

**THE IMPACT OF THE SEDIBA PROJECT ON THE ATTITUDE
OF PARTICIPATING EDUCATORS TOWARDS
CHEMISTRY AND CHEMISTRY TEACHING**

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ABSTRACT

Physical science is not a popular subject at school. This negative tendency can be observed in both educators and learners. One of the main causes of this lack of popularity is embedded in the attitude towards chemistry and chemistry teaching. This negative attitude can be attributed to the following factors:

- Lack of teaching aids
- Visualisation
- Perception of science
- Single approach to science teaching
- Scientific concept knowledge
- Environmental influences.

Most of these factors can be addressed by changing the attitude towards chemistry and approach to chemistry teaching of the educators. This study was aimed at probing into science educators' attitude towards chemistry and chemistry teaching. The empirical survey was conducted amongst a group of 37 science educators registered for an Advanced Certificate in Science (ACE) in the SEDIBA Project at the North West University, Potchefstroom Campus.

The investigation was done by means of a pre-test and a post-test. The results of both the pre-test and post-test were used to analyse the educators' attitude towards chemistry and chemistry teaching. Some of the factors influencing the attitude of educators towards teaching science that were investigated were:

- Use of teaching aids
- Application of different approaches to science teaching
- Attitude towards science

Results indicated that the above mentioned factors resulted in educators having a negative attitude towards chemistry and chemistry teaching prior to exposure to the SEDIBA project. The impact of the SEDIBA project was measured over a period of three months. Although there was not a big significant improvement over this short space of time on the attitude of

participating educators, results based on other criteria showed that intervention by instruction over time resulted in the increase of positive attitudes towards chemistry and chemistry teaching. This study indicates that a well-designed teacher program can change the attitude of educators towards science.

OPSOMMING

Natuurwetenskap is nie 'n populêre skoolvak nie. Hierdie negatiewe tendens kan by beide opvoeders en leerders waargeneem word. Een van die hoofredes vir hierdie ongewildheid lê in die houding teenoor chemie en chemie-onderrig, wat aan die volgende faktore toegeskryf kan word:

- Gebrek aan onderrighulpmiddels
- Visualisering
- Persepsie van wetenskap
- Enkelbenadering tot wetenskaponderrig
- Wetenskaplike begripskennis
- Omgewingsinvloede

Die meeste van die faktore kan aangespreek word deur die houding teenoor chemie en die benadering tot chemie-onderrig te verander. Die doel van hierdie studie was om wetenskaponderriggewers se houding teenoor chemie en chemie-onderrig na te vors. Die empiriese studie is gedoen met 'n groep van 37 wetenskaponderriggewers wat in die SEDIBA-projek by die Noordwes Universiteit se Potchefstroomkampus geregistreer was vir 'n Gevorderde Sertifikaat in Natuurwetenskaponderwys (GOS).

In die ondersoek is gebruik gemaak van 'n voor- en natoets. Die resultate van beide hierdie toetse is gebruik om die onderriggewers se houding teenoor chemie en chemie-onderrig te ondersoek. Faktore wat die houding van onderriggewers tot die onderrig van wetenskap bepaal, wat ondersoek is sluit in:

- Gebruik van onderwys hulpmiddels
- Toepassing van verskillende benaderings tot wetenskaponderrig
- Houding teenoor wetenskap.

Die resultate dui aan dat bogenoemde faktore 'n negatiewe houding teenoor chemie en die onderrig van chemie veroorsaak het voor blootstelling aan die SEDIBA-projek. Die invloed van die SEDIBA-projek is oor 'n periode van drie maande gemeet. Alhoewel daar nie 'n groot betekenisvolle verbetering in hierdie

kort tydperk verkry is t.o.v. die houding van deelnemende onderriggewers nie, wys resultate wat op ander kriteria gebaseer is, dat blootstelling aan die projek oor 'n langer tyd positiewe houdings teenoor chemie en die onderrig van chemie verhoog het. Hierdie studie dui aan dat 'n goedgestruktureerde onderwysprogram die houding van onderriggewers teenoor chemie kan verander.

CONTENTS

ACKNOWLEDGEMENT	III
ABSTRACT.....	IV
LIST OF FIGURES	XV
LIST OF TABLES	XV
LIST OF APPENDICES.....	XVI

CHAPTER 1

ORIENTATION TO THE STUDY

1. Introduction	1
1.1 Problem analysis.....	1
1.2 Hypothesis	3
1.3 Motivation for this study	3
1.4 Aims of the study.....	5
1.5 Definition of concepts	7
1.6 Methodology.....	8
1.6.1 Literature study.....	8
1.6.2 Empirical Research	8
1.6.2.1 Sample.....	9
1.6.2.2 The statistical technique.....	9

1.7	Classification of chapters.....	9
-----	---------------------------------	---

CHAPTER 2

ATTITUDE AND ATTITUDE MEASUREMENT

2.1	Introduction	11
2.2	Definitions of attitude.....	11
2.3	Theories of attitude	14
2.3.1	Elements of attitude	15
2.3.1.1	Consistency	16
2.3.1.2	Attitudes are predispositions	16
2.3.1.3	Attitudes are learned	17
2.3.1.4	Attitudes are evaluative.....	17
2.3.2	Science-related attitudes.....	18
2.3.3	Antecedents.....	19
2.3.4	Consequences of attitude.....	20
2.4	Attitude formation	21
2.4.1	Attitude and beliefs	22
2.4.2	Attitude and behaviour	23
2.4.3	Attitude and values	24
2.5	Factors influencing science-related attitudes	25
2.5.1	Educators' beliefs.....	26
2.5.2	Teaching competencies.....	28
2.5.3	Educators' beliefs about the teaching & learning of science.....	29
2.5.4	Educators' behaviour	32
2.5.5	Values, aims and society	34
2.5.6	Curriculum	35

2.5.7	Nature of science (NOS)	37
2.6	Attitude measurement	39
2.6.1	Self-report measure	40
2.6.2	The construction of attitudinal items	40
2.6.3	Theoretical consideration(s).....	41
2.6.3.1	Cognitive measure	42
2.6.3.2	Physiological measure.....	42
2.6.3.3	Behavioural measure	43
2.6.4	Practical considerations.....	44
2.7	Standard attitude scales.....	45
2.7.1	The scalogram analysis.....	46
2.7.2	Thurstone scale.....	47
2.7.3	Likert scale	48
2.7.4	Semantic differential scale	49
2.8	Conclusion	51

CHAPTER 3

ATTITUDE CHANGE

3.1	Introduction.....	52
3.2	The role of attitude towards science.....	53
3.3	Attitude change.....	55
3.4	Factors contributing to attitude exchange.....	55
3.4.1	Personal attributes of the tutor.....	56
3.4.2	Clarity of explanations.....	57
3.4.3	A clear structure for each lesson.....	58

3.4.4	Doing Hands-On activities	58
3.4.5	Variety of teaching strategies	59
3.4.6	Modelling, experience and reflection.....	60
3.4.7	Pedagogical Content Knowledge	61
3.4.8	Social Interactions	62
3.4.8.1	Parents.....	63
3.4.8.1	Peer.....	63
3.4.9	Nature of science.	64
3.5	Procedure for attitude exchange.....	65
3.5.1	Problem solving.....	66
3.5.2	Persuasion	67
3.5.3	Instruction	68
3.5.4	Social exchange.....	69
3.5.5	Motivation	69
3.5.6	Academic interest	70
3.6	Conclusion.....	71

CHAPTER 4

LEARNING AND TEACHING SCIENCE

4.1	Introduction.....	73
4.2	Theory of learning.....	74
4.3	Learning science	75
4.3.1	Meaningful learning.....	75
4.3.2	Cognitive conceptions of meaningful learning.....	77
4.4	Outcomes-based education	78
4.5	Constructivism.....	79
4.5.1	The constructivist learning theory	80

4.5.2	Constructivist teaching	82
4.6	Visualization.....	84
4.6.1	Models.....	86
4.6.2	Multimedia	87
4.6.3	Laboratory practical work	89
4.6.4	Lecture method.....	92
4.7	Understanding.....	94
4.7.1	What understanding is?	95
4.7.2	Learning for understanding	96
4.7.3	Teaching for understanding.....	96
4.8	Conclusion	98

CHAPTER 5

TEACHER DEVELOPMENT

5.1	Introduction.....	100
5.2	Teacher development.....	100
5.3	Distance education	101
5.3.1	Negative aspects of distance education.....	103
5.3.2	Positive aspects of distance education.....	104
5.4	In-service training	104
5.5	Evaluation of educator development programme.....	106
5.6	Assessment of lecturers/tutors.....	108
5.6.1	Procedure	108
5.7	Strategies for programme evaluation	109

5.8	Conclusion.....	109
-----	-----------------	-----

CHAPTER 6

THE SEDIBA PROJECT, THE SEDIBA CHEMISTRY SYLLABUS AND TEACHING STRATEGIES FOR CHEMISTRY

6.1	Introduction	111
6.2	Scenario in North West Province.....	111
6.3	What is the SEDIBA Project?	112
6.4	The SEDIBA Chemistry syllabus.....	114
6.5	Teaching strategy for the SEDIBA chemistry syllabus.....	119
6.5.1	Multimedia instruction	124
6.5.2	Laboratory methods	124
6.5.3	Lecture methods	125
6.6	Quality assurance in the SEDIBA project.....	125
6.7	Conclusion	126

CHAPTER 7

EMPIRICAL STUDY AND DISCUSSION OF RESULTS

7.1	Introduction.....	127
7.2	Aims of the Empirical study	127
7.3	Data assembling.....	127
7.3.1	Compilation of questionnaire	128
7.3.2	Aspects investigated in questionnaire.....	128

7.4	Processing of data	129
7.4.1	Statistical analysis	129
7.4.2	Effect size and practical significance	130
7.4.3	Cronbach's Alpha Coefficient	131
7.5	Demographic information.....	132
7.6	Discussion of the results.....	134
7.6.1	Sub-scale B.....	134
7.6.2	Sub-scale C.....	136
7.6.3	Sub-scale D.....	136
7.6.4	Sub-scale E.....	137
7.6.5	Sub-scale F.....	138
7.7	Discussion of results: Quality control.....	139
7.8	Findings.....	139
7.9	Conclusion.....	141

CHAPTER 8

SUMMARY AND RECOMMENDATIONS

8.1	Introduction.....	142
8.2	Summary.....	142
8.2.1	Chapter 1.....	142
8.2.2	Chapter 2.....	143
8.2.3	Chapter 3.....	143
8.2.4	Chapter 4.....	143
8.2.5	Chapter 5.....	143
8.2.6	Chapter 6.....	143
8.2.7	Chapter 7.....	144

8.3	Constraints for research.....	144
8.4	Recommendations.....	145
8.5	Intervention strategies.....	145
8.6	Recommendation for further studies	146
8.7	Conclusions.....	146
BIBLIOGRAPHY.....		147
APPENDICES.....		159

LIST OF FIGURES

CHAPTER 2

2.1	Schematic conception of attitudes	14
-----	---	----

LIST OF TABLES

CHAPTER 2

Table 2.1	Response patterns in perfect cumulative scale.....	47
-----------	--	----

CHAPTER 4

Table 4.1	Example of Models in nominal classifications	86
-----------	--	----

CHAPTER 6

Table 6.1	Contents of the SEDIBA chemistry syllabus	114
-----------	---	-----

Table 6.2	Enrolment and Diplomas awarded to the SEDIBA students.....	126
-----------	--	-----

CHAPTER 7

Table 7.1	Aspects investigated in questionnaire.....	129
Table 7.2	The effect-sizes indicated by ranges in d-values.....	131
Table 7.3	The Cronbach's Alpha reliability Coefficients	132

LIST OF APPENDICES

APPENDIX 1	Example of worksheet used by SEDIBA Chemistry students ...	159
APPENDIX 2:	Requisition for Permission	169
APPENDIX 3	Attitude questionnaire	170
APPENDIX 4	Sub-scales	178
APPENDIX 5	Responses to the questionnaire: Pretest and Posttest	181
APPENDIX 6	Comparison of educators' mean and standard deviation of Pretest & Posttests.....	186
APPENDIX 7	Comparison of educators' mean and standard deviation of Pretest & Posttests for each sub-scale	189
APPENDIX 8	Report on the evaluation of SEDIBA Physical science course by the participants: (Year 1-2003).....	190
APPENDIX 9	Example of SEDIBA's study manual.....	204
APPENDIX 10	Assessment guideline.....	211

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CHAPTER 1

ORIENTATION TO THE STUDY

1. Introduction

This study investigates the impact of the SEDIBA programme on the attitude of participating educators towards chemistry and chemistry teaching. The study was carried out in the North West Province of the Republic of South Africa. It dealt with educators who were enrolled with SEDIBA, a project run by the North West University, Potchefstroom Campus in South Africa.

1.1 Problem analysis

In the past decade the focus of science education has begun to shift from the preparation of a few learners for professional and technical careers to the preparation of all learners for life in a world of rapid scientific and technological change. This means that one of the major priorities of science educators should be to help all students to integrate what they learn about science and technology with their daily experience and their knowledge of societal issues (Nolen & Haladyna, 1990:115). The reform efforts are bound by a common theme: to ensure a scientifically and technologically literate citizenry for the 21st century (Shymansky & Kyle, Jr., 1992).

Whilst different educators seek different kinds of educator development within science education today, the professional growth they seek includes responses to such concerns as continuity, progression, differentiation, the inclusive curriculum, assessment, teaching and learning activities, curriculum science that is relevant, meaningful, and useful to the students, and resources to support teaching and learning (Bell & Gilbert, 1996:1-6).

Another concern for which some educators seek professional development is "differentiation", or ensuring that the learning expected of students at a given time is closely geared to the current learning skills and attainment status of the students concerned, and that prior experiences, knowledge, interests, concerns and values will assist students in reaching their full potential. The concern to improve

differentiation, and hence learning, has arisen for three reasons. One of these reasons is the "science for all" basis of many science-education systems, which requires that all students, including high and low achievers and students of different genders and cultures, will engage in and learn the same science lessons, and that their individual needs will be met. In addition to the areas of continuity, progression and differentiation, another area of interest for some educators seeking professional development is increasing and updating *subject knowledge*, and preparing the subject knowledge for teaching and learning activities (Bell & Gilbert, 1996:1-6).

To rub salt into wounds, the new OBE approach poses challenges to the science educator's methodologies, the resources for learners and educators and the support to educators in order to deal with the challenge (Dilotsotlhe, 1999:6).

In recent years, we have become more concerned not only with what students know about science but also with how they feel towards or about science. Questions such as the following have become important issues for science educators: What is the impact of science and scientists on students' views and attitudes? Do students enjoy their science classes? Do they feel that the facts and methods they learn in science classes are useful both at present and in the future? Unfortunately, schools seem to operate negatively in matters dealing with the affective domain (Hofstein, Ben-Zvi, & Welch, 1990:13).

Abraham *et al.*, 1982 (as quoted by Hall, 1992:239) indicate that a survey of research priorities supports the contention that attitudes are of primary concern in science education. Hall (1992), further reveals the outcome of studies from the United States and several countries that suggest that student interest in science may account for up to 25% of the variation in academic achievement in science. Yet, despite recognition of the importance of attitudinal goals, science educators apparently fail to systematically assess affective student outcomes. It appears that science educators often assume that various instructional components foster student interest and attention, hence educators fail to assess affective student outcomes (Hall, 1992:239).

Negative attitudes towards science and science teaching, particularly among science educators, could have a serious and long-lasting impact on student and

educator performance in general and within the North West province in particular. Thus a primary goal in educator education programmes should be to design and to implement specific courses, strategies and methods that promote a positive attitude towards science and science teaching among educators (Hall, 1992).

With this background, the following (research) questions were formulated:

- 1.2.1. What is an attitude towards science?
- 1.2.2. What are the causes of attitude?
- 1.2.3. How does attitude originate?
- 1.2.4. How is attitude measured?
- 1.2.5. How can attitude be changed?
- 1.2.5. What are the types of attitude scales?
- 1.2.6. What are the science-related affective factors?
- 1.2.7. What are the outcomes-based approaches to science teaching?
- 1.2.8. What is the impact of the SEDIBA programme on the attitude of participating educators towards chemistry and chemistry teaching?

1.2. Hypothesis

The hypothesis for this study can be stated as follows: *The SEDIBA upgrading programme has a positive impact on the attitude of participating secondary school educators towards chemistry and chemistry teaching.*

1.3 Motivation for this study

It has been found that many of the educators hold negative attitudes that appear to have arisen from their past experiences of science, particularly at secondary level. They also typically have a poor knowledge of science and lack confidence in their ability to teach the subject. This is a significant problem, because of its impact on classroom practice and the lack of confidence among teachers. This results in less time for teaching the subject; and also, when it is taught, it is taught poorly, employing didactical approaches rather than inquiry-based activities; and finally, it is possible that negative attitudes may be passed on to students (Palmer, 2001:123 and Souza Barros & Elia, 1998:11).

It is apparent that most of the former and current studies on attitude towards science focus on students (Ellis, 1993; Meichtry, 1993; Nichols & Miller 1994; Nolen and Haladyne, 1990; and Houtz, 1995) and pre-service elementary educators (Hall, 1992; Cronin-Jones and Shaw, Jr, 1992). Not one of these studies was done on secondary educators, and specifically not in South Africa.

Studies by Arnott and Chabane (1995), and Howie, (1997) (as quoted by Dilotsotlhe, 1999:3), conducted recently in South Africa indicate that there is a severe shortage of properly qualified science educators at secondary school level. Unfortunately the shortage has been masked by the well-publicised surplus of educators in other areas of education. The problem is exacerbated by the fact that many science educators trained at colleges of education have chosen the course as a second or third option, having failed to be selected for their first choice of career.

The demand and supply of general/physical science educators in the North West Province, studied by Arnott and Chabane (1995:28) (as quoted by Dilotsotlhe, 1999:3), indicate that there is an under-supply of secondary school science educators. At least 40% of these educators are un(der)qualified. The total number of diplomated and non-diplomated general/physical science educators in the North West Department of Education was 921, or 76% of the population, at the time when the survey was done (March 1996). One can deduce that in the case of an alarming approximately 660 general/physical science educators (around 54% of the provincial population), the highest qualification is matriculation physics and chemistry. Some do not have even this qualification (Smit *et al.*, 1997:8).

In the North West Province, only 53 educators had third year university physics as their highest qualification, and only 68 educators had third year university chemistry. The 17 educators whose highest qualification is physics at the fourth year university level include BSc(Ed) graduates whose physics course is distributed over four years in the educational degree.

The same was true for the 20 educators whose highest qualifications in chemistry were fourth year university level. The actual number of educators who had an honours degree in physics or chemistry could not be deduced from the data

available. Five educators possessed five years of University training in physics, and four a similar qualification in chemistry (Smit *et al.*, 1997:8).

Given this scenario, one will realise why the North West Province results in mathematics and science were so far below the norm. This was a challenge to the North West Department of Education and the Tertiary Institutions within the province. The answer to this crisis was the birth of the SEDIBA in-service upgrading programme that occurred in 1996, an endeavour to address the dire need of quality science educators in the North West Province (Wesi, 1997:65).

The SEDIBA programme boasts a sustained average pass rate of almost 80%. According to Prof. Smit, the director of the project, the success of the project may be ascribed to the unique way in which it is presented. Through the interaction of the participating educators with colleagues a positive attitude towards mathematics and science education is also promoted (PUK News: 2003).

It is therefore pertinent to investigate the impact of the SEDIBA programme on the attitude of science educators towards science and science teaching.

1.4. Aims of the study

The focus of this study is on the attitude of educators towards chemistry and chemistry teaching. Specific objectives set for this study were as follows:

1.4.1. To conduct a literature study on the origin of attitude and factors influencing attitude.

Recent literature was explored to find definitions of attitude. Amongst topics that were discussed were the theories of attitude, attitude formation, factors influencing science-related attitude, attitude measurement and standard attitude scales.

1.4.2. To give a detailed discussion of factors contributing to attitude exchange.

Attitude plays an important role in science teaching or learning. Studies from the United States and several foreign countries suggest that student interest in science may account for up to 25% of the variation in academic achievement in science

(Simpson, 1978). A literature study was conducted to determine the role of attitude towards science, factors contributing to attitude exchange and procedures for attitude exchange.

1.4.3 To give a brief discussion of the teaching approaches in science, with particular reference to the constructivist approach.

