time than others, probably because they intended to carry on studying at university and wished to do this as soon as possible.

7.8 RECOMMENDATIONS

Arising from the study and its key findings are a number of specific recommendations regarding this sector of higher education. Given the nature of this study, it is not appropriate to generalise the findings to all the Colleges of Education, even though they may apply. The following recommendations thus centre around key issues, which were highlighted by evidence emerging from this particular study focusing on the formerly Colleges of Education formerly for the African students.

7.8.1 There is an urgent need for a revised strategy on recruitment and selection of candidates to science courses at colleges of Education.

It is believed that a revised strategy concerning the recruitment and selection of students for this College of Education sector is urgently needed. This strategy should include:

- the revision of the Admission policy at Colleges of Education with particular attention to the recruitment of Primary Diploma students,
- identifying/revising the criteria for selection into science courses at Colleges of Education, in order to attract better quality students. Selection procedures should include the use of reliable and valid instruments including language proficiency tests.

In particular, this revised strategy should include the means (by way of interviews) to determine the college applicants' motivation, confidence, attitudes and commitment towards science and science teaching in the final selection stage.

7.8.2 There is a need for the restructuring of preservice science programmes at Colleges of Education

Due to low content knowledge of physical science (and other attributes) exhibited by these students entering the colleges, different kinds of interventions and alternative methods for improving the students' physical science knowledge base (as well as other skills) to an acceptable level, need to be introduced. This could be in the form of intensive remedial bridging and/or academic support programmes, such as those adopted by other higher education institutions. These programmes are aimed at establishing a more solid, foundation in terms of students' understanding and content knowledge of physical science; developing language and communication skills in English as well as improved study methods.

7.8.3 The role of Colleges of Education (as part of the transformation of higher education in South Africa) with regard to the training of secondary science teachers, needs to be reassessed.

The performance of the secondary teachers' diploma students was low and indicated a low level of knowledge, and leads to concerns about these students' content knowledge in particular. If, as this study suggests, there is some doubt about the effectiveness of the Colleges' intervention in developing this knowledge base, alternative strategies for producing secondary school teachers need to be considered. Different countries around the world (including developing and newly developed countries such as Malaysia) have followed the route of secondary school teachers especially being university graduates in order to ensure a better quality of candidates in terms of content knowledge, in particular, entering the teaching profession.

Incentives need to be introduced by government for black graduates to be encouraged to enter the teaching profession

7.8.4 There is a need for the development of communication skills programmes for physical science at school level.

There is an urgent need for the introduction of programmes or increased attention to be given to the issue of language/communication skills for physical science. In the science test, many of the open-ended questions were poorly answered and indicated a low level of language proficiency. Furthermore, in the survey amongst lecturers at the RADMASTE workshop, several lecturers referred to students' inability to communicate in English. Language and communication programmes are needed to enhance the students' understanding, interpretation and expression of physical science. This is of particular importance for, but not limited to, students who are English Second language speakers.

7.8.5 The way forward

The final recommendation is that the findings of this study should be taken up by a larger, national study, in conjunction with the implementation of the new Higher Education policy and the transformation of Higher Education. The envisaged study should investigate and evaluate Preservice Science programmes (and teacher trainees) in the Colleges of Education sector as a whole. More work is needed to follow entrants into science courses at the Colleges and to assess their quality (in terms of knowledge, attitudes and pedagogical issues) in greater depth, as they leave the College and enter into teaching.

Finally, given the fact that teaching has a low status generally on South Africa and that this in turn attracts a low calibre of students, two possibilities emerge:
Firstly, to improve the status of teaching to attract better students (which has serious financial implications) and secondly, to develop the present College of Education syllabus along the lines already mentioned (7.8.2).

It is clear that intervention in the Colleges is needed in order to break the cycle of mediocrity in Physical Science teaching and learning in South Africa and to ensure the production of (South Africa's) scientists, engineers and technologists for the future.

A final word

Since this dissertation was completed, a number of developments regarding the colleges of education have since taken place. Several colleges have been selected for closure, whilst others have been transformed into community, agricultural or nursing colleges. A process of transformation and reconstruction of the higher education system is currently underway. A technical committee has been established by the Department of Education to investigate and prepare a report as a first step towards incorporating the colleges of education into the higher education system. This would mean that the colleges would fall under the jurisdiction of the Ministry of Education and no longer under the provincial authorities. The incorporation of the colleges of education into the higher education system will take in either one of two ways. They will either be incorporated into an existing university or technikon or they will become an autonomous college of education. To do the latter they will require an enrolment of 2 000 full-time students. This is planned to occur from the 1999/2000 financial year.

Neither the framework for *"Incorporating colleges into the higher education sector"* report (Department of Education, 1998a), nor the "*Norms and Standards for Educators*" report (Department of Education, 1998b) published this year, specifically address the issues recommended in section 7.8. The question of entrance requirements into colleges of education has yet to be addressed and until the issues around the autonomy of the colleges have been resolved, admission policies will remain in the background. Likewise, the critical situation regarding the provision of qualified, competent and dedicated science teachers is also unlikely to be addressed until the implementation of the new policies surrounding teacher education.

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Author Howie S J
Name of thesis Physical Science Content Knowledge Of First-Year Preservice Science Teacher Trainees At Colleges Of Education In South Africa Howie S J 1999

PUBLISHER:
University of the Witwatersrand, Johannesburg
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