Constructivism is an approach that has been suggested to deal with the teaching and learning problems associated with students' alternative conceptions. The discussion of this aspect was based on the rationale and the use of the constructivist approach in the teaching and learning of science. Furthermore, the rationale for OBE and aspects of visualisation were discussed.

1.4.4 To give a concise discussion of what the SEDIBA Project is, and the teaching strategy for the SEDIBA chemistry syllabus.

A literature study was done to determine what the SEDIBA Project is and why it was established. Different teaching strategies as used in chemistry were reviewed.

1.4.5 To give a brief discussion of educator development programmes with a detailed approach to distance education and in-service training.

A literature survey was done to find out what projects in educator development involve, how quality assurance is brought about within the projects, and how it is sustained.

1.4.6 To give a concise discussion of how the SEDIBA Project enables participating educators to overcome the demands of Outcomes-Based Education.

The discussion was based on what OBE is and what strategies are applied by SEDIBA to enable educators to apply OBE effectively in their teaching.

1.4.7 To determine the impact of the SEDIBA project on the attitude of participating educators towards chemistry and chemistry teaching

A pre-test and post-test were administered to probe educators' attitude towards chemistry and chemistry teaching.

1.4.8 To suggest intervention strategies to deal with attitude of educators towards chemistry and chemistry teaching.

Intervention strategies were suggested on the basis of the results of the empirical study.

1.5 Definition of concepts

1.5.1 Attitude

The author took the position, substantially that of Bagozzi and Bumkrant, that an attitude towards a concept such as science consists of the person's collection of beliefs about it, and episodes that are associated with it, that are linked with emotional reactions (White, 1988; Souza Barros & Elia, 1998). A person with a negative attitude towards science does not reflect the following scientific attitude: curiosity, rationality, willingness to suspend judgement, open-mindedness, critical-mindedness, objectivity and intellectual honesty, humility and reverence for life (Aiken, Jr. & Aiken; 1969: 295). It is generally accepted that science-related attitudes are not immutable. If they were, science educators would be relegated to doing little more than teaching facts and principles, and our view of education would have to be changed. Fortunately, attitudes form and change throughout peoples' lives (Koballa, Jr.,1992:63). A literature study on attitude is done in Chapter 2.

1.5.2 Educator

Educator generally, and for this study, refers to someone who is in charge of a group of learners. The educator's objective is inter alia to impart knowledge.

1.5.3 Chemistry

Uvarov & Isaacs (1993:74), define chemistry as the study of the composition of substances, and of their effect upon one another. Therefore chemistry is an experimental science which means that all chemical knowledge is the result of experiments. The term chemistry as used in this study refers to one part of the physical science syllabus for Grades 10-12.

1.5.4 Secondary school

The terms secondary school, secondary level and secondary-school level for the purpose of this study refer to the final phase of secondary school education, that is, Grades 10-12.

1.5.5 The SEDIBA Project

The SEDIBA (Setswana word for well or fountain) Project is a partnership involving the Potchefstroom University for CHE, the North West Education Department, and NASCHEM – a division of DENEL, a large armaments corporation. The project is aimed at improving the quality of science and mathematics teaching by assisting science and mathematics educators to gain mastery of their subject and to teach it with confidence and commitment. The SEDIBA Project is discussed in Chapter 5.

1.6. Methodology

The methodology of this research comprises the following components:

1.6.1 Literature survey

A comprehensive literature study was done to acquire an understanding of the main aspects of attitude and science-related attitude as given in 1.5.2. The main aspects of attitude selected for investigations are attitude and attitude change; origin of attitude; attitude measurement; consistency of attitude; and types of attitude scales. The main objective was to provide a base on which the scientifically accepted ideas could be compared with the results of the empirical investigation and thereby identify attitude change. To achieve this, a DIALOG search was conducted to find recent studies on the subject.

1.6.2 Empirical research

A Likert type Science Attitude Scale modified from different instruments originally created and validated by Hall (1992), Cukrowska, Staskun & Schoeman (1999), and Du Toit, Lachmann, Nel, Vreken & Van Schalkwyk (1991), developed

specifically to measure attitude of participating educators towards chemistry and chemistry teaching, was administered to the educators. A pre-test was administered in January during the first contact session prior to any instruction and the post-test on the last day of the second contact session on the last day during June.

1.6.2.1 Sample

The study used as experimental group a group of in-service science educators (N=37) enrolled for the SEDIBA programme (the one-year Advanced Certificate in Education (ACE) – taken part-time over a period of two years – in science teaching) at the Potchefstroom University for Christian Higher Education. All these educators were in possession of a minimum qualification of a three-year educator's diploma and taught chemistry/physics or physical science in secondary schools (Grade 8 to 12). The study was conducted during the first semester (January to June 2003) of their first year.

1.6.2.2 The statistical technique

The statistical Support Services of the Potchefstroom University for Christian Higher Education assisted in the statistical analysis of the empirical data

1.7 Classification of chapters

1 Orientation to the study

Literature study

- 2 Attitude and its origin**
- 3 Attitude change**
- 4 Teaching and Learning**
- 5 Educator development**
- 6 SEDIBA, SEDIBA Chemistry syllabus**

Empirical study

- 7 Empirical study and discussion of results**

8 Summary and recommendations

The next Chapter is the literature study conducted on attitude and attitude change. The attitude-related variables surveyed include definitions of attitude, theories on attitude, attitude formation, factors influencing science-related attitudes, attitude measurement and standard attitude scales.

CHAPTER 2

ATTITUDE AND ATTITUDE MEASUREMENT

2.1 Introduction

Attitude is a common notion, understood as distinct from knowledge and ability and yet, like them, both a determinant and a consequence of learning (White, 1988:100). Conceptions of attitude have undergone many changes in the past four decades. Most of these changes were necessitated by the failure of attitudes to live up to their promise as the central device for explaining and predicting behaviour (Fishbein & Ajzen, 1975: v).

In an historical sense, the study of attitudes has gone through three distinct phases:

1. The 1920s and 1930s: A concentration on fairly static issues of attitude measurement and how this related to behaviour.
2. The 1950s and 1960s: A focus on the dynamics of change in an individual's attitudes.
3. The 1980s and 1990s: A swing towards unravelling the structure and function of systems of attitudes (Jones, 1997:1)).

Unfortunately, despite the vast amount of research and the publication of countless books and articles on the topic, there is little agreement about what an attitude is, how it is formed or changed, and what role, if any, it plays in influencing or determining behaviour (Fishbein & Ajzen, 1975:v).

2.2 Definitions of attitude

An attempt to define attitude is difficult because there is little agreement about its meaning and its nature (Zembylas, 2002:80). The concept overlaps with other kinds of psychological concepts and it is in this area of overlap that some clarification must first be attempted (Halloran, 1967:14). There is no substantial difference between the everyday and psychological uses of the word "attitude", though in time differences could develop if the psychological meaning becomes

more precise. For the moment, as with many other constructs, the meaning of attitude remains vague and ambiguous (White, 1988:100).

Fishbein and Ajzen (1975:5) find attitude to be characterised by an embarrassing degree of ambiguity and confusion. Concepts such as attitude, attraction, attribution of dispositions, liking and behavioural intention have been used to account for a wide variety of interpersonal behaviour patterns and have been incorporated within the general label "attitude", together with many others.

A favourite way to proceed in defining an attitude is to first present a dozen definitions from the literature and then, after commenting on their common elements, to present one's own in the hope that it is a distillation of the essence of these other definitions (Rokeach, 1972:111).

Gordon Allport defined attitude as "a mental and neural state of readiness, organised through experience, exerting directive or dynamic influence upon the individual's response to all objects and situations within which it is related" (as supported by Halloran, 1967; White, 1988; and Jones, 1997).

Daniel Katz (as quoted by Halloran, 1967:15) defines attitude as the predisposition of an individual to evaluate some symbol or object or aspect of the world in a favourable or unfavourable manner. He refers to opinions as the verbal expressions of attitudes, but accepts that attitudes can be expressed in a non-verbal manner. Attitudes, according to Katz and many others, include both an affective or feeling core of liking or disliking, and the cognitive or belief elements, which describe and perceive the object of the attitude, its characteristics and its relationships to other objects. All attitudes therefore include beliefs, but not all beliefs are attitudes.

Rokeach (1972:111) defines attitude as a relatively enduring organisation of beliefs around an object or situation predisposing one to respond in some preferential manner.

Triandis (1971:2) came up with a definition that includes many of the central ideas used by attitude theorists. His definition of attitude is as follows: "an attitude is an

idea charged with emotion which predisposes a class of actions to a particular class of social situations".

Fishbein and Ajzen (1975:6) realised that most investigations would probably agree that attitude can be described as "a learned predisposition to respond in a constantly favourable or unfavourable manner with respect to a given object".

Jones (1997:1) in her lecture came up with what she called two simple and straightforward definitions:

"A relatively enduring organisation of beliefs, feelings and behavioural tendencies towards socially significant objects, groups, events or symbols" or "A general feeling or evaluation – positive or negative – about some person, object or issue".

Ostrom (1996) and Scholl (2000) define attitude as a mental predisposition to act in a way that is expressed by evaluating a particular entity with some degree of favour or disfavour. He finds individuals generally to have attitudes that focus on objects, people or institutions. Attitudes are attached to mental categories. Mental orientations towards concepts are generally referred to as values.

The word attitude (from Latin aptus) is defined within the framework of social psychology as a subjective or mental preparation for action. It defines outward and visible postures and human beliefs (Souza Barros & Elia, 1998:2).

I will take the position, substantially that of Bagozzi and Burnkrant (as in White, 1988; and Souza Barros & Elia, 1998), that an attitude to a concept such as science is the person's collection of beliefs about it, and episodes that are associated with it, that are linked with emotional reactions.

We have seen then that there are several approaches to the study of attitudes and many definitions of the concept. We have also seen that there is some overlapping, a lack of clarity and precision, some confusion and some conflict. Perhaps, however, the area of disagreement and confusion is not as great as it appears at first sight. Despite the qualifications that have been made, the concept attitude has much to be said in its favour and there is certainly sufficient agreement

to allow the sort of definitions referred to above to be used as a valid working basis (Halloran, 1967:26).

2.3 Theories of attitude

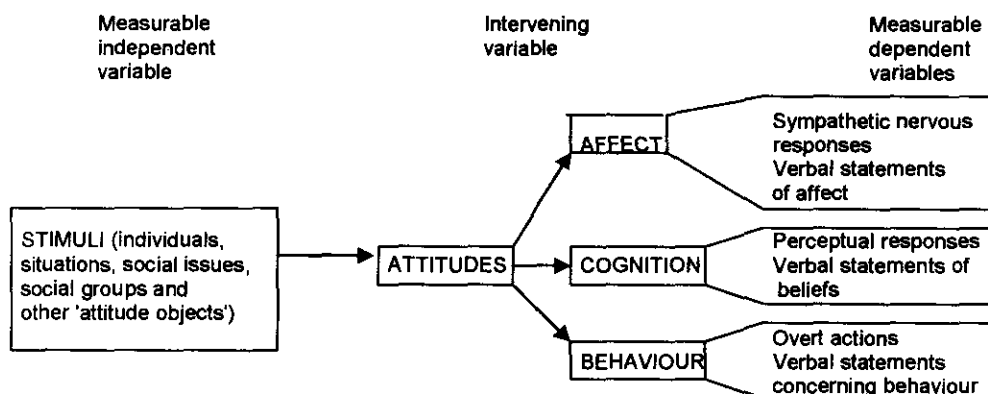
From its beginnings in the early years of the 20th century, social psychology was concerned with studying attitudes. The term has encompassed a variety of psychological behavioural dispositions. For example, people may have an expectant attitude, a disgruntled attitude, a co-operative attitude or an authoritarian attitude (Davis & Ostrom, 1996:73).

Halloran (1967) and Triandis (1971) state three main components of attitudes are:

1. Cognitive component, which has to do with beliefs about the object, including evaluative beliefs
2. Affective or feeling components, which has to do with likes and dislikes
3. Action tendency or component.

Rosenberg and Hovland's schematic conception of attitude (Halloran, 1968 and Triandis 1971) portrays how a stimulus situation can trigger a behavioural outcome with its components. Figure 1 below shows this schematic conception of attitudes.

Figure. 1: SCHEMATIC CONCEPTION OF ATTITUDES



From this schematic conception of attitude, one realises that part of the bridge between the stimulus situation and the behavioural outcome is the attitude with its

three components, each giving rise to observable and sometimes measurable effects (Halloran, 1967:22).

Unlike Crutchfield and Ballachey (as in Halloran, 1967:22); Rosenberg and Hovland (as in Halloran, 1967 and Triandis, 1971), Scholl (2000:1) in his notes on attitudes and attitude change, finds attitudes to comprise four components. In addition to the three mentioned above, he came up with the fourth:

- A. Cognitions – Cognitions are our beliefs, theories, expectancies, cause-and-effect beliefs and perceptions relative to the focal object.
- B. Affect – The affective component refers to our feeling with respect to the focal object such as fear, liking or anger.
- C. Behavioural Intentions – Behavioural intentions are our goals, aspirations and our expected responses to the object of our attitude.
- D. Evaluation – Evaluations are often considered the central component of attitudes. Evaluations consist of the imputation of some degree of goodness or badness to an attitude object. When we talk of a positive or negative attitude towards an object, we are referring to the evaluative component. Evaluations are functions of cognitive, affective and behavioural intentions towards the object. It is most often the evaluation that is stored in memory, often without the corresponding cognition and affect that were responsible for its formation (Scholl, 2000:1).

Attitudes are relatively permanent, limited to socially significant events or objects, and attitudes are general, involving at least some degree of abstraction (Jones, 1997:2).

2.3.1 Elements of attitude

There are a number of most important basic features of attitude: the notion that attitude is consistent, is learned, that it predisposes action, and that such actions are consistently favourable or unfavourable towards the object (Fishbein & Ajzen, 1975:8).

2.3.1.1. Consistency

The consistency of an attitude relates to the strength of an individual's feelings towards a particular object in different settings or situations. It differs both from the stability of attitudes over time, and the inter-relatedness of kindred attitude, which may involve a more deeply internalised world view (Anderson, 1994:381).

Attitudes are inferred from consistencies in the responses of persons to social situations having some social objects in common. However, such consistencies are by no means extreme (Triandis, 1971:8).

At least three types of consistency are distinguished by Fishbein and Ajzen, (1975):

*First, a person may be observed to consistently perform the same response or set of responses in the presence of a given stimulus object. This stimulus-response consistency may be taken as reflecting an attitude towards the object.

*Second this interpretation involves the degree of consistency between different responses with respect to the same object. The requirements in this case are that, whatever the responses that are elicited by the object; they should be consistent with one another. The response-response consistency has also been taken as indicative of an attitude towards the object. Like stimulus-response consistency, the notion of response-response consistency fails to discriminate between attitude; trait; motives; and various other concepts.

*Third type of response consistency is related to multiple behaviours at different points in time. A set of behaviours may exhibit evaluative consistency over time. That is, on different occasions a person may perform different behaviours with respect to an object. The overall consistency of this kind could also be defined as consistent.

2.3.1.2 Attitudes are predispositions

Attitude is typically viewed as a latent or underlying variable that is assumed to guide or influence behaviour. Indeed, attitudes are not identical with observed

response consistency. Attitude cannot be observed directly but has to be inferred from observed consistency in behaviour. The stimulus-response interpretation of consistency implies that the individual is predisposed to make a particular response or set of responses in the presence of a given object. Knowledge of a person's attitude, therefore, permits prediction of one or more specific behaviours. Once a person's predisposition has been established, it is expected that the person will perform (behave) in a certain way or manner. The stimulus-response interpretation of consistency implies that a given attitude always elicits a given response or set of responses (Fishbein & Ajzen, 1975:217).

2.3.1.3 Attitudes are learned

According to this analysis, we form and develop attitudes in order to understand the world around us, to protect our self-esteem, to adjust in a complex world, and to express our fundamental values. To understand the world, we need concepts that summarise the complex information that impinges on us from our environment. We also learn attitudes through direct exposure to the attitudinal object (Triandis, 1971:102). At the most general level, we learn to like objects we associate with good things, and we acquire unfavourable feelings towards objects we associate with bad things. On a day-to-day basis we automatically acquire an attitude towards some new object when we learn its associations with other objects, attitudes or qualities towards which we already have attitudes (Fishbein & Ajzen, 1975:217).

2.3.1.4 Attitudes are evaluative

In discussing the notion of response consistency, we noted that the major characteristic that distinguishes attitude from other concepts is its evaluative or affective nature. Indeed, there is widespread agreement that affect is the most essential part of the attitude concept. Attitude may be conceptualised as the amount of affect for or against some object (Fishbein & Ajzen, 1975:11), the disposition to respond towards an "object" in a positive or negative manner. Attitudes thus can range from very favourable to very unfavourable on an evaluative continuum (Davis & Ostrom, 1996:73). Attitudes lead to evaluations that may be more or less emotionally toned and they also tend to order the priorities between different responses or programmes of action. An attitude is not directly

observable, it is an inferred entity, something that is not measured directly but decided from other observable data (Halloran, 1967:14-15).

2.3.2. Science-related attitudes

Teachers realise the importance of how students feel about science subjects and courses; nevertheless, they place little emphasis on affective objectives. The affective domain is often neglected because teachers have difficulty designing strategies to develop positive attitudes among students and documenting their development. The seemingly arbitrary use of terms associated with the affective domain has further contributed to the neglect. Recent research provides suitable guidelines to focus attention on this important domain. The literature indicates that the affective domain related to science education is primarily concerned with attitudes related to science. The development of positive attitudes towards science has long been viewed as a legitimate goal of science education. Science curriculum developers have for some time sought to improve students' attitudes towards science and scientists. Concern for student attitudes towards science has also risen with regard to the possibility of increasing enrolment in elective science courses by improving attitudes towards science among adolescents (Koballa, Jr., 1989:1).

Attitude towards science refers to a general and enduring positive or negative feeling about science. It should not be confused with scientific attitude. Statements such as "I like science", "I hate science", are considered to be facts that denote a general positive or negative feeling towards the formal study of science (Koballa & Crawley, 1985:223).

A person with a negative attitude towards science does not reflect the following scientific attitude: curiosity, rationality, willingness to suspend judgement, open-mindedness, critical-mindedness, objectivity and intellectual honesty, humility and reverence for life (Aiken Jr. & Aiken, 1969: 295).

Attitudes towards science are not inherited traits but learned predispositions acquired over a period of time (Koballa & Crawley; 1985:224). "The more cognitive scientific attitudes" include such desired traits as intellectual honesty, critical appraisal, objectivity and curiosity. Curiosity is defined as: "A kind of intrinsic motivation and may be conceptualised as an intention to seek information about an object, event, or idea through exploratory behaviour". A child who exhibits curiosity will react positively to unusual elements in his/her environment, will want to know more about himself and his environment, seek new experiences, and persist in examining and exploring (Hofstein, *et al.*, 1981:229-230).

2.3.3 Antecedents

The widespread belief in the relevance of attitudes to social behaviour has inspired greater interest in how attitudes can be changed and therefore manipulated to improve society. An extensive array of antecedent variables have been explored, most of which relate to the effects of persuasive communication (Ostrom: 1996, 74).

Ostrom (1996:74) identified the following attitudinal theories of antecedents:

- i) Attitude can be represented as an evaluative disposition falling somewhere on a pro-to-anti continuum. It is an unelaborated concept referring only to a location on the evaluative continuum. Past experiences, informational influences, reinforcements and motivational pressures all contribute to the attitude at the time they occur. The resulting attitude is the cumulative accretion of those events. Each life experience makes its contribution at the time of occurrence and thereafter remains irrelevant to the status of the attitude.
- ii) Attitude is the set of beliefs the person holds about the attitude object. The basic elements of an attitude are the individual beliefs or cognitions. The evaluative disposition is the resultant of all those beliefs that are salient at the time the observed response is initiated. In this view of attitude, there is no single "true" evaluative disposition, only an average that emerges over a variety of responses.

iii) Another point of view refers to the set of motivational forces operating on the person that are relevant to the object. The basic elements of an attitude consist of the values, needs, drives, motives and personality dispositions of the person.

2.3.4 Consequences of attitude

Regarding consequences, theories would need to show how an attitude combines with other theoretical variables to affect the particular response system being observed. Attitude has a direct influence on the observed response (Ostrom, 1996:74). One thing, attitudes encompass more than interest and extend to traits such as curiosity and appreciation, and for another the nature of a person's attitudes affects not only whether any learning occurs but also the style of that learning. In other words, attitudes influence the operation of cognitive strategies (White, 1998:109).

More important is the attitude towards the act itself, since that attitude incorporates feelings about attitude object, the type of behaviour and the temporal-social context in which the behaviour is elicited. When the hypothetical construct includes more than just an evaluative disposition, other properties of attitudes also provide a conceptual basis for studying consequences. For example, internally consistent attitudes have a stronger effect on behaviour than do inconsistent ones. Organised belief sets should have the same effects as cognitive schemas. Ego-involved attitudes are viewed as affective responses more strongly than less personally relevant attitudes (Ostrom, 1996:75).

Several attitudinal phenomena are not yet well understood by attitude theorists. Little is known about the sudden and intense emotional arousal that attitudes sometimes produce. Little is known about how attitudes lead people to make enormous personal sacrifices on behalf of their loved ones and ideals. Little is known about the massively dramatic reversals in attitude that sometimes occur. Although enormous strides in understanding attitudes have been made since the early years of the 20th century, these and other unresolved issues indicate that fundamental questions are still unanswered (Ostrom, 1996:75).

2.4 Attitude formation

Attitudes are not innate – they are learned, they develop and they are modifiable and subject to change. Attitudes are not merely latent states of preparedness awaiting the presentation of an appropriate object for their activation. They have motivational qualities and can lead a person to seek (or avoid) the objects about which they are organised (Halloran, 1967:14-15). It is a product of experience, but it enters into subsequent experience as a directive factor (Halloran, 1967:15 and Ostrom, 1996:73).

Early attempts to identify the origin of attitudes focused on the needs or functions that attitudes may serve. Thus attitudes were assumed to have instrumental or utilitarian functions: knowledge functions, expressive functions and ego-defensive functions (Ajzen, 1996:75). Attitude theorists assume that attitudes are acquired through experience and that attitudes exert a directive influence on overt responses. Approaches to the development of attitude theory focus on the processes through which attitudes develop and affect our lives.

These theories draw on the various psychological processes that have been studied in the areas of reinforcement and learning, cognition and memory, and needs and motivation (Ostrom, 1996:73).

A general trend towards cognitive or information-processing explanations of social behaviour has brought a concomitant decline in the importance accorded to needs and automatic conditioning process. Instead stress is now placed on the role of information as a basis of attitude formation.

According to this view, beliefs – representing people's subjective knowledge about themselves and their world – are the primary determinants of attitudes. Each belief links the attitude object to a positively or negatively valued attribute (Ajzen, 1996:75).

An attitude represents a person's general feeling of being favourably or unfavourably disposed towards some stimulus object. In our conceptual framework, as a person forms beliefs about an object, he automatically and simultaneously acquires an attitude towards that object. Each belief links the object

to some attribute; the person's attitude towards the object is a function of his evaluations of this attribute (Fishbein & Ajzen, 1975:216-216).

Even on a day-to-day basis we automatically acquire an attitude towards some new object when we learn its associations with other objects, attributes or qualities towards which we already have attitude (Fishbein & Ajzen, 1975:216-216).

2.4.1 Attitude and beliefs

Beliefs refer to a person's subjective probability judgements concerning some discreditable aspects of the world; they deal with the person's understanding of himself and his environment (Fishbein & Ajzen, 1975:131). The assumption that attitudes have an informational foundation ties the question of attitude formation to the origin of our beliefs about ourselves and about our environment (Ajzen, 1996:75).

We have defined belief as the subjective probability of a relationship between the object of the belief and some other object, value, concept or attribute. Thus a person may believe that he/she possesses certain attributes so that a given behaviour will lead to certain consequences, with certain events occurring contiguously.

This implies that belief formation involves establishment of a link between any two aspects of an individual's world. One obvious source of information about such a relationship is direct observation (Fishbein & Ajzen, 1975:131). Based on personal experience, beliefs of this kind tend to be held with great confidence and to resist change (Ajzen, 1996:75). A person may perceive that a given object has a certain attribute (Fishbein & Ajzen, 1975:131). Often they reflect reality quite accurately (Ajzen, 1996:75).

These direct experiences result in the formation of descriptive beliefs about the object concerned (Fishbein & Ajzen, 1975:132). Over time, however, many factors tend to distort memory of events and thus reduce the accuracy of beliefs based on direct experience. Generally speaking, the greater the number of beliefs that associate the object with positive attributes, and the smaller the number of beliefs

that associate it with negative attributes, the more favourable is the resultant attitude towards the object (Ajzen, 1996:75).

Much of our information is acquired through conversation with other people or is communicated to us by a variety of sources, such as television, radio, newspapers, and books (Ajzen, 1996:75). Interaction with another person may lead to the formation of beliefs about such unobservable characteristics or dispositions as the person's honesty, friendliness, introversion or intellect (Fishbein & Ajzen, 1975:132). Acceptance of such second-hand information and its incorporation into the receiver's belief system depends on the coherence and persuasive power of the information provided in the communication. Additional factors include credibility of the source, type of appeal, and personality characteristics of the receiver (Ajzen, 1996:75).

Beliefs that go beyond directly observable events may be called inferential beliefs. Many of our beliefs are formed neither on the basis of direct experience with the object of the belief nor by way of some inference process. Beliefs formed by accepting the information provided by an outside source may be termed informational beliefs (Fishbein & Ajzen, 1975:27-28).

2.4.2 Attitude and behaviour

Attitudes are considered behavioural dispositions, thus it is natural to assume that they direct and in some sense determine social action. As a general rule, positive attitudes are expected to produce favourable behaviours towards the attitude object, while negative attitudes are expected to produce unfavourable behaviours (Ajzen, 1996:76).

What should be understood is this: attitudes involve what people think about, feel about, and how they would like to behave towards an attitude object. Behaviour is not only determined by what people would like to do but also by what they think they should do, that is, social norms, by what they have usually done, that is, habit, and by the expected consequences of the behaviour. By contrast when we measure a particular behaviour towards a particular person or issue, there are probably seven or so elements influencing the behaviour. The subject who responds has attitudes not only towards the object, but also towards objects

closely related to that object. Each of these attitudes may have a different function, and the subject's behaviour will be determined by several of these attitudes (Triandis, 1971:15).

It should be understood that attitude is an unobservable, hypothetical construct that must be inferred from measurable response to the attitude object. Nonetheless, single behaviour can be predicted from attitudes towards the behaviours themselves. There is growing evidence, however, that response tendencies reflected in attitudes towards specified actions can change as a result of situational demands or unanticipated events (Ajzen, 1996:76).

Most investigators would agree with the definition of attitude as a learned predisposition to respond to an object in a consistently favourable or unfavourable manner (Fishbein & Ajzen, 1975:336). Social learning theory says that most human behaviours are learned through observation and modelling, and that people "rarely ... learn behaviours under natural conditions that they have never seen performed by others"(Hart, 2002:6).

This definition implies a strong link between attitude and behaviour, and the traditional view has been that any stimulus object comes to elicit an attitude which mediates or determines all responses to the object. It follows that if one could measure this attitude, one would be able to explain and predict a person's behaviour (Fishbein & Ajzen, 1975:336)

One way to think about the relationship between attitude and behaviour is to use an analogy. Analogously, attitudes are neither a necessary nor a sufficient cause of behaviour. They are "facilitative causes". To summarise, behaviour is a function of attitudes, norms, habits and expectancies. When all factors are consistent, there is consistency between attitudes and behaviour, and when the four factors are inconsistent, there is much less consistency. Attitude is not a necessary or a sufficient cause of behaviour, but it is a contributing cause (Triandis, 1971:15-16).

2.4.3 Attitude and values

It has been proposed that attitude is a response locating an object of thought along some dimension of judgement. They (attitudes) are systems with structures,

including relationships within one attitude between several objects, relationships between several attitudes with regard to the same object, and belief system, that is, those involving relationships between several attitudes without necessarily referring to one single object. These systems, in turn, make up what is usually referred to as the "tripartite definition" of attitude: cognitive; affective and conative (De Corte & Weinert, 1996:490).

According to Allport (1935) (as quoted by De Corte & Weinert, 1996:490), the concept of attitude and value are highly interconnected because the concept of values has something broader than the concept of attitude; values have sometimes been seen as "causing" attitudes. Comparing the tripartite conception of attitudes to what has been said above about value systems, it turns out that, attitudes systems and value systems have the same structure and must be measured in similar ways. If people are said to have particular values and particular attitudes, then it is probably accepted that both are similar and have been similarly influenced (De Corte & Weinert, 1996:490).

Applying the principles presented above means, then, that to change a moral attitude one can change a set of moral values, which can be done through de-equilibration of people's value structure, by evaluative judgements, by "consider the opposite" techniques, or by participation and role-taking exercises. Knowledge transformation is only a necessary, not a sufficient, condition for attitude and value change (De Corte & Weinert, 1996:490-491).

2.5 Factors influencing science-related attitudes

While it is true that there are teachers whose attitudes are positive towards the promotion of good science teaching-learning situations, for most students in many countries the reality of school classrooms consists of lessons where science is transmitted by the teachers, at best, as a set of facts, laws and data (Souza Barros & Elia, 1998:1). Daily lessons tend to focus on the recall of facts, concepts and principles, while the development of a positive attitude towards science at best is considered peripheral to these cognitive outcomes (Koballa, Jr. & Crawley, 1985:222).

A sound footing in science education goes beyond the student's mastery of facts and ideas; it must include the development of attitudes and behaviours that promote clear, rational thinking and appropriate rational actions both in the workplace and in the community (DeBear, 1988:1). The assumption that students will acquire positive attitudes towards science as they learn more science facts is no longer valid. Planning is required to ensure the development of positive attitudes towards science. Failure to plan and teach for the development of positive attitudes towards science may well result in a science curriculum that fails to prepare students to make judicious decisions about science as their future needs dictate (Koballa, Jr. & Crawley, 1985:222).

The results brought about by science researchers' pedagogical experiments have good consequences only when rooted within the school as an institution (teacher, curriculum and defined pedagogical practices) and within a particular context (culture, programme, country). So, we conclude that there are no universal methods to modify this situation. That is, there is a variety of science-teaching styles as a result of strong interaction existing between teaching attitudes and competencies, school and society, as suggested by Souza Barros & Elia, (1998:1).

The present discussion is mostly limited to secondary school science teachers, but it applies to primary teachers, without loss of perspective. Souza Barros and Elia (1998:1) quote Fensham (1992) as mentioning that "secondary school teachers are more aware of their difficulties, seeking answers to cope with their and their students' problems, while university and college teachers have a naïve standing in relation to what goes wrong in the classroom". Children find science learning difficult, and we may add that teachers also find science teaching difficult (Souza Barros & Elia, 1998:2).

2.5.1 Educators' beliefs

The term belief is reserved for the information that a person accepts to be true, in these examples, about science as a school subject. The information may have been acquired firsthand or picked up from the comments of other people. However acquired, the information may have positive, negative or evaluative implications (emotional attachment) for the study of science (Koballa, Jr. & Crawley, 1985:223).

So educators' ideas and beliefs about teaching and learning are powerful influences on their attitudes to classroom practice, and thus on their actual approaches to science teaching (Gunstone & White, 1998:4).

One significant component of attitude has been the role played by beliefs in teachers' teaching change. Over time, a substantial body of literature has emerged, providing evidence that teachers' beliefs drive their teaching of science. In order to change teachers' practices, teachers' beliefs need to be considered. However, beliefs are difficult to change, the beliefs teachers expose are not always consistent with the way they teach, and changing educators' beliefs takes time (Hart, 2002:4).

Beliefs about teaching are well established by the time a student enters college and are developed during the apprenticeship of observation that occurs over their years as a student. Their beliefs include ideas about what it takes to be an effective educator and are brought to their teacher preparation program. Given this, it seems imperative that teacher education programmes assess their effectiveness, at least in part, on how well they nurture beliefs that are consistent with the programme's philosophy of learning and teaching. Also, they need to study how consistent the beliefs teachers expose after participating in a programme are with their teaching practices, i.e., can teachers do more than "talk the talk" (Hart, 2002:4)?

The educators' actions in classrooms are based on ideas and beliefs about teaching and learning. These beliefs may be profound, they may be sadly limited, but they are held. It is the nature of the beliefs that is of interest: their existence can be assumed (Gunston & White, 1998:3).

If educators' beliefs are incompatible with the philosophy of science education reform, a gap develops between the intended principles of reform and the implemented principles of reform, potentially prohibiting essential change. Educators hold beliefs beyond matters of their profession and although these global beliefs influence teachers' practice, they can be distinguished from the beliefs teachers hold that are more specific to the education process. Educational beliefs include beliefs about the nature of knowledge, about the roles of schools in society, and about their work, the subject matter they teach, and their roles and

responsibilities. These beliefs are referred to as pedagogical content beliefs, and it is maintained that along with pedagogical content knowledge, these beliefs provide a strong link to classroom action (Levitt, 2001:1-2).

This is also how a certain relationship to knowledge is perpetuated. This is the relationship based on the belief that science teachers teach the way they were taught and subscribe to the widely held interpretation according to which they have been given the single, simple duty of executing teaching programmes, as though these programmes were simply concerned with factual matters and did not represent socio-political projects in action. In other words, these prospective teachers have learned a certain way of "punctuating" educational situations and defining their role therein. At that point, they are quite capable of making use of a certain reflexivity and holding forth most instructively on the importance of an emancipative relationship to knowledge, since this is what their professors want (DéSautels & Larochelle, 1998:3-4)

2.5.2 Teaching competencies

Baird *et al* (1991) (as quoted by Souza Barros and Elia, 1998:4) indicate that there is good agreement that teachers who are seldom asked to reflect upon their own teaching could be no more than mere repeaters of book material. Since teachers have a major role in any education reform they should be solicited to understand new proposals and to participate in their formulation, to analyse their performance and modify their behaviour, their personal conceptions on how to teach and what to teach. Most teachers, influenced by how they were taught, tend to replicate the model (Souza Barros and Elia, 1998:4).

Just as one belief can dominate all others in shaping attitudes to classroom practice, so can the teachers' understanding of chemistry. In particular, if teachers' understanding of reactions is very poor, they do not use analogies (for they do not understand their significance themselves); they avoid laboratory work; they reject any form of student discussion; they use examples. Their classroom practice is limited to lectures taken from texts and demonstration of solutions and standard quantitative problems (Gunstone & White, 1998:2).

Educators' lack of confidence is due to a poor conceptual and phenomenological chemistry foundation. In many countries around the world the number of lay science teachers is high, and many of those that have received education are not ready for the job (Souza Barros & Elia, 1998:3).

Levels of self-confidence in applying effective teaching methods are claimed to be highly related to teacher effectiveness, in which the ability to establish a warm and friendly atmosphere in the classroom, to plan lessons, and to assess learning and development of students are crucial (Altun & Kaya, 1996:569). Wubbels (as quoted by Altun & Kaya, 1996:569) states that many student teachers have negative attitudes and behaviours towards what is presented to them in educator education programmes due to poor transfer of theoretical components and skills into classroom practice. Wubbels argues that many teacher education programs fail to influence student teachers' preconceptions of teaching and learning and fail to develop appropriate skills.

2.5.3 Educators' beliefs about the teaching and learning of science

Other than educator knowledge, it is teachers' view of teaching and learning, the nature of science and the purposes of education that are of prime influence in shaping their attitudes to classroom practice (Gunstone & White, 1998 and Levitt, 2001:3).

The knowledge, beliefs and theories a teacher holds about the nature of science and about the teaching and learning of science determine to a great extent what science education will be for a child (Levitt, 2001:3 and Gallard & Gallagher, 1994:641). The type of science experiences individuals encounter influence their perceptions of science teaching and learning. Since educators tend to teach as they were taught, the dichotomy in these courses sets up a dilemma of teaching science content, as learned in the science courses, or process, as learned in the methods courses. Educators may be convinced of the value of hands-on activities and use co-operative learning from their science methods course, and from general pedagogical workshops, but are not able to develop science content from such activities. They may not even know what science students are supposed to learn from the activity. Ineffective instructional practices as well as inappropriate

assessment methods are often learned from time spent in science classes (Levitt, 2001:3).

Teachers often perceive their role in science as dispensers of facts because they feel they may not, but should, have all of the right answers when a student asks a question. They avoid situations where these questions are or can be asked, thus they instead rely on the information in a textbook. In this case the teacher's belief about science, and the teacher's belief about his or her role in science, influence decision about the teaching of science (Levitt, 2001:3-4).

Imagine educators who believe that what they say in a classroom is then known in the form it was uttered by the educator by every student in the classroom. That is, imagine teachers whose ideas and beliefs about learning and teaching are solely that the teacher gives and the learner receives, and that the learner receives only that which the teacher gives. Such educators would have attitudes to and behaviours in classrooms that are extraordinarily limited: they would see the educator's role solely in terms of organizing a clear and logical exposition and ensuring that students listen. While concern with having students listen may well lead these educators to use some demonstrations, their general approaches would be limited and didactic. And the educator would see these limited approaches as appropriate. Their approach would be consistent with the beliefs they hold (Gunstone and White, 1998:3).

At the other extreme, consider teachers whose beliefs about teaching and learning are that all students' learning must come from students themselves and that the teacher cannot directly tell students anything. In the language used in the first fictitious example, the teacher cannot give and the learner cannot receive. In such cases the teachers would again have attitudes to and behaviour in the classroom that were extraordinarily limited: they would see the teacher's role solely in terms of organizing resources that students have decided they need; they would not give answers to any students' questions, etc. Again, such teachers would justify their classroom approaches by reference to their underlying beliefs about teaching and learning.

An obvious point from these two fictitious examples is that for both extremes the underlying beliefs about teaching and learning are indefensible. Justifiable views of

teaching and learning and consequently more appropriate classroom approaches will lie between these extremes (Gunstone & White, 1998:3).

Constraints perceived by teachers contribute to their beliefs about the teaching and learning of science. Many teachers believe they need sophisticated equipment to teach science; many believe that science concepts are too advanced for students and often overlook the science in children's everyday lives. The reason often given for not teaching science, "There is not enough time to teach science," becomes a self-fulfilling prophecy as teachers who are uncomfortable teaching science, for any reason, spend more time emphasizing other subject areas. The combination of these beliefs often results in a lack of time spent teaching science or lack of meaningful science taught at the school level. The average of one-half hour per day spent teaching science might be indicative of teachers' belief about the relative unimportance of the subject compared to others and their own reluctance to teach it (Levitt, 2001:4).

High school teachers attach a high value to students' designing and doing experiments, and to students linking the ideas of science with personal experiences from outside the classroom. They valued pedagogies that would foster these student behaviours. At the heart of this valuing was belief in a particular view of learning – that individual learners each construct their own understandings, and therefore are responsible for their learning. What these teachers claimed to see as more appropriate was derived from this view of learning. Also contributing to the valuing of laboratory and linking approaches were beliefs about the nature of science and purposes of education which were consistent with the approaches. These teachers expressed the purpose of their students' studying science more in terms of general education, of seeing the significance of science for understanding the world around them, than in terms of preparation for further study of science at university (Gunstone & White, 1998:1).

However, the notion of conflict between teachers' beliefs and practices is very complex and is linked with other important factors. These factors include a teacher's own educational and personal experience and, in the case of private school teachers, high expectations of the school, parents and students. The teachers' own social and economic backgrounds, as well as their formal education, contribute to the development of sets of attitudes and beliefs that are, in some

respects, "elitist". This may give rise to a conflict among their students' learning needs, how the teachers were taught to impart knowledge and the type of knowledge the national curriculum requires of them to emphasize. This conflict can become very personal and as a consequence the reactions of science teachers will vary. Some teachers may simply blame the Ministry of Education. They may feel that the situation has been taken out of their hands and that there is nothing they can do. Private school teachers, whose students may all continue with university study, may never experience conflict about their teaching and the relevance of science to their students. In contrast, teachers in public schools may become so frustrated and feel so powerless that they choose to leave the profession for one that allows a greater degree of professional control (Gallard & Gallagher, 1994:641-642).

2.5.4 Educators' behaviour

Classroom interaction between teachers and students occurs rapidly in a classroom. Teachers in secondary schools may have interactions with many students in a day. However, teachers are usually not aware or are not able to describe or remember what happens in these interactions with their students. They are not aware of how many questions they had asked students and what kind of feedback students had provided. On the other hand, students who are directly involved in classroom activities observe more of the teachers' typical behaviour and are more familiar with their teachers' idiosyncrasies (She and Fisher, 2002:63-64).

Student perceptions are indicators of the quality of a classroom environment. There is an enhanced student achievement in classes that students felt had greater cohesiveness, satisfaction and goal direction, and less disorganization and friction. Classroom environment perceptions can influence students' outcomes.

Students' attitude scores were higher in classrooms in which students perceived greater leadership and helping/friendly and understanding behaviour from their teachers. Favourable students' attitudes could be promoted in classes in which students perceived more personal relevance, shared control with their teachers, and negotiated their learning. The communication style of science teachers is the

most important variable in explaining differences in students' appreciation of the lessons and subject being taught at the class level (She & Fisher, 2002:64-65).

The relationship between attitude and behaviour fits in well with the theory of behavioural change. The extent to which adults were willing to approach, touch and handle a boa constrictor correlated strongly with their previous personal beliefs about how they would perform at such tasks. Each individual has a sense of "self-efficacy" which is concerned with judgements about how well one can organize and execute courses of action required to deal with prospective situations that contain many ambiguous, unpredictable and often stressful, elements. Self-efficacy is a construct of both "efficacy expectations", which are the beliefs in one's ability to execute the behaviour successfully, and "response-outcome expectancies", which are beliefs that one's actions will produce the desired outcome. Self-efficacy is highly context-dependent, so a person may have a high self-efficacy with respect to one task but a low self-efficacy with regard to another task (Bandura 1977 & 1981), as quoted by Palmer (2001).

Application of this theory to the profession of teaching would suggest that teachers' behaviour with regard to the teaching of science would be determined by their confidence in their own ability to teach science (efficacy expectation) as well as the belief that their teaching strategies would be effective (response-outcome expectancies). Furthermore, their self-efficacy beliefs about teaching science need not be related to their self-efficacy beliefs about the teaching of other subjects, such as reading or writing. It is therefore important that one of the main aims of the in-service training of teachers should be to cultivate a more positive self-efficacy by developing their confidence to teach science effectively. The next step is to address the question of how to improve their confidence (Palmer, 2001:123).

Behaviours of participants have a mutual influence on each other. The behaviour of the teacher is influenced by the behaviour of the students and in turn influences the student behaviour. Non-verbal behaviour, for example, the teacher's facial expression as perceived by students, is an important aspect of non-verbal behaviour for determining the level of the teacher's co-operative interpersonal behaviour. The more teachers smiled, the more helpful, friendly, and understanding the students perceived them to be (She & Fisher, 2002:65-66).

2.5.5 Values, aims and society

Science education is once again in the midst of reform. The reform efforts are bound by a common theme: to ensure a scientifically literate citizenry for the 21st century. Current reform initiatives beg the basic questions: "Where are we going with this reform?" "Why are we going there?" and "How will we get there?" Substantive change in how science is taught and in what is taught in science necessarily involves players from the full spectrum of the culture. Science and school cannot be isolated from the larger societal and cultural context (Shymansky and Kyle, Jr., 1992:745-746).

We understand that in most situations the three components of attitude appear concomitantly to shape teachers' classroom posture, through a direct and indirect interaction between society, school and teachers. How society sees the need for change and the demands of what is considered modern influence teachers' views and behaviour in school (Souza Barros and Elia, 1998:2).

Values cannot be divorced from education. They are crucial in determining what is both taught and learned. "Learning of Science" is a broad phrase, which leaves open exactly what it is that is to be learned. The aim that people express for learning, for courses of study, and for institutions reflect their values. Aims are specific ways of giving force to values. Values are not absolutes, not truths to be discovered or revealed; they are arbitrary, determined by individuals and society; nearly always in dispute, though at certain times the argument is more heated than at others; they differ between communities.

Educational values change with time and place, they are values that are held about what should take place in someone else and they are derivative. Values have shifted from the maintenance of tradition to beliefs that science is the root of Western economic power, thus the education system has changed (White, 1988:1-5).

Over a century ago, one of the fundamental questions of schooling was: "What knowledge is of worth most?" Conflicts have persisted over what should be taught. This issue is as much an ideological and political as an educational one. Educational and curricular issues have always been enmeshed in the history of

class, race, gender and religious relations. A contemporary way of phrasing the above question to highlight the profoundly political nature of the educational debate is: "Whose knowledge is worth most?" Science educators have largely ignored or failed to recognize the importance of this issue. How we respond to two distinct societal demands that predominates the reform literature will, to some extent, determine whose knowledge ought to be taught. That is, should science education ensure a scientifically oriented work force versus scientific and technological literacy for all?

Traditionally, the offering of different knowledge – tracking to accommodate the perceived needs of science-bound students – has created unequal structures with unequal outcomes. The differentiated structure of schooling throws up a barrier to achievement and participation in science and technology. Teachers – and others concerned with curriculum decision-making – must begin to engage in serious discourse regarding the ideology, content and values that will become the hallmark of the emerging curriculum reform. Debate should focus upon what (whose knowledge) counts as a legitimate science education. What should students know and be able to do? How should that knowledge be organised for purposes of instruction? (Shymansky and Kyle, Jr.1992:750).

2.5.6 Curriculum

Teachers are recognised as the central determining factor in the successful implementation of reform in science education. Reform in science education requires more than just a change in classroom practice. With its basis in a contemporary view of the nature of science, science education reform requires a different way of thinking about science, including the teaching and learning of science (Levitt, 2001:1). Differences between the goals of curriculum developers and what teachers actually practice has called attention to the influence teachers exert in the implementation of science curricula in high schools. This issue is a major one in a field such as physics (science) that foresees drastic curricular changes (some of which have already been implemented) on this level. On the other hand, there are a high percentage of pupils who fail science and pupils' negative attitudes towards science and science learning grow steadily (Gil-Perez and Carvalho, 1998:1).

As consensus concerning the nature of the learner and the characteristics of the curriculum grows, it becomes more and more apparent that implementing reforms requires a change in our view of the pre-college teacher. Teachers are thwarted in their effort to gain a more effective understanding of learning and instruction because they are isolated from each other and cannot participate in the sort of intellectual debate and discussion characteristic of the profession. In addition, teachers are often the recipients of a knowledge-telling approach to educational reform rather than partners in efforts to improve science instruction. Teachers have much to contribute to understanding the nature of learner and the nature of learning. The ideas that permeate curriculum reform efforts need to also infuse the preparation of teachers and the support of those who are teaching. The problem is to retain teachers once they are on the job. The isolation and lack of opportunities for professional interaction and communication are pivotal factors in teacher persistence (Linn, 1992:831).

The totality of socially transmitted behaviour patterns from advancements in science – the culture of science – is difficult to define in a world composed of political, demographic, socio-cultural and economic diversity. Scientific knowledge and practices have not equally benefited developing and developed nations. It seems that scientific knowledge and practices are not extended beyond the laboratory by generalisation to universal laws. The curricula in science are overstuffed and undernourished. The information age has made it increasingly difficult for teachers and students to identify the science, mathematics and technology that are truly essential (Shymansky & Kyle, Jr., 1992:750 & 762). Michael Apple (quoted by Shymansky & Kyle, Jr., 1992:746) argues that school curricula have become increasingly dominated by political and economic interests that simultaneously think of an area like science and technology education as both the reason for losing ground in international arenas and a promise for regaining position. His discussion focuses on the tension created when educational goals of student emancipation and empowerment are confounded with political and economic interests.

The study indicates that science teachers' beliefs about science teaching and learning do not always fit the mandates of the educational system, thereby creating a conflict between beliefs and practices. The idea of conflict between teachers' beliefs and their practices is not unique to certain countries. Many secondary

teachers face similar conflicts between society's expectations and the resources available to meet them. For a science teacher, conflict may arise because his/her beliefs about teaching science clash with the science curriculum he/she is required to implement. In some instances conflict may mean a lack of teacher autonomy, not viewing teaching and learning in ways similar to curriculum developers, or not being offered assistance in implementing new teaching and learning ideas (Gallard & Gallagher, 1994:639 & 641).

However, at the heart of the conflict situation are the beliefs teachers bring to the teaching-learning situation that are a result of prior experiences, both formal and informal (Gallard & Gallagher, 1994:641). They have ideas, attitudes, and behaviours related to teaching based on a lengthy "environmental" training period (the period in which they themselves were students). The influence of this incidental training is enormous because it corresponds to reiterated experiences acquired in a non-reflective manner as something natural, thus escaping criticism (Gil-Perez & Carvalho, 1998:2).

National Education influences science teachers' autonomy to make decisions in many different ways, including the application of important controlling mechanisms that engender compliance with the national science programme. As a consequence, science teachers' decisions about science teaching and learning are influenced by education mandates in the form of laws and policy reminders. Teachers must achieve an accommodation between educational policies and required programmes and their actual practices with real students in real classrooms with limitations of time, energy, resources and space. Moreover, classrooms exist in communities which have a range of expectations of what teachers and students should accomplish; and students also come with varied capabilities, backgrounds, hopes and aspirations (Gallard & Gallagher, 1994:641).

2.5.7 Nature of science (NOS)

The effects of language in science instruction, the content emphasis of instructional materials, integrated science curricula and instruction in general were curricular variables found to have a negative impact on student understanding of the nature of science (Meichtry, 1993:429). The understanding of the nature of science and the conceptual mastery of content are classical. Science teachers

have a tacit understanding, strongly shared by students that many aspects of science have to do with manipulation of mathematical symbols. They do not carry out innovations of new curricula and methodologies, which is partly due to entrenched beliefs about teaching science as telling science, instead of teaching as a process, science as a way of thinking. They show little interest and lack of compromise towards innovation in school (Souza Barros & Elia, 1998:3).

It is not possible to change what teachers and pupils do in the classroom without transforming their epistemology, their conceptions of how knowledge is constructed, their view about science. We have to pay attention to many other distortions, as indicated by Gil-Perez & Carvalho (1998:3-4), for instance:

- Extreme inductivism, enhancing "free" observation and experimentation and forgetting the essential role played by the making (formulating) of hypotheses and by the construction of coherent bodies of knowledge (theories). On the other hand, in spite of the great importance assigned to experimentation, science teaching remains purely bookish, quite frequently, with little practical work. For this reason, experimentation keeps the glamour of an "unaccomplished revolution". This inductivist vision underlies the orientation of learning as discovery and the reduction of science learning to the process of science.
- A rigid view (algorithmic, exact, infallible... dogmatic). Scientific method is presented as a linear sequence of stages to be followed step by step. Quantitative treatment and control are enhanced, forgetting, or even rejecting, everything related to invention, creativity and tentative constructions. Scientific knowledge is presented in its final state, without any reference either to the problematic situations that are at its origin, to its historical evolution or to the limitations of this knowledge that appears as an absolute truth not exposed to change.
- A "veiled" and elitist view. No special effort is made to make science meaningful and accessible; on the contrary, the meaning of scientific knowledge is hidden behind mathematical expressions. In this way, science is presented as a domain reserved for specially gifted minorities, transmitting poor expectations to most pupils and favouring ethnic, social and sexual discrimination.

- A socially neutral view. Science is presented as something elaborated upon in ivory towers, forgetting the complex STS relationships and the importance of collective decision-making on social issues related to science and technology.

These teachers' spontaneous epistemology constitutes a serious obstacle to the renewal of science teaching in as much as it is accepted uncritically as common-sense evidence. However, it is not difficult at all to generate a critical attitude towards these others commonsense views (Gil-Perez and Carvalho, 1998:3-4).

2.6 Attitude measurement

Attitudes, interests and values are central to the education process both as ends and means. Depending on whether they are positively or negatively directed towards a particular object they are considered to promote or inhibit student behaviour in class, the home, and peer-group and ultimately learning and the choice of a career. Furthermore, they are considered to influence choices to attend, respond, value, participate and make a commitment to educational activities. Thus the development of favourable attitudes, interests and values towards a particular object is a stated goal of most educational programmes. Even when not stated as a goal, such programmes influence the attitudes, interests and values of students who take part, again either positively or negatively (Anderson, 1994:380).

Attitude was defined as a person's location on a dimension of affect or evaluation. Belief was defined as the person's location on the probability dimension that links an object and an attribute. Intention was also defined as a dimension of probability, but the link here involves the person and some action with respect to the object. Finally, behaviour was defined as a person's observable response when studied in its own right. An almost unlimited variety of measurement procedures have been employed in the attitude research (Fishbein & Ajzen, 1975:53). The purpose of this entry is to examine this field, broadly regarded as attitudes, and methods used to measure such attitudes, and quality of measurement these methods produce, as well as the practical problems involved in attitude measurement (Anderson, 1994:380). The following major attitude-scaling methods will be discussed: Guttman, Thurstone, Likert, and Osgood *et al.*, usually known as semantic differential scales. All of these standard scaling methods yield a single score that

represents the person's location on an evaluative dimension, i.e. that they are all measure of attitude as here defined (Fishbein & Ajzen, 1975:53).

2.6.1 Self-report measure

A self-report instrument consists of a series of sentences or adjectives (hereafter referred to as "items") to which those persons whose attitude is being measured are expected to respond. To measure attitude, these items must be: a) related to the target of the attitude; b) located somewhere on or along the attitudinal continuum; and c) capable of being understood as intended by those who are expected to respond to the items. In an attempt to construct a self-reporting instrument that meets these three criteria, four types of scaling techniques have been widely employed. Three of these techniques are named after the individuals who developed them – Thurstone (1928), Likert (1932), and Guttman (1950). The fourth, developed by Osgood *et al.* (1957), is referred to as the "semantic differential" technique (Anderson, 1994:382).

All measurement involves observation of one or more responses made by a subject, whether they are verbal (e.g., questionnaire response) or overt behavioural response. The subject is asked to make a judgement about himself or about some other person, object or event (Fishbein & Ajzen, 1975:56-57).

The Thurstone, Likert and Guttman techniques rely on sentences, while the semantic differential technique relies on adjectives to measure the strength and direction of the attitude. In addition, however, they differ in two other important respects; (a) the position of the items on the attitudinal continuum, and (b) the nature of the response required to indicating position along the continuum (Anderson, 1994:382).

2.6.2 The construction of attitudinal items

Once the attitudinal object and the type of attitude scale have been determined, the next step is to develop an item pool, or collection of attitude statements, from which a scale can be constructed. Self-report measures require, at a minimum, that those responding should find the items included in a scale meaningful and interesting (Anderson, 1994:383). Edwards (1983:13-14) summarised the "Informal

criteria" for editing statements as suggested by Wang (1932), Thurstone and Chave (1929), Likert (1932), Bird (1940), and Edwards and Kilpatrick (1948). They are as follows:

1. Avoid statements that refer to the past rather than to the present.
2. Avoid statements that are factual or capable of being interpreted as factual.
3. Avoid statements that may be interpreted in more than one way.
4. Avoid statements that are irrelevant to the psychological object under consideration.
5. Avoid statements that are likely to be endorsed by almost everyone or by almost no one.
6. Select statements that are believed to cover the entire range of the affective scale of interest.
7. Keep the language of the statements simple, clear, and direct.
8. Statements should be short, rarely exceeding 20 words.
9. Each statement should contain only one complete thought.
10. Statements containing universal terms such as *all*, *always*, *none* and *never* often introduce ambiguity and should be avoided.
11. Words such as *only*, *just*, *merely* and others of a similar nature should be used with care and moderation when writing statements.
12. Whenever possible, statements should be in the form of simple sentences rather than in the form of compound or complex sentences.
13. Avoid the use of words that may not be understood by those who are to be given the completed scale.
14. Avoid the use of double negatives.

However, it should be recognised from the outset that as in any writing task much depends on the skill in the use of words and expression of ideas of the person responsible for writing the attitudinal items (Anderson, 1994:383).

2.6.3 Theoretical consideration(s)

When constructing or selecting an attitude's measuring instrument, one must specify a) attitude objects, b) the conceptual attributes of the attitude construct relevant to the aims of the research or response continua, and c) the response domain/people (Davis & Ostrom, 1996:72 and Triandis, 1971:26). One can

measure attitudes towards any type or variety of behaviour, idea, concept or entity. An attitude may be very specific and concrete, may refer to a social category or be quite broad and abstract (Davis & Ostrom, 1996:72).

Prior to developing or selecting a measuring instrument of attitude, it is necessary to define what is meant by the concept. Most authorities view an attitude as a hypothetical construct, the most prominent attribute of which is its evaluative character. As a hypothetical construct, attitude is not available for direct observation. Its existence is revealed by its effect on the person's observable responses (Davis and Ostrom, 1996:72).

2.6.3.1 Cognitive measure

In studying the cognitive component a number of questions are asked. The discovery of the criteria attributes used by people in categorizing an experience is an important aspect of psychology. The relationships between various physical stimuli and the subjects' judgements can be determined. We can vary the behaviour of a person on a single dimension of stimulation and can study the reactions of subjects to this behaviour. If we use a large number of judgmental continua and find that the responses of the subjects are highly inter-correlated, we can conclude that the subjects employ a limited number of criteria attributes to make judgements (Triandis, 1971:29).

2.6.3.2 Physiological measure

The most direct measurement of the affective components involve the utilisation of physiological procedures. However, most of the standardised methods of measurement use verbal responses and attempt to measure "the degree of positive or negative affect associated with some psychological object" (Thurstone, 1931 as quoted by Triandis, 1971:35). Physiological measures attempt to prevent distortion by assessing involuntary responses over which the individual has little or no control.

A large number of physiological responses have been considered in the search for a valid, non-verbal indicant of attitude. Among them are the galvanic skin response (GSR), measuring electrical skin conductance, heart rate, palmar sweat, pupillary

dilation and constriction, respiration, etc. Despite considerable research efforts, there is little evidence to indicate that any physiological measure can be used as a valid indicant of attitude. One problem is that most physiological measures appear to assess general arousal and therefore cannot be used to distinguish between positive and negative affective states (Fishbein & Ajzen, 1975:94).

While such measures do detect arousal or intensity, the information they provide is not specific enough for the measurement of an identified attitude. In particular, the evaluation dimension of the attitude concerned with the direction and aim of arousal remains unknown and possibly unknowable (Anderson, 1994:386). In conclusion, it would definitely be desirable to have a non-verbal measure of attitude that is not under the subject's control, but it appears unlikely that any known physiological measure or reaction will serve this purpose (Fishbein & Ajzen, 1975:94).

2.6.3.3 Behavioural measure

The behavioural component of attitude involves the behavioural intentions of the subject towards the attitude object. It can be inferred from observations of the consistencies of a person's behaviour in response to situations that have common characteristics (Triandis, 1971:51-52). They are comparable to verbal responses to items on an attitude scale. The implication of this notion is that overt responses must be submitted to the same scaling procedures that are applied to verbal items before these can be assumed to reflect attitude. It should be obvious that not all behaviours with respect to a given object are valid indicants of attitude towards that object (Fishbein & Ajzen, 1975:95).

Behaviours or behavioural patterns can be observed in two settings: naturalistic and contrived. Naturalistic settings are those in which people typically find themselves and are unaware that they are being observed. In contrast, contrived settings are those that are unfamiliar and/or those in which people are aware they are being observed. Both settings have problems associated with them.

While naturalistic settings may have greater face validity, the behaviour that is being investigated may occur very infrequently, thus making data collection time consuming and costly. Unfortunately, while contrived situations may be less time-

consuming and costly, the external validity (that is, the generalisability of the data across persons, settings and times) may be suspect. Regardless of the settings or occasion, it is important that multiple observations of the behaviour be made. The reliability of ratings made on the basis of one behavioural observation is no stronger than the reliability of inferences that are based on one item (Anderson, 1994:385).

2.6.4 Practical considerations

Research goals dictate the degree of structure used in the measuring instrument. For example, in a most unstructured and open-ended format, the person might be asked, "What do you think of X?" In contrast, in the most structured format, the person is presented with a set of alternatives in multiple-choice format. If the research is exploratory in nature, the open format is often preferable. It will provide more information about subjects' thoughts, often identifying issues the researcher had not previously considered. In addition, the unstructured format provides subjects with greater freedom of expression, thus often enhancing rapport. Structured formats, however, are much easier to score, provide less opportunity for distortion in coding, focus responses more directly on issues of primary concern, and may be administered to large groups of people. Thus, when the researcher has clearly identified the particular feelings, beliefs and behaviours of interest, the closed format is generally preferable. Most research uses of attitude scales assume that the person is aware of his or her attitude and is also willing to fully and accurately convey it. For many attitude issues and research settings, this assumption is reasonably accurate (Davis & Ostrom, 1996:73).

Unobtrusive techniques are designed to prevent persons from being aware that they are being observed in any way. When indirect techniques are used, persons are usually aware that they are being evaluated. However, they should not be aware that it is their attitude that is of interest to the test giver. Instead, they are under the impression that the evaluator is interested in some other aspect of their behaviour, such as logical thinking ability, moral judgements or perceptual abilities. Finally, one must consider the limitations of time and resources available for scale construction, administration and scoring. If time is limited, self-reporting techniques involving few items in a structured format are generally preferable. Such techniques require less time both for administration and for scoring. Most

structured scales can also be administered in large groups, whereas indirect, unobtrusive or physiological measures often cannot be applied in such a manner. In addition, self-reporting measures are often cheaper and do not require the complex materials sometimes necessary for other methods (Davis and Ostrom, 1996:73).

2.7 Standard attitude scales

Inadequacies in the design of closed item questionnaires are often blamed for the lack of consistent research findings regarding science-related attitude. Since attitude is a construct that must be measured indirectly, usually through self-reporting, it is imperative that instruments used to assess attitudes be both reliable and valid (Koballa, Jr.,1989:4). Before further discussion, however, we should clarify what we mean by the reliability and validity of a measurement: Reliability refers to the extent to which we obtain information that is free of measurement error. If an instrument is reliable, the information it provides is stable; also, similar results are obtained when the instrument is used more than once to measure the same thing (Triandis, 1971:26). This means consistency across items, settings, raters and/or time. Consistency across item or settings is referred to as "internal consistency," while consistency across time is commonly labelled "stability," and across raters is called "inter-rater reliability" (Anderson, 1994:387).

Validity refers to the degree of relevance of the instrument; a perfectly reliable instrument may have no relevance to what we think it is measuring, but it may have relevance to some other phenomenon (Triandis, 1971:26). Adams (1982) (as quoted by Anderson 1994:387) suggests there are three basic types of validity that pertain to attitude measurement: content, predictive and construct validity. "Content validity" applies only when attitudes are an intended outcome of the process of schooling. "Predictive validity" applies only when attitude is being used to predict other characteristics or behaviours of students or teachers. However, the crux of the validity of an attitude-measuring instrument is its "construct validity" (Anderson, 1994:387).

Mathematical computations to determine instrument reliability are routine but the absence of systematic planning for establishing validity is a flaw common to most attitude instruments. Establishing validity is a process that involves human

judgement in addition to statistical procedures according to Abdel-Gaid, Trueblood and Shringley (1986) (quoted by Koballa, Jr. 1989:4). Heeding this warning, a number of closed-item attitude scales were developed (Koballa, Jr.1989:4).

2.7.1 Scalogram analysis

This procedure was developed by Guttman to check on the unidimensionality of a set of statements (Triandis, 1971:42). In practice, scalogram analysis can perhaps be most accurately described as a procedure for evaluating sets of statements or existing scales to determine whether or not they meet the requirements of a particular kind of scale, set forth in some detail by Guttman. We shall refer to this particular kind of scale as a *Guttman scale* or a *cumulative scale* (Edwards, 1983:172). This approach involves the development of a different kind of scale from the scales to be discussed. It has interesting properties, which are not claimed by those who developed the other kinds of scales (Triandis, 1971:42).

If a set of statements with a common content constitute a Guttman scale, then an individual, with a higher rank (or score) than another individual on the same set of statements must also rank just as high or higher on every statement in the set as other individual. In the case of attitude statements, we might say that this means that a person with a more favourable attitude score than another person must also be just as favourable as or more favourable in his response to every statement in the set than the other person. When responses to a set of attitude statements meet this requirement, the set of statements is said to constitute a *unidimensional scale* (Edwards, 1983:172).

In order to clarify the properties or characteristics of a cumulative scale, consider an example from the area of ability testing. A test designed to measure some ability is composed of a number of items varying in level of difficulty; that is, the items differ in terms of the number of respondents who solve the problem posed in the item. Such a set of items forms a perfect cumulative scale under the following conditions: A person solves all items up to a certain difficulty level and no items beyond that level. Thus, the more items a person passes, the higher his level of ability, and the most difficult item passed corresponds to his ability level. It follows that the number of items passed can be taken as an index of his ability. Response

patterns of a perfect cumulative ability scale are shown in Table 2.1 (cf. Guttman, 1944) as at Fishbein & Ajzen (1975:65).

Table 2.1: Response Pattern in a Perfect Cumulative Scale

Response Pattern	Item difficulty						Ability score
	Low	1	2	3	4	5 High	
A		0	0	0	0	0	0
B		1	0	0	0	0	1
C		1	1	0	0	0	2
D		1	1	1	0	0	3
E		1	1	1	1	0	4
D		1	1	1	1	1	5

Note: A 0 indicates failure, a 1 success with respect to a given item.

As Table 2.1 shows, such a cumulative scale has two interesting properties. First, knowledge of a person's ability score allows one to predict his performance on each item of the scale. A person with a score of 3 must have response pattern D, indicating that he passed the three easiest items and failed the two most difficult items. Secondly, of two respondents, X and Y, if X has a higher score than Y, then X has passed all items that Y has passed, as well as at least one additional (more difficult) item. These properties imply that items on a perfect cumulative scale are ordered along a single dimension (in our example), i.e. an ability dimension. As pointed out above, the properties of cumulative scales provide information about the relationship between ability scores and performance on items on the scale (Fishbein & Ajzen, 1975:65).

2.7.2 Thurstone scale

The method of paired comparisons is useful in scaling statements when the number of statements to be scaled is not too large. If comparative judgements are to be obtained for each pair of statements, then each subject will have to make $n(n - 1)/2$ comparative judgements. If we have a fairly large number of statements to scale, we may not be able to obtain subjects who will make the necessary time available required to obtain the comparative judgements. A solution to this problem is to use a scaling method that requires each subject to make only one comparative judgement for each statement. The *method of equal-appearing intervals* has been widely used in obtaining scale values for a large number of statements (Edwards, 1983:83).

The first step in Thurstone scaling (Fishbein & Ajzen, 1975:70) involves the collection of a large pool of belief or intentional items related to some attitude object. Thurstone assumed that responses to such items are expressions of the person's attitude. More specifically, he made the assumption that different items may express different degrees of favourableness or non-favourableness towards the attitude object. A major purpose of Thurstone scaling is to specify the location of each item on the evaluative dimension by assigning a scale value to the item (Fishbein & Ajzen, 1975:70).

One major criticism of the equal-appearing interval procedure has focused on Thurstone's assumption that the judges' own attitudes do not influence their judgements and thus have no influence on item scale values (Fishbein & Ajzen, 1975:71). Both the Thurstone and Guttman scales have estimates of internal consistency built into the techniques used to develop them. For Thurstone scales, internal consistency is estimated for each respondent by a mean error statistic, which considers the range of scale values associated with the statements endorsed by the respondent or respondents. The smaller the range, the more consistent the responses. For a Guttman scale, the estimate of internal consistency is based on the coefficients of reproducibility and scalability (Anderson, 1994:387).

2.7.3 Likert scale

This method was developed by Likert (1932) and has the advantage that it does not require the use of judges. Thus, attitude statements are given a value by a statistical procedure that employs the data from the sample of persons whose attitudes are being studied. The Likert method begins with n statements that are given to the sample of individuals who are to be studied (Triandis, 1971:42). The items may be statements of either beliefs or intentions. For each item, the investigator first decides whether it indicates a favourable or unfavourable attitude towards the object in question. If the item is ambiguous or appears to indicate a neutral attitude, it is immediately eliminated. The investigator thus fulfils the function of the judge in Thurstone scaling, except that his task is simplified because items are merely placed into three categories: favourable, unfavourable and rejected. The remaining items are administered directly to a sample of

subjects representative of the target population. Typically, subjects are asked to respond to each item in terms of a five-point scale defined by the labels:

(a) strongly agree (b) agree (c) undecided (d) disagree (e) strongly disagree

A preliminary estimate of each respondent's attitude is obtained as follows:

First, responses to each item are scored from 1 to 5. Strong agreement with favourable items is given a score of 5, and strong disagreement with these items are given a score of 1. Scoring is reversed for unfavourable items, such that disagreement with an unfavourable item results in a high score. The person's preliminary attitude score is obtained by summing across all his item scores. For a set of 100 items, these attitude scores could range from 100 to 500; the higher the score, the more favourable the attitude (Fishbein & Ajzen, 1975:71-72).

Constructing a Likert scale requires the elimination of items that do not reflect the attitude under consideration. Thus an item analysis is performed. To be retained, an item must meet Likert's criterion of internal consistency.

According to this criterion, the more favourable a person's attitude, the more likely he should be to endorse favourable items and the less he should be to endorse unfavourable items (Fishbein & Ajzen, 1975:72).

2.7.4 Semantic differential scale

The most general method for measuring affect is the semantic differential scale. This instrument allows the researcher to present any attitude object, be it person, issue, institution, practice, picture, musical composition or anything else (Triandis, 1971:47). A scale of this type consists of a series of bipolar adjective pairs (e.g., good–bad, beneficial–harmful) listed on opposite sides of a page with seven spaces in between. The attitude object is identified at the top of the scale and may be a word, statement or picture. The respondent is instructed to evaluate the attitude object by placing a mark in one of the seven spaces between each adjective pair (Koballa, Jr., 1989:4).

In Osgood's behaviour theory the implicit anticipatory response to a stimulus object is viewed as the object's meaning. Since this implicit response cannot be directly observed, overt responses to the object have to be considered. In his search for overt responses that are "maximally dependent upon and sensitive to meaningful states, and minimally dependent upon variable," Osgood *et al.*, (1957) and Osgood (1952) (as related by Fishbein & Ajzen, 1975:73) settled on verbal responses to the object or concept. Thus, the semantic differential technique is based on the premise that, since the basic function of ordinary language was assumed to be the communication of meaning, ordinary language could be used to differentiate between concepts and measure their meaning (Fishbein & Ajzen, 1975:73).

A first step is to devise a "sample of alternative verbal responses which can be standardised across subjects and (which would) be representative of the major ways in which meanings vary." To increase the measuring instrument's sensitivity, a seven-point scale is inserted between the bipolar adjective pairs so that the subject can indicate both the direction and intensity of each judgement.

A large number of such bipolar scales were constructed in an attempt to obtain a representative sample of the possible dimension along which concepts can be judged. The semantic differential scale involves providing the respondent with one or more concepts to differentiate and a set of bipolar adjectives against which to do so. The respondent's task is to rate each concept on each scale. In this manner, a profile of rating is obtained for each concept; it is assumed that two concepts are similar in meaning to the extent that their profiles are similar (Fishbein & Ajzen, 1975:73-74).

In a large number of studies involving different scales and different concepts, Osgood and his associates have repeatedly found three basic factors or dimensions underlying semantic differential ratings. Based on inspection of the scales that had a high loading on these factors, the three major dimensions were interpreted as *evaluation*, *potency* and *activity*. Osgood argued that a person's attitude towards an object is equivalent to the object's evaluative meaning for the person. He thus concluded that one could measure a person's attitude towards any object by having him rate that object on a set of items known to have a high loading on the evaluative factor. Once a set of evaluative items has been identified, this set can be used to measure attitudes towards a large number of

concepts. This apparent generality of the semantic differential has resulted in its being used in a variety of contexts, and indeed, it is probably today's most widely used attitude-measuring instrument (Fishbein & Ajzen, 1975:74).

2.8 Conclusion

This Chapter focused on attitude as an important component of this study. As already mentioned in the introduction to this Chapter, it was important to conduct a literature study on attitude. This was done to provide background on attitude and factors contributing to the formation of attitude. Attitude-related factors and different descriptions of attitude have been explored but several attitudinal phenomena may not yet be understood by attitude theorists (Ostrom, 1996:75). Little may be known about the sudden and intense emotional arousal that attitude produces. Little may also be known about how attitudes lead people to make enormous personal sacrifices on behalf of their loved ones and ideals. Little may be known about the massive reversals in attitude that sometimes occur. Though enormous strides in understanding attitudes have been made since the early years of the 19th century, these and other unresolved issues indicate that fundamental questions are still unanswered (Ostrom, 1996:75).

Attitudes are hypothetical constructs developed by social psychologists or educators (hence the term: "construct validity"). Their existence is inferred from what people say or do. The estimation of the construct validity of an attitude instrument requires an understanding on the part of the instrument developer or researcher of the following: (a) the definitions of attitude and the target; (b) the way in which the attitude fits into some larger conceptual framework; and (c) a set of hypotheses based on the relationship between attitude and the other constructs within the conceptual framework (Anderson, 1994:387).

The next chapter will cover the concepts of attitude change and consistency of attitude.

CHAPTER 3

ATTITUDE CHANGE

3.1 Introduction

How we think about something makes a difference, not only at the level of theory, but also in terms of practice. We are now quite used to seeing pictures of disasters in which thousands of people lose their lives due to storms, drought and so forth. We are told to think of these as *natural disasters*. But is this the appropriate way of understanding the situation, or is it really a form of category error? The problem is not, for example, the annual rains – a natural occurrence – and their consequence but rather the economic structures that allow only a small minority of individuals to control the very lives of the bulk of the people of the region involved. Note that this different approach to the problem of floods and resulting food scarcity would require a different practice. Not only would we send immediate aid to help the victims of the floods, but we would also engage in a large-scale programme of land distribution to make land tenure much more equal (Apple, 1992:779-780).

The reason why it is so crucial that we educators gain the ability to step back and ask who is defining our problems for us and who benefits from those definitions was given by Apple (1992:780). This is particularly important for science educators, because along with many other curricular areas there are immense pressures to reform science education, to make it more efficient and effective, and to give it a more significant place in the school curriculum. Thus the issue of change (attitude) is an element of the curriculum, and teaching can only be fully understood in its connections to larger social and educational tendencies and relations (Apple, 1992:780).

Attitude change strategies may be planned and implemented to improve a person's attitude to science. But what specifically is it that the designer of the change experiment seeks to improve? Researchers in the field of social psychology have usually distinguished between the following possibilities: attitudes, beliefs and behaviours (Koballa, Jr., & Crawley, 1985:226).

In order to change a person's attitude towards science, one need to know first the role that attitude plays in an individual.

3.2 The role of attitudes towards science

Attitudes serve as convenient summaries of a wide variety of beliefs. In a much broader sense, a person's attitude towards science conveniently summarises his/her emotional response to basic beliefs about science. In addition to the fact that attitudes towards science serve as convenient summaries of our beliefs about science, they are important to other people for other reasons. They help others predict the kind of science-related behaviours we are likely to engage in more accurately than almost anything else we can tell them. Attitude towards science may also express important aspects of one's personality (Koballa, Jr., & Crawley: 1985:226).

Katz (as quoted by Koballa, Jr., & Crawley, 1985:226), described four functions that attitudes may serve for a person. Firstly, attitudes may serve an ego-defensive function. These are attitudes that protect people from unflattering truths about themselves or about others who are important to them. Attitude, secondly, may also serve a value-expressive function, which occurs when holding a certain attitude allows the person to express an important value. A third purpose served by attitude is that of knowledge. Knowledge of attitudes enables people to better understand other people and events around them. Finally, attitudes may also serve a utilitarian function. These attitudes help people avoid punishment and gain rewards (Koballa, Jr., & Crawley, 1985:226-227).

More important is the attitude towards the act itself, since that attitude incorporates feelings about the attitude object, the type of behaviour and the temporal-social context in which the behaviour is elicited (Ostrom, 1996:75). Triandis (1971:4) found that attitude helps people understand the world around them by organizing and simplifying a very complex input from their environment. It helps people protect their self-esteem by making it possible for them to avoid unpleasant truths about themselves. Lastly it helps them adjust in a complex world by making it more likely that they will react so as to maximise their rewards from the environment; and it allows them to express their fundamental values (Koballa, Jr., & Crawley, 1985:224).

Attitude towards science has become an important concept for a number of reasons. Attitudes towards science are thought to fulfil basic psychological needs, such as the need to know and the need to succeed. Attitudes towards science are thought to influence future behaviours, such as interest in working on a science project at home and in visiting a science museum (Koballa, Jr., & Crawley, 1985:224).

Attitudes can serve an instrumentality function in which they are used to obtain rewards and avoid punishments in our social world. People often espouse attitudes as a way of managing the impressions others form of them. Attitudes can serve a value-maintenance function, in which they are viewed as deriving from (and providing sustenance to) more basic values like "equality" and "financial security." Attitudes can serve a knowledge function, helping us deal effectively with the complex and overwhelming flow of information encountered in life. Attitudes allow us to simplify this information by reducing it to categories specific to each attitude object and then attaching a positive response disposition to the category (Ostrom, 1996:74).

It can serve a consistency function, since people need to view themselves as reasonable and consistent in their attitudes and beliefs; awareness of inconsistencies is uncomfortable and motivates the person to restore cognitive equilibrium. Attitudes can serve a uniqueness function, letting people develop attitudes that distinguish them from others in their social group. Attitudes can serve an ego-defensive function, defending the person against unflattering self-truths deriving from antisocial impulses and inner conflicts, and from sources of information external to the self. Attitudes can serve a reactance function: Because people resist threats to their freedom to think and feel as they choose, they adopt attitudes directly opposite to those advocated by coercive sources (Ostrom, 1996:74).

The evaluative characteristic of attitudes operates in the service of these motives: Positive attitudes emerge only if basic motivational needs are satisfied by positive responses towards the attitude object. The observed attitudinal response will be determined by whatever set of motives is dominant at the time of the response. Thus, like the "set of beliefs" conception, the "set of motives" view assumes there

is no single "true" attitude; consistency over responses derives from the stability of the person's underlying motive structure (Ostrom, 1996:74).

3.3 Attitude change

More recently, the study of attitude change has become an important focus of science educators (Koballa, Jr., & Crawley, 1985: 224). Inculcating attitudes and aiding their growth is an important part of science education as indicated by the plethora of studies that have reported on changes in the science-related attitude of students and teachers. Most of the attitude-change studies recounted in recent reviews were concerned with attitudes towards science or science teaching and considered a shift in the positive direction as desired (Koballa, Jr., 1992:64).

Because of the interrelationships among beliefs, attitudes and behaviour (intended or actual), any discussion of attitude change must also deal with belief change, behaviour change and context. Furthermore, the principles that are involved in changing someone's attitude towards science are the same as those that are involved in changing beliefs about science and science-related behaviour (Koballa, Jr., & Crawley, 1985:226). Beliefs about the object and attitude evaluations can therefore be viewed as two different determinants of attitudes at which an influence attempt can be directed (Fishbein & Ajzen, 1975:396).

Current trends in attitude research in science education suggest that investigators are becoming more aware of the need to rely on sound theory rather than intuition alone to guide the design of their investigations. Theories of attitude change described in the socio-psychological literature have added much to what is known about improving attitudes towards science. Based on this body of research, suggestions can now be made for enhancing the development of positive attitudes in the science classroom (Koballa, Jr., & Crawley, 1985:227).

3.4 Factors contributing to attitude exchange

Attitude towards an object is determined by a person's beliefs that the object possesses certain attributes and by his evaluations of those attributes. Thus attitude can be changed by changing one or more of the existing salient beliefs

and by introducing new salient beliefs, or by changing the person's evaluations of the attributes (Fishbein & Ajzen, 1975:396).

3.4.1 Personal attributes of the tutor

Confidence and enthusiasm are the catalysts that facilitate the implementation of the other strategies. As a science teacher, you need to show interest in the subject and make your students also to enjoy science and to be able to go out there and teach it (Palmer, 2001:133). A teacher's attitude towards science is reflected in the time the teacher spends teaching science and the manner in which it is taught (Koballa, Jr., & Crawley, 1985:228-229).

Teachers' styles, and mainly their attitudes, are strong context outcomes rooted in experience and do not become automatic routine conducts, in the sense that they are developed via very slow interactions (action/reaction) and become well established constructs for each individual only after some time. In that sense attitudes can be constructs for each individual only after some time. Thus attitudes can be modified only by each individual, when he/she becomes aware, via elements and evidence, that new postures would be better to deal with the world around him/her. So we could argue about the possibility of modifying teaching attitudes by means of teaching programmes when we teach specific competencies in the pre-service courses. One basic aspect to improve classroom practice is simple: to allow the teacher to identify and reflect on the aspects of their practice that need to change. Teachers should be directly involved in defining priorities about what their real problems are and should be able to select appropriate solutions (Souza Barros & Ellia, 1998:6-7).

One of the main aims of in-service training of teachers should be to cultivate more positive self-efficiency by developing their confidence to teach science effectively. It has been suggested that increasing the science content component of their college courses would give the teachers more confidence. It should be noted that increased science knowledge in itself will not consistently result in improving self-efficiency. Palmer (2001:124) reviewed a number of early studies and realised that an inquiry-based science methods course increased both interest and confidence. Similarly, others found that an inquiry-based methods course resulted in an

improvement in self-confidence. A methods course involving hands-on experiences, peer teaching and tutoring developed their students' confidence.

In addition, he reviewed a method class using a constructivist approach emphasizing gender equity and concluded that it resulted in improved self-confidence. Furthermore, courses with components of practice teaching as well as student-centred approaches and process approaches could positively influence students' attitudes (Palmer, 2001:124).

The studies above show that it is possible for college courses to improve in-service teachers' confidence to teach science. Furthermore, the research suggests that this is most likely to occur when science content courses are tailored specifically to the needs of these students, and when the science method course emphasises inquiry or other student-centred approaches (Palmer, 2001:123-124).

3.4.2 Clarity of explanations

Science courses often discourage students by stressing the simplicity of abstract principles and by labelling the results of students' own struggles to understand the world as "misconceptions." As a result, teaching simple principles has the potential of widening the gap between the ideas held by students and the ideas held by scientists. Often these ideas make sense to scientists. Students complain that they cannot use these abstract science ideas to determine effective home energy conservation measures, to design safe storage for food at picnics, to understand genetic counselling, or to analyse the risks and benefits of toxic waste disposal plans. Students cannot integrate these so-called simple principles with their own experience, and therefore they cannot apply them to everyday concerns (Linn, 1992:822-823).

Hazen and Trefil (as in Linn, 1992) point out that it is important to carefully choose the goals of science instruction, that selecting principles for students to learn and understand is a crucial aspect of effective science courses, and that practical examples are crucial to the success of science instruction. They advocate a set of simple ideas that are unlikely to seem similarly simple to students. Ideas often seem simple to scientists because they focus on microscopic events and synthesise a broad range of phenomena in a formal or mathematical model. Yet

students, unable to observe the microscopic events described by these principles, often find the principles inaccessible. In addition, scientific principles sometimes sound contrary to students' observations of the natural world. Thus, rather than finding these principles simple, students find them abstract, difficult, incomprehensible and frustrating. It is hardly surprising that, as a result, students choose to memorise scientific information rather than to integrate it with their observations of the natural world or to understand it (Linn, 1992:823).

Clear explanations using simple language, with minimal use of scientific jargon, influence attitudes by helping students understand the subject (Hart, 2002: 4)

3.4.3 A clear structure for each lesson

Hazen and Trefil in *Science Matters* (as quoted by Linn, 1992:823) suggest that the way to overcome the current ineffectiveness of science instruction is to tell students what you expect them to know. Much of the research suggests that instruction is more effective when students are helped to construct ideas by themselves. At the beginning of each workshop/lesson/presentation, an overview that accurately describes the purposes and structure of the session has a positive influence on attitudes (Hart, 2002: 4)

3.4.4 Doing hands-on activities

In regard to positive attitudes towards science teaching, a few studies have acknowledged the significance of well-planned programs that provide students with a sufficient science background using small classes and frequent hands-on experiences (Altun & Kaya, 1996:569).

The work of Freedman (1997) adds to the body of evidence that attitude towards science influences achievement, with the additional idea that a hands-on laboratory programme influences students' attitude towards science and influences their achievement in science knowledge. The results and conclusions of his investigation add to the evidence supporting the Schibeci and Riley model. It appears that science instruction that includes a regular laboratory experience is a viable and effective instructional method for science teachers. Therefore, hands-on laboratory work, as a part of the science curriculum, offers a method for raising

achievement levels and promoting positive attitudes towards science among science students (Freedman, 1997: 353-355).

3.4.5 Variety of teaching strategies

In order to change educators' practices, teachers' beliefs need to be considered. However, beliefs are difficult to change. The beliefs teachers espouse are not always consistent with the way they teach, and changing educators' beliefs takes time. Since most beliefs are formed through experience over time, pedagogical practices that support constructivist theory can be nurtured by engaging novice educators in constructivist experiences both in learning and teaching science. The experience alone does not ensure change, but certainly facilitates it. Change is limited when pre-service educators learn science content differently than they learn science methods. Pre-service programmes have to impact on educators' development. If the science content is taught by lecture and the methods courses use a constructivist environment, the experience is diluted, and the chances for change to occur are significantly decreased (Hart, 2002: 4-5)

The first step in improving the status of science as a school subject is to establish a minimum time period for science to be taught daily at the elementary level. Lengthy, consecutive seatwork assignments, characterised by students reading textbook chapters and completing worksheets, have been found to have an unfavourable impact on "time on task" and to do little to enhance the development of a positive attitude among elementary and secondary students. However, the use of models, illustrations, and laboratory work by teachers to explain concepts has been shown to have the opposite effect (Koballa, Jr. & Crawley, 1985:228-229).

Various science councils advise that the classroom should incorporate group activity because they influence how students learn and reinforce the collaborative nature of the scientific enterprise. This emphasis on student-centred instruction marks a shift away from the traditional instructor-centred paradigm, which provides few opportunities for students working in small groups, to a paradigm that has opportunities to negotiate meaning and construct conceptual understanding in a community of learners. Small-group instructional methods have been implemented in undergraduate science, mathematics, engineering and technology (SMET)

education. Students experience positive interdependence as they work through problems in a collaborative setting.

Meta-analyses of the impact of small-group learning in undergraduate SMET have demonstrated significant positive effects on student achievement, attitudes and persistence (Tien, Roth & Kampmeier, 2002: 606-607).

Cooper (1995) and Frederick (1994) realised that, (as indicated by Tien *et al.*, 2002) a majority of undergraduate science courses continue to be taught predominantly in a lecture format because of the instructors' concern that they will lose control of the classroom, the belief that interactive learning comes at the expense of content, and the insistence that evidence of greater student achievement should precede change (Tien *et al.*, 2002:607).

3.4.6 Modelling, experience and reflection

Modelling. Social learning theory says that most human behaviour is learned through observation and modelling and that "rarely do people learn behaviours under natural conditions that they have never seen performed by others." Modelling is a particularly effective way to teach abstract behaviours, such as examinations of values and standards of conduct. Given the complex nature of teaching within a constructivist framework of learning, it is reasonable to assume that modelling can be a critical component in facilitating teacher change.

Teacher modelling is, of course, predicated on the assumption that observation of skilled performers facilitates learning. Thus, teacher modelling of authentic inquiry (both laboratory-/fieldwork-based and literature-/media-based) can play a crucial role in enculturation. First, it demonstrates a commitment to the value of inquiry as a means of learning: the teacher models the learning process by acting as a more expert learner. Secondly, it shows students how scientists plan, conduct, interpret and report scientific inquiries: the teacher models scientific investigation by acting as a more expert scientist (Hodson, 1998:150)

The more complex the skill or thinking process, the greater the need for an opportunity to observe performance of the skill or thinking process. "Mental modelling" of reasoning processes further enhances learning (Hart, 2002:6).

The mental modelling of thinking processes used in planning lessons of this nature or in reflecting on the act of teaching can assist prospective educators in developing their own mental models of thinking involved in teaching and learning science, and in beginning the process of challenging and changing their beliefs (Hart, 2002:6).

Teachers need first-hand experience in learning science as a student within a constructivist environment. They need to observe teaching within such an environment, and they need to plan and teach lessons for such an environment. Experiences both as students and as teachers will influence how teachers think and what they ultimately do (Hart, 2002:6)

Another prominent aspect of this culture of school science education is the demand for mastery of abstract, academic knowledge, which only later, if at all, will be revealed as capable of application to real world matters. Often students' intuitions about the real world are discredited or ignored, driving a wedge between school science and everyday understanding. The fairly clear message is that what children know about the physical world is neither valued nor valid (Hodson, 1998:101).

Teacher reflection is critical in teacher change. The act of reflecting on beliefs and behaviours allows teachers to make connections between their thoughts and actions and to recognise, expose and confront contradictions and inconsistencies. Teachers need to explore their own as well as their students' thinking about science. They need to observe the thinking processes of others and participate in conversations about the behaviours they observe (Hart, 2002:6)

3.4.7 Pedagogical content knowledge

The concept of pedagogical concept knowledge (PCK) is introduced by Shulman (1987) to acknowledge the importance of the transformation of subject matter knowledge *per se* into subject matter knowledge *for teaching*. PCK is described as that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding. It encompasses teachers' knowledge of representations and instructional strategies in relation to

knowledge of student learning, both with respect to a specified content area (Van Driel, De Jong & Verloop, 2002:573).

With respect to the development of PCK, the following results from these studies seem relevant:

- Knowledge of subject matter. The development of PCK depends on teachers having a "deeply principled conceptual knowledge of the content." The subject matter knowledge they have acquired during disciplinary education usually contains misconceptions and deficiencies. During this program, the in-service teachers develop a more coherent and integrated subject matter structure.
- Teaching experience with respect to specific topics. The development of PCK among science teachers is promoted by constant use of subject matter knowledge in teaching situations. Initially, the science teachers separate subject matter knowledge from general pedagogical knowledge. As a result of teaching experiences, however, these types of knowledge are being integrated.
- Knowledge of students' conceptions and learning difficulties. By getting acquainted with the specific conceptions and ways students are reasoning, teachers may start restructuring their subject matter knowledge into a format that enables productive communication with their students. They may benefit from studying students' preconceptions with respect to a specific topic during a teacher education course, and compare and discuss these preconceptions in relation to their own conceptions. Such activities may stimulate teachers to generate transformations of subject matter knowledge and topic-specific teaching strategies.
- Participating in specific workshops. The PCK of in-service science teachers in intensive workshops on specific teaching strategies develops towards that of expert teachers (Van Driel *et al.*, 2002:574-575).

3.4.8 Social interactions

Social interactions are known to influence student attitudes towards science. The fact that attitudes can be influenced by the norms and goals of groups to which students belong, want to belong or hold in high regard provides the rationale for using social influence to improve attitudes towards science (Koballa, Jr. & Crawley, 1985:228).

Schooling can no longer function in isolation from the realities of present-day living. Schooling must begin to transpire in the context of the public sphere and experiences of learners. The traditions of school practice, dating back several centuries, must be questioned. A consensus has been reached that science learning is more than information absorption; students must be actively engaged in the process of learning so that they can apply their observations, knowledge and interpretations to the world around them. The process of learning and teaching then must reflect the dynamic, open-ended, aesthetic and investigative dimensions of science (Shymansky and Kyle, Jr. 1992:743).

3.4.8.1 Parents

Parental attitudes and beliefs regarding the importance of science in daily living may easily be translated by students into support or lack of concern for the study of science in school. A student who says "My Dad doesn't need to know about what's inside a cell nucleus to do his job," may perceive science and the science teacher to be somewhat threatening. Students who embrace such parental beliefs about science are those less likely to take science classes seriously and put forth much effort to learn. They may also become uninvolved or instigate considerable classroom disruption. In such cases, the apparent contradiction between parent and teacher beliefs must first be changed if student beliefs and attitudes are likely to improve. Perhaps during parent-teacher conferences parents could be encouraged to participate with their children as co-investigators in science activities to be performed at home (Koballa, Jr. & Crawley, 1985:228).

3.4.8.2 Peers

More influential than the attitudes of parents and teachers towards science are the attitudes held by peers (Koballa, Jr. and Crawley, 1985:229). Peer influence is of particular importance among adolescents. For example, if girls on the high school cheerleading squad believe science to be a masculine enterprise and intend to take no additional science courses beyond those required for graduation, it is likely that other female students who aspire to be cheerleaders will acquire similar beliefs and intentions. In fact, social psychologists have found that a majority can be influenced by as small a minority as two persons, if the minority is consistent in its actions and communications. Recognizing the influence that social leaders have

on other students, teachers should direct their effort towards the social leaders when attempting to change attitudes towards science. If they are not easily recognised, a sociogram, once prepared, may help provide the needed information. If social leaders can be convinced of the benefits that may be derived from studying science, their new attitudes towards science are likely to be passed on to peers who hold them, or the group to which they belong, in high esteem (Koballa, Jr. and Crawley, 1985:229-230).

3.4.9 Nature of science

Many teachers hold the view that science knowledge is unproblematic; science provides right answers; truths in science are discovered by observing and experimenting; and that choices between correct and incorrect interpretations of the world are based on commonsense responses to objective data. Teaching based on this traditional view of science attempts to transmit to learners' concepts that are precise and unambiguous, using language capable of transferring ideas from expert to novice (teacher student) with precision (Malcolm, 1994:57).

As influential as parents, teachers and peers are in changing student attitudes towards science, student attitudes are also affected by disagreement voiced about the cultural roles of science today and in the future. The attitudes held by some segments of society suggest that scientific investigation must be sharply curtailed if humankind is to survive. Curtailing scientific research and limiting the applications of science and technology have been proposed as a solution to this picture of doom. Students need also to be exposed to views of other segments of society, persons who envision that major scientific and technological advances will permit us to continue to make improvements in our technologically sophisticated way of life while making strides towards increased environmental quality. This view of science must be presented if students' attitudes towards science are to be improved.

Efforts to improve attitudes towards science through contact with significant others is the basis of Kurt Lewin's Group Dynamics approach to attitude change, where students are viewed as social beings in need of others. Furthermore, the influence of significant others on the formation of beliefs, attitudes and subsequent behaviours should not be ignored.

Social arrangements, situations in which people subconsciously, intuitively or deliberately perform for others, should be considered the major determinant of attitude change. This point of view may have serious implications for the selection of topics and role assignments in science classrooms (Koballa Jr., & Crawley, 1985:230).

Traditional science courses convince students that science is a collection of facts to be memorised rather than a set of principles warranted by evidence. They are convinced that science is best learned by memorisation, that science learned in school does not apply to everyday experiences, and that everything in the science book will always be true. Thus, current courses convince many students that understanding science will not benefit them now or in the future. Although it is not surprising that many students prefer memorising information to learning principles, the reasons for these views suggest that courses need to both teach students alternative forms of understanding and assess progress with measurements of this understanding (Linn, 1992:824-825).

3.5 Procedures for attitude exchange

For the most part, effort to improve attitudes by science educators have taken the form of learning science content, or of comparing innovative forms of teaching with a more traditional one. Recently, theoretical models derived from social psychology have been employed in science education. Although no option for improving science attitudes should be overlooked, basing the study of attitudes on a theoretical model derived from social psychology seems to be a fruitful option. Recognised by social psychologists are the following seven approaches to attitude change, with each approach subsuming numerous related theoretical models: the conditioning and modelling, message-learning, judgmental, and motivational, attribution, combinatory, and self-persuasion approaches (Koballa, Jr. 1989:2).

Problem-solving, persuasion, instruction, social exchange, motivation and academic interests will be discussed as means of attitude exchange.

3.5.1 Problem-solving

The first step is to identify students who hold negative attitudes (i.e., who dislike science and who do not feel confident to teach it). By definition, one cannot obtain a measurement of self-efficacy unless one uses a quantitative approach, so the accepted procedure is to select a high-quality instrument and administer it to the whole class of in-service teachers at the beginning of their methods course, and at its end. This approach can provide irrefutable evidence of improvement in self-efficacy. The class should be a homogeneous group of students. It should be noted that the quantitative technique does not specifically identify those students who initially held negative attitudes, nor does it attempt to track them from pre-test to post-test (Palmer, 2001:125).

The priority should therefore be to identify those who initially have negative attitudes, and attempt to implement procedures that will not only improve their attitudes but will actually convert them to positive ones. This qualitative change in attitude, from negative to positive, will be referred to as, "attitude exchange," in order to distinguish it from smaller, incremental changes in attitudes (Palmer, 2001:125).

The second step is to implement factors that cause attitude exchange. A number of authors have taken the important step of identifying specific course factors that are perceived positively by students. Most studies found that students are most comfortable with hands-on activities and group work, and preferred "enthusiastic, helpful, encouraging teachers who can make science fun and make difficult concepts easy to understand". Teachers who had a negative attitude towards science valued a supportive learning environment, freedom to ask questions, a constructivist approach, a slow pace of learning, hands-on activities and reinforcement (Palmer, 2001:125).

Shrigley (1976) (as stated by Palmer, 2001) found that third year education students value instructors who present practical activities in class, are experienced in classroom activities, who can teach both science content and methods, and who model teaching strategies similar to those proposed for children. In order to find whether factors such as these actually precipitate attitude exchange and if so, which ones are most important, it is necessary to identify students whose attitudes

have changed from negative to positive, and then to investigate what caused this change (Palmer, 2001:125).

3.5.2 Persuasion

Many strategies used to induce the occurrence of desirable science-related beliefs, attitudes and behaviours involve the use of persuasive messages. Science educators need to become acquainted with persuasion in the context of social influence and learning theory to be able to evaluate its usefulness in the science education milieu. Persuasion is the conscious attempt to bring about a jointly developed mental state common to both source and receiver through the use of symbolic cues (Koballa, Jr., 1992:63 and Wood, 2002), or "any change in attitudes that results from exposure to communication" (Petty & Cacioppo, 1986, as quoted by Koballa, Jr., 1989) and embodies many aspects of teaching.

This definition, following the lead of Larson (1986) and Trenholm (1989) (as indicated by Koballa, Jr. 1992:67), stresses the necessity of co-operation between source and receiver in the act of persuasion and projects the essence of the process by which new scientific ideas come to be accepted. At the heart of the persuasion process is the modification or formation of beliefs that are held with regard to evidence and good reasons. Persuasion is aimed at establishing certain beliefs so that they are held in conjunction with their foundation in argument and evidence. Central to the persuasion process is the concern that the message-recipient modifies his beliefs for reasons that he regards as good and sufficient, not simply that he modifies his beliefs. Persuasion is considered successful when a belief or attitude change is based on grounds that are considered convincing by the recipient (Koballa, Jr. 1992:70)

Persuasion is easily distinguished from indoctrination and brainwashing. Persuasion depicts a situation that is marked by the conscious intent of the source to persuade and in which both the source and receiver function as active agents in the persuasion process (Koballa, Jr. 1998 and Wood, 2000). The recipient of a persuasive appeal is always free to accept or reject it, but the same is not true for indoctrination and brainwashing. Like persuasion, indoctrination is concerned with the change and formation of beliefs; they differ, however, in that in persuasion the

emphasis is placed on the reasons for the belief as opposed to the content of the belief. Much of what children learn in school, public or private, is implanted by indoctrination (Koballa, Jr. 1989:3).

Petty, Ostrom and Brock (1981) (as quoted by Koballa, Jr., 1992:64), grouped the numerous models of persuasion into four major theoretical approaches: the learning approach, the consistency approach, the perceptual approach and the functional approach. The learning approach is the oldest and most thoroughly researched. In addition, it seems to be the most easily applied and often serves to facilitate research based on the other theoretical approaches. Therefore, science educators need to be acquainted with persuasion in the context of social influence and learning theory, in order to be able to evaluate its usefulness as a mechanism for developing and changing science-related attitudes (Koballa, Jr. 1992:64).

3.5.3 Instruction

Hovland and Janis (1959) (as indicated by Koballa, Jr., 1992:71) provided insight into the difference between persuasion and instruction. They wrote that "attention and comprehension determine what the message recipient will learn concerning the content of the communicator's message; other processes, involving changes in motivation, are assumed to determine whether or not he will accept or adopt what he learned. The effect of persuasive message is dependent on two factors: learning the message content and accepting what is learned. In line with this somewhat antiquated view, incentives, those promised or expected rewards, are necessary to insure adoption but not learning." (Koballa, Jr., 1992:71)

However, as currently conceived, persuasion and instruction appear to have a great deal in common. Both constructs involve communication, which includes

giving arguments and evidence for the purpose of getting someone to believe or do something. Furthermore, both have recently been influenced by the theoretical framework referred to as constructivism. That is, people respond to formal instruction and persuasion in terms of their pre-existing perspectives. Viewed from this position, both persuasion and instruction require conscious cognitive activity on the part of the recipient while engaged in a quest for understanding. Both persuasion and instruction are also concerned with the modification and formation

of beliefs that are held "evidentially". The purpose of instruction: "is to shape someone's belief or behaviour by helping him see that the belief is reasonable and the behaviour is justified" (Koballa, Jr., 1992:71-72).

3.5.4 Social exchange

Social exchange theory emphasises the interchange that takes place between the message source and message recipient in a persuasive context. The operation of social exchange is characteristic of a give-and-take situation wherein persuasion occurs when the source and receiver reach an agreement regarding the costs and benefits associated with a desirable attitude change (Koballa, Jr., 1992:74-75).

To date, the social exchange theory has not served as the theoretical base for studies in science education. Nonetheless, it suggests practices that should be considered when persuasion is intended. Bettinghaus (1973) (as indicated by Koballa, Jr., 1992:75) recommends that the persuader thoroughly study the immediate and long-term cost-benefit ratio of the desired attitude change for both the source and the receiver before delivering the message. The message should present the evidence to support the desired attitude and explain the costs of adopting the new attitude in terms of the imminent gains (Koballa, Jr., 1992:75).

3.5.5 Motivation

To understand motivation in behavioural psychology it is necessary to look a little more carefully at the stimulus-response mechanism. In the classroom the teacher reinforces 'good' behaviour and 'correct' responses with smiles and nods of encouragement or even a spoken "well done." This is designed to motivate school children to learn. The same expressions of congratulation please adults too. If one wishes to praise one's learners to encourage them to keep on trying to achieve the chosen goal, there is another part of the theory on reinforcement that will come in handy too. This is the effectiveness of intermittent reinforcement. If one always smiles and encourages every piece of good work, two things happen. First, it is difficult to appear genuine, and false praise is very off-putting. Secondly, learners get used to the reinforcement and if one sometimes forgets to do so, they stop trying and ask why one has changed one's behaviour. The secret is to give intermittent (and genuine) praise (Cotton, 1995:54-55).

Motivational factors are likely to influence the way in which students approach studying. The strategies they employ can in turn affect their comprehension and retention of this new material. Strategies that make use of the integration of new information with prior knowledge, for example, are thought to enhance comprehension and retention of knowledge because they increase depth of processing (Nolen & Haladyna, 1990).

3.5.6 Academic interests

Academic interests are often assumed to be important domain-specific intrinsic motivational determinants of academic achievement. Interests influence academic achievement and learning in school. In the present investigation, we therefore hypothesise that interest has no substantial effect on learning in lower secondary school, but that it later becomes an important predictor of course selection and learning in upper secondary school when students have more options. Most authors conceptualise interest as a person-object relation that is characterised by value commitment and positive emotional valences. Interest-driven actions involve personally valued objects or activities; they are accompanied by positive emotions and are self-intentional. Interest can pertain to objects in the physical or natural environment, to symbolic representations, or to activities. Individual interests are conceived as dispositions that are based on mental schemata associating the objects of interest with positive emotional experiences and the personal value system (Köller, Baumert & Schnabel, 2001:448-449).

During interest-driven actions, the latent disposition becomes the actualised interest (state). The experience of competence, personal control, feeling of autonomy, self-determination and a positive emotional state are characteristics of this action. Thus, interest usually serves as the independent variable and achievement as the dependent variable. In most studies, interest is treated as a dispositional variable. Schiefele (1996) (as quoted by Köller *et al.*, 2001:450) conducted experimental studies in which he investigated the role of interest in learning with texts. Interest emerged as a significant predictor of several achievement measures, even when controlling for important cognitive factors such as mental ability, prior knowledge and reading ability. Analyses presented by

several author support the assumption that achievement and/or self-perceived competence affect interest (Köller *et al.*, 2001:449-450).

Harter (1978:1982) (as indicated by Köller *et al.*, 2001:450-451) proposed that students feel intrinsically oriented in areas in which they perceive themselves to be competent. Support for this hypothesis was derived from evidence that students who experienced an increase in perceived competence following an educational transition showed gains in intrinsic motivation and school-related affect, whereas those who experienced a decrease in perceived competence showed losses in intrinsic motivation and school-related affect. Apart from the role that academic interest plays in learning, it is often considered to be an important determinant of course selection in high school (Köller *et al.*, 2001:450-451).

3.6 Conclusion

While establishing and strengthening certain science-related attitudes that have long been considered the responsibility of science educators, most of the science-related attitudes held by teachers and students are acquired incidentally rather than as a result of planned efforts. Three factors seem to be primarily responsible for this less-than-desirable state of affairs. First of all, all science educators have yet to reach a firm consensus regarding the kinds of attitudes that should be deliberately inculcated or modified. The major roadblock in such a plan involves agreement within the science education community regarding which attitudes should be stressed in science education programmes. A second factor that has contributed to the current state of affairs regarding science-related attitudes is that the strategies that can be employed to inculcate and modify attitudes are unknown to most science educators. The third factor that has contributed to the current state of affairs regarding science-related attitudes is that many science educators harbour a number of misconceptions regarding the process of persuasion (Koballa, Jr., 1992:76-77).

Further support for the use of persuasion in science education is its striking similarity to instruction. Both persuasion and instruction require conscious cognitive activity by the source and the receiver, and involve communication which includes giving arguments and evidence for the purpose of getting someone to do something or believe something (Koballa, Jr., 1992:77).

The next Chapter covers the following topics: learning theory, learning science, teaching science and understanding science.

CHAPTER 4

LEARNING AND TEACHING SCIENCE

4.1 Introduction

Science education is once again in the midst of reform. As of this writing, numerous publicly funded development projects, teacher preparation and enhancement programmes, as well as private foundation and business supported initiatives are underway. The reform efforts are bound by a common theme: to ensure a scientifically literate citizenry for the 21st century (Shymansky & Kyle, Jr., 1992:745). Although scientific literacy is by no means a new term, it has become established as one of today's slogans or rallying calls, along with the more recent 'authentic science', and is increasingly being used as a substitute term for the goals of science education. While scientific literacy seems to be almost universally welcomed as a desirable goal, Jenkins, 1990; Eisenhart *et al.* 1996; and Galbraith *et al.* 1997 (as quoted by Hodson, 1998:2) indicate that there is little clarity about its meaning. Pella *et al.* (1966) (as quoted by Hodson, 1998:2) suggested that it comprises an understanding of:

- the basic concepts of science;
- the nature of science;
- the ethics that control the scientist in his or her work;
- the interrelationships of science and society;
- the interrelationships of science and the humanities; and
- the differences between science and technology.

Becoming scientifically capable involves considerably more than the acquisition of scientific skills, knowledge and understanding. It involves the development of personal qualities and attitudes, the formulation of one's own view on a wide range of issues that have a scientific and/or technological dimension and the establishment of an underlying value position (Hodson, 1998:2-3).

If we really want scientific knowledge and understanding to be used for informed action, it must be taught and experienced, at least in part, in the contexts of use. That is, conducting scientific investigations, both inside and outside laboratories; and engaging in social and environmental action (Hodson, 1998:4).

There are some obvious ingredients that have to be present in order for any reform movement to have a measurable impact. These are adequate financial support, active involvement of scientists and educators, acceptance of the "final product" by science teachers and educating teachers in the use of the final products, whether they be curricular materials or instructional practice (Mestre, 1994:3).

Today we have available a large (and growing) body of research findings on learning and problem-solving in the sciences and mathematics. This body of research, generally termed "cognitive research," most of which has emerged over the last fifteen years, has important implications for learning and instruction. The focal concern of cognitive research is to understand the mental processes involved in the acquisition of knowledge, and in the use of the knowledge to solve complex problems (Mestre, 1994:4).

4.2 Theory of learning

Traditional theories (based largely on stimulus-response views of behaviour) have been superseded by newer theories based on cognitive psychology and concern for social, cultural and developmental factors. Traditionally, learning has been defined as a change in behaviour or performance resulting from experience and practice. Although a concern for change is still evident, the emphasis has shifted to the restructuring of knowledge and changes in understanding rather than changes in behaviour. "Problem-solving" rather than "memorisation" has become the prevailing metaphor (Shuell & Moran, 1994: 3340).

Over the years, various theoretical and philosophical differences regarding learning have existed, although some convergence of thinking has occurred. As understanding of learning evolved, several transitions can be identified. Behavioural theories of learning dominated the field prior to the 1960s, when the "cognitive revolution" began to influence thinking about human behaviour. Although cognitive psychology seldom focused on learning per se, it influenced the way psychologists thought about the acquisition of knowledge. During the 1980s, limitations of research in cognitive psychology (e.g., the use of laboratory rather than real-world tasks and a failure to consider non-cognitive factors such as motivation, interest and emotion) led to new and sometimes controversial theories,

such as situated cognition and cognitive apprenticeship (Shuell & Moran, 1994:3340).

4.3 Learning science

A goal of science education is that students acquire sound conceptual knowledge about the world and how it works. Students should acquire this knowledge through the formulation of relationships among ideas. The interrelated understandings students acquire should further allow them to create new ideas from what is already known (Cavallo & Schafer, 1994:393). However, many students tend not to learn meaningfully and thus may have difficulty relating what is taught to them in science with other scientific ideas and with their real-world experiences. Instead, much of their learning tends to involve memorisation of facts in which newly learned material is not related in ways that make sense to the learner (Novak, 1988) (as indicated by Cavallo & Schefer, 1994:394).

4.3.1 Meaningful learning

The difference in the way students approach learning determines whether learning is meaningful or rote learning (Chin & Brown, 2000: 109). Different researchers (Cavallo & Schafer, 1994; Chin & Brown, 2000) quote Ausubel (1963, 1968) who indicated that the formulation of "non-arbitrary relationships among ideas in the learner's mind" is meaningful learning. One major difference between meaningful learning and simpler forms of learning is that the former is usually concerned with understanding, while the latter is usually concerned with behavioural change (Shuell & Moran, 1994:3341).

For meaningful learning to take place, Ausubel (1963, 1968) and Novak (1988) (as quoted by Cavallo & Schafer, 1994; Chin & Brown, 2000) found that (a) the concepts to be presented to the learner must be potentially meaningful and hence must provide opportunity for the learner to form non-arbitrary relationships with existing conceptual frameworks (meaningful learning task) (b) the learner must have a conceptual framework to which the new concepts can be linked (relevant prior knowledge) and (c) the learner must manifest the meaningful learning set. To fulfil this last criterion, the learner must actively attempt to relate what is known to substantive aspects of new concepts.

In contrast, rote learning/simpler forms of learning are arbitrary, verbatim and not related to experience with events or objects, and lack affective commitment on the part of the learner to relate new with prior knowledge (Chin & Brown, 2000:109).

Learners must have the desire or tendency to make connections among concepts (Cavallo & Schafer, 1994:395). Another difference is that meaningful learning involves the acquisition of a complex body of knowledge, while simpler forms/rote learning typically involves a collection of separate and isolated facts. Meaningful learning is also more likely to extend over a prolonged period and to involve different phases of learning (Shuell & Moran, 1994:3341).

Shuell and Moran (1994:3341) defined meaningful learning of complex material as an active, constructive, cumulative, self-regulative and goal-oriented process. They identified the following five characteristics of meaningful learning that contribute to understanding of the concept:

a) Active

The learner must carry out various cognitive operations on the information being learned for it to be acquired in a meaningful manner.

b) Constructive

Knowledge is not an entity that can be passed intact from one person (teacher, book, etc) to another (the learner). Each learner perceives and interprets new information in a unique manner (based on factors such as prior knowledge, interest, motivation, attitude towards self, etc.), and then elaborates this information by relating it to existing knowledge and/or other aspects of the material being learned. Consequently no two students end up with exactly the same understanding of the concepts and facts being studied.

c) Cumulative

New learning builds upon the individual's prior knowledge and mental models, although prior knowledge can inhibit as well as facilitate new learning.

d) Self-regulative

As learning progresses, the learner must make decisions about what to do next (e.g., rehearse a particular piece of information, seek an answer to a question that comes to mind, look for similarities among various pieces of information). Effective learners also monitor the learning process, making periodic checks of how well the material is understood. The self-regulation of learning involves a number of factors, including meta-cognition, self-efficacy and studying (Shuell & Moran, 1994:3341-3342).

e) Goal-oriented

Meaningful learning is more likely to be successful if the learner has at least a general idea of the goal being pursued and holds appropriate expectations for achieving the desired understanding. Providing instructional objectives is one of many ways to establish goals, although in many instructional situations it is more appropriate for students to develop or discover goals independently (Shuell & Moran, 1994:3342).

4.3.2 Cognitive conceptions of meaningful learning

A cognitive view of learning is a general approach that views learning as an active mental process of acquiring, remembering and using knowledge. It occurs through multiple opportunities and diverse processes to connect to what is already known (Jacobs, Gawe & Vakalisa, 2002: 278). The learner interprets the information to be acquired and the task in which it is embedded and constructs a mental representation of the task and material based on these perceptions and relevant prior knowledge. As essential information is always missing from the physical stimulus, the learner adds information to make sense of the situation. Thus the learner's representation is unique and it may or may not be consistent with similar representations formed by other individuals. In fact, the learner's perceptions of the instructional situation and type of psychological processing in which the learner engages is the single most important factor in determining what the individual learns (Shuell, & Moran, 1994:3341).

Recent literature indicates that this tendency to formulate relationships is important, regardless of how learners acquire new concepts (Cavallo & Schafer, 1994:395). Knowledge is the outcome of learning. It is more than the end product

of previous learning; it also guides new learning. The cognitive approach suggests that one of the most important elements in the learning process is what the individual brings to the learning situation (Jacobs *et al.*, 2002:241).

4.4 Outcomes-based education

The historical account emphasises that outcomes-based education (OBE) did not emerge as a coherent and comprehensive curriculum reform in South Africa (neither did the SEDIBA Project). Its origins lie in a number of disparate influences, both internal and external; both historical and contemporary; both educational and economic. The fact that OBE has such different formative influences helps explain the conceptual confusion, even contradictions, underlying the meanings and relationships among key terms such as C2005, OBE and the NQF. This high degree of policy incoherence will clearly have critical consequences as the shift towards implementation begins to suggest lessons learned about the management of curriculum policy in transition and the relationship between policy and practice (Jansen, 1999:14).

Following the intentions imposed by the South African Qualifications Authority Act (the SAQA Act), a new ballgame was introduced with regard to curriculums, learning programme development processes, ways of providing education and training, as well as how learning occurs and how assessment takes place. One can say that the SAQA Act determines the form of the ball that is used during the game. If a cricket ball is created, the name of the game will be cricket and likewise only tennis can be played if a tennis ball is created. This implies that the appearance and structure of the ball determines the type of game that can be played. In the case of the SAQA Act, the ball that has been created will only allow the outcomes-based learning game to be played. The playing field must accordingly be set and rules and roles of the players, referees and spectators must be devised (Olivier, 2001:28).

Making the paradigm shift towards outcomes-based education and training means that new terminology and rules for learning are developed. The details of the new rules should be clarified and the roles of players and spectators ironed out. To be able to join the new game, one must make a paradigm shift from traditional learning towards outcomes-based learning. "Shifting the paradigm" really means

an alternative answer, or way of explaining solutions, to problems using the same, but slightly changed, concepts, approaches, constructs or methods. A real paradigm shift involves a new approach to a problem or set of circumstances, based on a totally new point of departure and coupled with new thinking constructs (Olivier, 2001:29).

When applied to outcomes-based education and training, a paradigm shift means that neither content-based, nor criteria-based, nor competency-based terminology, wording or approaches can directly be translated into the outcomes-based concept. The basis of this concept is that learning is based on achieving an end product and that learning takes place within the context of the outcome. What is learnt outcomes-based cannot be achieved by only reading books, doing assignments, completing worksheets, absorbing information as presented by teachers or trainers, or by mastering skills. Outcomes-based learning gives learners real-life experience when they achieve real outcomes. The outcomes-based learning approach focuses on knowledge, skills, values and competencies that are applied within a specific context in order to meet an outcome. When learners achieve these, it proves that they did participate in their own development and had the benefit of mastering methods, techniques and procedures related to real-life situations (Olivier, 2001:29-32).

4.5 Constructivism

Today there is a strong challenge to the information processing perspective – constructivism. Grounded in the work of Gestalt psychologists Piaget, Vygotsky, Bruner, Bartlett and Dewey, this general orientation emphasises the individual's construction of meaning. The focus is on meaning-making and knowledge construction, not memory for information. Many constructivist perspectives also consider the social context a major factor in determining what people come to know about themselves and the world (Jacobs *et al.*, 2002:279).

Perhaps the best way of appreciating the constructivist view of learning is to contrast it to its predecessor, the behaviourist view of learning. The behaviourist approach to teaching an individual some complex process consists of breaking up the process into components (parts), teaching the individual each component, and then teaching the individual how to string together the various components until

ultimately the desired behaviour is obtained (Mestre, 1994:5). Jacobs *et al.* (2002:279) view learning as the acquisition of facts, skills and concepts which occur through drill and guided practice. From the behaviourist perspective, the process has been learnt once the individual exhibits behaviour that displays competence (Mestre, 1994:5).

Conspicuously absent from the behaviourist approach are two things. The first is an interest in the cognitive mechanism used by the individual to learn the complex process. Recent cognitive research, in fact, suggests that a complex process cannot be learned by decomposing and teaching individuals sub-processes without regard to the context within which the complex process will be performed. Knowing how the sub-process interacts within the context of performing the entire process is as important as knowing how to perform the individual sub-processes. In short, knowing the individual sub-processes does not "add up to" knowing the entire complex process (Mestre, 1994:5).

Also absent from the behaviourist approach is an interest in whether or not the process learned made sense to the individual. This also would seem to be an important consideration because if the process learned conflicts with knowledge already possessed by the individual, then the individual either will not be able to accommodate in memory the process learned in any meaningful sense or will construct parallel, conflicting knowledge. To summarise, the focus of the behaviourist approach is the final manifestation of "competence" by the subject, not whether the knowledge learned made any sense to the subject, or whether the subject will be able to use the knowledge learned in novel contexts. Maybe the behaviourist approach might be better described as training rather than educating (Mestre, 1994:5-6).

4.5.1 The constructivist learning theory

Constructivist views of learning in science suggest that learners can only make sense of new situations in terms of their existing understanding (Keogh & Naylor, 1996:1). It takes the point of view that individuals actively construct the knowledge they possess (Mestre, 1994:6). This construction of knowledge is a life-long, effort-full process requiring significant mental engagement by the learner. Further, the knowledge that we already possess affects our ability to learn new knowledge.

If new knowledge that is to be learned conflicts with previously constructed knowledge, the new knowledge will not make sense to us and may be constructed in a way that is not useful for long-term recall or application in a variety of situations.

According to Novodvorsky (1997:243) there are five elements of a classroom environment that are indicative of students' constructing knowledge. They are:

- Students actively hypothesise, check and possibly change their ideas as they interact with phenomena.
- Students actively engage with others in attempts to understand and interpret phenomena.
- Students make personal sense of ways of viewing the world.
- Students are socialised into the practices of the scientific community.
- Students generate links between existing knowledge and new phenomena.

From these indications, the assumptions on which the constructivist approach to science teaching is based are evident. It is based on several assumptions.

The first assumption of the constructivist theory is that knowledge is constructed in the mind of the learner. This implies that the learning process involves the characteristics of the learner, his or her abilities, attitudes and perceptions of the world. The constructivist view takes into account learner differences. Every learner is unique, both in terms of abilities and perceptions of the world. The individual's perception of the world is constructed as a result of observations made of the surroundings and personal experiences with "the stuff of science" (Novodvorsky, 1997: 242).

This in turn leads to the formation of attitudes as explained in section 2.4. Thus in every individual's mind, there exists constructs of how the world operates. These constructs influence the way incoming knowledge is interpreted and understood. It is thus possible that the same set of information can be interpreted differently by different people. This point illustrates the critical role played by attitudes in learning. In terms of abilities, constructivism recognises the fact that it is impracticable to expect learners to achieve success at the same rate. It recognises the fact that the individual's attitudes towards certain topics influence his/her learning. These attitudes are guided by beliefs, value systems and prior

knowledge possessed by individuals. In this regard, learning takes place best when learners feel good about the learning task and have positive attitudes towards it. For this to be achieved, learners must be led to realise the significance of the learning task and its relevance to their everyday lives.

The second assumption of the constructivist theory is that students bring along with them some prior knowledge about science upon entering science classrooms. The constructivist theory asserts that the prior knowledge of the child has a direct impact on his learning and should not be ignored. The assumption that students' minds are like empty vessels waiting to be filled with knowledge is in total contrast to the constructivist view of learning (Novodvorsky, 1997: 242).

The third assumption of the constructivist learning theory is that learning is a lifelong process and is not confined to a specific period in the life of individuals. It is a continuous process and does not take place in stages. Learning can take place anywhere, both inside and outside the science classroom. The traditional way of looking at learning is that learning takes place only when information is presented to the learner by the teacher in the classroom situation, or when the learner obtains information from textbooks. Whatever the information acquired by individuals prior to and after formal instruction, it is not recognised by the traditional model of learning (Driver, Guesne & Tiberghien, 1985:9)

4.5.2 Constructivist teaching

Du Toit *et al.* (1991), indicated a number of articles and research reports which were published during the last decade concerning the problems of science teaching and, more specifically, of teaching chemistry in the Republic of South Africa. The following problem areas were identified: poorly and under-qualified science teachers; problems concerning science syllabi; poor motivation and high failure rates at university of chemistry students; a drop in the number of students graduating in chemistry and physics; and a wide variety of problems concerning the salaries of scientists (Du Toit *et al.*, 1991:49).

Novodvorsky (1997:242-243) identified nine components describing the teacher's role in guiding the students' construction of knowledge. They are as follows:

a) *Structure learning around primary concepts.*

The teacher starts with the "big picture" in selecting concepts on which students will focus. The teacher also guides students in reducing complexity and breaking concepts into manageable chunks. This is in contrast to the teacher presenting a series of disconnected facts or formulas with the expectation that students will build their own big picture.

b) *Ask about students' existing knowledge before sharing your own or the textbook's knowledge to guide lessons and units.* The teacher leads brainstorming sessions (without contributing ideas) and uses the students' ideas to set the direction of activity. The teacher may ask leading questions or make suggestions about the direction of an activity if necessary. This is in contrast to the teacher's not asking about students' previous knowledge and presenting the textbook or lecture as the sole source of information.

c) *Guide students in generating their own hypotheses and alternative interpretations.* The teacher guides students in generating explanations and interpretations without contributing ideas. This is in contrast to the teacher's providing the hypotheses or interpretations for students to verify.

d) *Use responding questions and encourage students to elaborate on their questions and responses.* With responding questions, the teacher routinely asks questions based on students' responses and asks them to expand on their questions and justify their responses. The most common question is, "How do you know?" This is in contrast to the teacher's stopping at the students' initial responses and asking them to explain their ideas.

e) *Provide materials and opportunities for students to test ideas.* The teacher provides a wide variety of materials and multiple opportunities for students to work with the materials. The teacher provides minimal help when asked. This is in contrast to the teacher's providing step-by-step instructions for students' work.

f) *Allow time for students to construct relationships among concepts.* The teacher uses time flexibly, allowing virtually all students the time needed to answer their questions and construct relationships among concepts. This is in contrast to

the teacher's maintaining a rigid schedule where only the quickest students have time to construct relationships.

g) *Focus the students' attention on misconceptions or contradictions within their predictions.* The teacher asks students to explain any contradictions within their predictions or among various groups' results. The teacher may ask leading questions to focus students on contradictions. This is in contrast to the teacher's explaining away any misconceptions or dismissing contradictions.

h) *Provide an atmosphere conducive to small-group interaction.* The teacher applies the principles of co-operative learning to small-group interaction. This is in contrast to having students work individually with little or no interaction.

i) *Use high-level, embedded assessment.* The teacher embeds assessment within tasks and assesses both the scientific process and the final product. This is in contrast to assessing students with instruments different from their classroom work and on knowledge recall.

4.6 Visualization

Students have many problems understanding dynamic three-dimensional processes. A glance at any general chemistry textbook shows a multiplicity of representations used in different contexts with no correlation between representations, or no reason why one was chosen. Some students can switch contexts easily; but most do not integrate the knowledge or extract from representations the ideas the experts see in them. While experts use different models and switch easily between them when solving problems, students tend to believe the representation as a complete model of the concept.

The problem of teaching fundamental concepts of chemistry centres on the conceptual understanding of the chemical process at a sub-microscopic level. When a chemical reaction takes place macroscopically, students can observe and explain the nature of the reaction. However, most students in chemistry classes are unable to describe and illustrate what is happening in a chemical reaction at sub-atomic level, i.e. in terms of atoms and molecules. Neither can they visualise

and form their own images of the interactions in atomic bonding in a given chemical process (Dolo, 2000:14).

Linus Pauling (as quoted by Shusterman & Shusterman, 1997:771) once said that a topic must satisfy two criteria before it can be taught to students. First, students must be able to assimilate the topic within a reasonable amount of time. Secondly, the topic must be relevant to the educational needs and interests of the students. Unfortunately (according to Shusterman & Shusterman), the standard general chemistry textbook presentation of "electronic structure theory", set as it is in the language of molecular orbitals, has a difficult time satisfying either criterion. Many of the quantum-mechanical aspects of molecular orbitals are difficult for most beginning students to appreciate, much less master, and the few applications that are presented in the typical textbook are too limited in scope to excite much student interest (Shusterman & Shusterman, 1997:771).

The ability to represent matter at a microscopic level is important in explaining phenomena and chemical reactions or changes fundamental to the nature of chemistry. However, the traditional and conventional representation of orbitals as distribution functions are also abstract to students and are sometimes inaccurately simplified by most chemistry instructors (Dolo, 2000:15). Students always have difficulty in visualizing the true nature and reality of concepts such as atoms, molecules, orbitals, electron clouds, etc. This shortcoming could be due to students' inability to differentiate between concepts such as solids, liquids, gases, elements, compounds, substances, mixtures, solutions, etc. and the lack of instruction in which these terms are related to the particular structure of matter (Dolo, 2000:15).

Although most students in the chemistry class could state the definition of a chemical reaction and balance chemical equations correctly, they were still confused about chemical change. Especially concepts about chemical change that occurs in real-life situations indicated that this pattern of confusion about chemical change among students who have successfully learned about balancing chemical equations is a common one (Hesse & Anderson, 1992:278). Therefore, to understand chemistry, a connection must be made between the concrete world of macroscopic, visible phenomena and the abstract world of atoms and molecules.

There are different ways in which visualisation can be promoted. For the sake of this study, the focus will be on the:

- The use of models
- Multimedia
- Laboratory practical work
- The lecture method

4.6.1 Models

Models are constructions of the human mind and are temporary by nature. They are not pictures of the underlying reality but are representations of real entities (Smit, 1995:622). In order to understand what models are, Table 6.2 shows example of models as classified by Gilbert (1991).

Table 4.1: Example of models in nominal classifications

Data bases	Data tables, diagram, pictures, figures, drawings, maps, graphs, tracings, recordings.
Representational	Concrete replicas, scale models, copies, examples, samples, demonstrations, prototypes
Analogue	Analogical images, concrete analogues, medical laboratory animals
Simulation	Computer simulations, games, role playing, mock-ups, artificial tornados, artificial earthquakes
Procedural	Directions, systems of rules, executive systems, schemata, archetypes, guidelines, matrices
Conceptual/theoretical	Verbal and written descriptions, mathematical formulae, ideals, standards, predictions, concept network, reports

The importance of models in science teaching has been well established. Knowledge of reality is acquired in terms of models. Wittgenstein (1963) (as indicated by Smit, 1995:621) states that, starting with facts, the human mind constructs images. These images are models of reality. In contemporary science education theory, models feature prominently. Constructivist teachers (refer to paragraph 4.5) first identify learners' naïve conceptions or personal model, and they aim their teaching at establishing the scientific model in the learner's mind (Maloney 1984, Driver *et al.* 1985, Driver 1988, as referred to in Smit, 1995:621).

Students do have their own sets of theories and beliefs about the nature of matter and the functions of explanations, and those beliefs may lead them to understand and explain chemical change in quite different ways. Thus, learning about the nature of chemical change is not just a matter of learning a few facts and rules. Instead, it is a complex process of conceptual change involving many aspects of the students' conceptual ecologies (Hesse & Anderson, 1992:278). It is obvious that any teaching strategy requires of the teacher a sound knowledge of the origin, nature and functions of scientific models (Smit, 1995:621).

As science can be defined as a process of constructing predictive conceptual models, this definition unites both the processes and product of science and identifies model building as a super-ordinate process skill. Therefore, models that need to be produced must represent consistent, predictive relationship. These models are representations of "target" systems existing in the ambient world. They are the systems of words, numbers, pictures, programmes, actions and concrete images that constitute scientific communications (Gilbert, 1991:73).

Models fulfil a key function in human thinking processes and in the learning of science. Harré (1970) (as quoted by Smit, 1995:633) states that there are only two carriers (vehicles) of scientific thought: iconic models and sentences (language). Although not all iconic models occur in scientific models, scientific models are central and play a vital role in scientific thinking. A sound knowledge of the nature and functions of scientific models will, for this reason, certainly contribute to a better understanding of concepts of chemistry (Smit, 1995:633).

4.6.2 Multimedia

Multimedia instruction refers to the application of the computer as a tutorial tool in instruction. The computer as a tool for multimedia instruction gives the teacher and the learner new ways to organise, store, retrieve and transform information. Although multimedia technology is a relatively new concept of utmost importance in education today, it is also a concept that is still developing and that is difficult to bring into focus (Dolo, 2000:21).

Advances in computer hardware, scientific visualisation and computational methods of visualisation have enabled multiple conceptual and visual representations of atomic and molecular concepts. Much of science is sub-microscopic. It is difficult for students to see the connection between the sub-microscopic world of atoms, ions and molecules and the macroscopic properties of matter. Computational research in the sciences made very effective use of available computing resources in simulating the behaviour of complex systems. Routine use of these simulations is possible because of the development of interactive (i.e., real-time, individually controlled) visualisations in three dimensions. The coupling of simulations with visualisation presents scientists with a powerful description that matches the three-dimensional dynamic nature of their field. Now more than ever before, computational science tools are being placed in the context of science education tools (Trunfio, Berenfeld, Kreikemeier, Moran & Moodley, 2003)

In order to enhance visualisation in chemistry, Paselk (1994:225), has developed a series of software programs under the title: "*Visualization of the abstract in chemistry*", for beginning chemistry. The goals of Paselk's work include:

- ❖ A series of modules addressing the fundamental phenomena associated with bonding, including the electronic structures of atoms and molecules,
- ❖ A second series of programs looking at the microscopic phenomena underlying commonly observed system and,
- ❖ A reference periodic table.

Paselk's approach to bonding begins with atomic orbitals. This is followed by a study of Lewis structures, VSEPR theory and a look at quantum models of bonding, including orbitals, hybridisation and molecular orbitals. At the heart of the programs involving orbital models is a set of rigorously calculated visualisations created with the latest computational chemistry programs. The operation of these programs results in a manipulative 3-D object appearing on the screen on which the proper atoms may be placed. The resulting molecule may now be rotated in three dimensions for thorough observation, and finally a molecular geometry may be named and entered. At all stages in the process feedback is provided by sound effects and messages, including hints when errors are made (Paselk, 1994:225).

Shusterman and Shusterman (1997) also developed computer-generated three-dimensional models of electron density distributions, which largely satisfy Pauling's two criteria. According to Shusterman and Shusterman, (1997), students found electron density models easy to understand and use, and because these models are easily applied to a broad range of topics, they successfully convey to students the importance of electronic structure. In addition, when students finally learn about orbital concepts they are better prepared because they already have a well-developed three-dimensional picture of electronic structure to fall back on. Students who understand and use electron density models do not need to "unlearn" anything before progressing to more advanced theories. From this point onward they can examine and describe the electronic structure of atoms, molecules, reactive intermediates and even reaction transition states in a simple, uniform way, and a vast range of chemical information and reasoning is opened up to them (Shusterman & Shusterman, 1997:771).

Computer-graphics representations are used to show students different ways of seeing diagrams. But, according to Smith and Jones (1989) (as quoted by Trunfio *et al.*, 2003) students develop intuition by doing, not by seeing, and this is precisely what the new technologies allow us to consider. The use of molecular visualization, a scientific technique perfected in recent years, programs the actual structure and motion of atoms and molecules based on the laws that govern their motion. Thus the students can actually see, in real time, the microscopic behaviour and, in some cases, using split-screen software programs, can simultaneously see the corresponding macroscopic behaviour. By changing the condition of the system (e.g. temperature), students can better understand how both sub-microscopic and macroscopic properties depend on conditions. These materials can be used across a continuum of intellectual depth, from the demonstration of qualitative concepts to a fully fledged tool of exploration and self-discovery, and they can be used to teach a wide range of topics (Trunfio *et al.*, 2003).

4.6.3 Laboratory practical work

Currently, most practical work in school science is referred to as laboratory-based experiences. Hodson (1996:756) proposed that practical work in science education involves three associated purposes:

- (1) To help students learn science (acquiring conceptual and theoretical knowledge);
- (2) To help students learn about science (developing and understanding of the nature and methods of science); and
- (3) To enable students to do science (engaging in expertise in scientific inquiry).

According to the interview results derived from Tsai's (1999) study, constructivist students conceptualise properly the purposes of practical work in laboratory activities. For example, constructivist students believe that laboratory experiences help them understand the scientific concepts involved in a richer or more concrete manner (the first purpose), understand the processes of science and where scientific knowledge came from (second purpose), and understand how scientists do/did science (the third purpose) (Tsai, 1999:671).

Achieving comprehension of laboratory activities and proficiency in laboratory skills often proves to be difficult for students. Dechsri, Jones & Heikkinen, (1997) quote Johnstone (1991), suggesting that these difficulties are related to the limitations of students' working memory, the active system of memory in which information is assembled and organised prior to recall. Ellis and Hunt (1989) (as in Dechsri *et al*/ 1997:891) indicate that limitations of working memory determine how many items can be stored and rehearsed before they are lost owing to competition from new information. In the laboratory concepts are not only learned and applied, but new skills, equipment and terminology are encountered that must be learned and acted upon within a limited time period (Dechsri *et al.*, 1997:891).

The acquisition of knowledge of science can be justified as illumination of phenomena, the construction of a coherent system of explanations of natural events, and the appreciation of a lengthy and intensive human enterprise to make sense of the universe. This implies that knowledge will involve understanding and valuing of the facts and explanations of science, and commitment to them. The core purpose of laboratories is to assist learning persons with a deep understanding of those facts and explanations (White, 1996:763).

Experience in a laboratory adds meaning to a student's knowledge of a concept. Many learning theorists have proposed that meaning involves the learner in perceiving links between the items of knowledge about a concept that he or she

possesses. Gagne and White (1978) (as quoted by White, 1996:763) described five sorts of knowledge: propositions, images, episodes, intellectual skills and motor skills. Later, White (1988) added two more: strings and cognitive strategies. For the sake of this study, only episodes will be discussed. Episodes are recollections of events in which the person took part, or at least observed. We cannot recall everything we experience, at least in part, because repetitions of the same event cause blurring of specific details. Engagement is what gives student laboratory-work an advantage over demonstrations by the teacher. If episodes are to have a long-term effect on understanding, they must be memorable and must be associated by the learner with the knowledge they support. It would, of course, be difficult to have every laboratory experience so distinctive, so surprising, engaging or dramatic, that each led to a singular, memorable episode (White, 1996:763-766). Success of school science experiments reinforces the illusion of certain knowledge in science (White, 1996:768 & Tsai, 1999:671).

Learning science, learning about science and doing science are also closely related. Students can learn some science and learn more about science by doing some well-designed scientific investigations under the watchful eye of a professional. In any scientific inquiry, students achieve three kinds of learning. First, enhanced conceptual understanding of whatever is being studied or investigated. Secondly, enhanced procedural knowledge, i.e., learning more about experiments and co-relational studies, and acquiring a more sophisticated understanding of observation, experiment and theory. Third, enhanced investigative expertise. Providing opportunities for students to report and debate their findings, and supporting them in reflecting critically on personal progress made during the inquiry, are key elements in achieving this integrative understanding (Hodson, 1996:757).

Procedural understanding, ideas about acceptable laboratory practice, perceptions of the purpose of the investigative task and the physical and temporal constraints of their situation will influence the investigative behaviour of any group of students. What is of particular interest are the changes in investigative procedures noted and the extent to which these are subsequently reflected in students' reports (Campbell, Kuanda, Allie, Buffler & Lubbe, 2000:848).

In conclusion, White (1996) quotes Gardner and Gauld, emphasizing that: *"Merely being in the laboratory and doing lab-work there do not, by themselves, foster scientific attitude: it is the quality of the experience that students have there that is critical"*.

4.6.4 Lecture method

Lecturing is one of the most frequently used methods of teaching science in secondary and tertiary institutions. Out of the number of definitions of the concept "lecturing" Brown and Race (2002) got from different people, only two will be used for this study:

1. "Lecturing is a traditional form of teaching with the primary objective of imparting knowledge to learners about a particular topic. In this respect it is not very effective, though it remains pretty well the ubiquitous strategy in post-secondary education for supplying learners with knowledge and is sufficiently institutionalised to be expected. Effective lecturing recognises the limitations of this medium and augments the knowledge-supply function with learning texts (e.g., lecture notes and handouts). It focuses, instead, on those aspects of teaching that can only be delivered face-to-face: inspiring and motivating, making a subject "come alive" and using performance skills to engage with the subject matter and explain it".

2. "Theoretically it's about passing on information and knowledge to learners to equip them to meet the learning outcomes. In practice, it's about doing that and developing a questioning and inquiring mind, through scenario, role play, questioning the status quo, analysis and interpretation, considering bias issues, and so on".

Gibbs (1998b) (as quoted by Brown & Race, 2002) quotes Marris arguing: "The essential function of lectures is to place knowledge in a meaningful context. By his synthesis of different points of view, or textbook treatment; by his emphasis on essentials, and the extrapolation of basic principles; by the clarity with which he relates the parts of his exposition, a lecturer can enable the student to perceive the subject coherently. But, perhaps even more usefully, he can provide a more personal context, showing why the subject interests and excites him, how he has

used it in his own experience, how it relates to problems whose importance his audience already understands. From this, the student can more easily imagine how he himself could use it: he develops his own context of motives for mastering a problem" (Brown & Race, 2002:48-49).

Brown & Race (2002:49) give the principal reasons for lecturing as indicated by Bligh (2000a). They are:

- ❖ To aid memory during the lecture;
- ❖ To aid revision;
- ❖ To see the developing structure of a topic;
- ❖ To relate and reorganise during further study;
- ❖ To select what is important;
- ❖ To know what has to be learnt; and
- ❖ To maintain attention.

Reasons for the use of lecturing may be summarised as follows (Brown & Race, 2002:49-60):

- ◆ So that we can enthuse our students;
- ◆ To give the students the information they need;
- ◆ To cover the syllabus;
- ◆ To help students gain a sense of identity;
- ◆ Because it is a cost-effective means of curriculum delivery;
- ◆ As a means of accounting for class contact time, i.e. to quantify it;
- ◆ To keep track of the students;
- ◆ Because we like giving lectures!;
- ◆ To help students map the curriculum;
- ◆ So that students can estimate how they are doing;
- ◆ So that the lecturer can estimate how students are doing;
- ◆ So that students' feelings and attitudes can be changed or developed;
- ◆ To help students learn how to turn information into knowledge;
- ◆ To help students learn how to learn; and
- ◆ To help students tune in to our culture of assessment.

For instruction to be effective, it must encourage the kind of learning that leads to conceptual understanding. Such learning occurs when knowledge is constructed by the individual. The goal of teaching should be to structure classroom interaction to facilitate students' developing conceptions for themselves. They can construct conceptions if they experience situations that bring them to question their own conceptions and are then facilitated to develop what are for them more viable replacements (see paragraph 4.5). Instructors are thus faced not with getting students to construct new knowledge, but with getting them to construct this knowledge in the face of strongly held beliefs. In order to address that we need to identify general teaching strategies which induce students to make changes in their beliefs about how the world works (Dykstra *et al*, 1992:616).

Of all the strategies that one can employ to help learners construct their own knowledge, the most important and helpful is a conceptual map. Conceptual maps enable us to give explicit specifications of the elements and relationships associated with conceptual change in a highly organised and precise way. In particular, it enables us to make the difference between "concepts" and "conceptions" more explicit: the nodes in the network represent what we have been calling *concepts* (e.g. "force") while *conceptions*, expressible as propositions (e.g. "motion *implies* force"), are combinations of concepts related by explicit links (Dykstra *et al*., 1992; Novak, 2002; and Pendley, Richard, & Novak, 1994).

4.7 Understanding

Knowledge, skill and understanding are the stock in trade of education (Blythe *et al*., 1998:1). They have traditionally been the mainstay of education. We want students to be knowledgeable about history, science, geography and so on. We want students to be skilful in the routines of arithmetic, the crafts of writing, the use of foreign languages. Achieving this is not easy, but we work hard at it (Perkins, 1993:24). Most teachers show a vigorous commitment to all three. Everyone wants students to emerge from schooling or learning experiences with a good repertoire of knowledge, well-developed skills and understanding of the meaning, significance and use of what they have studied (Blythe *et al*., 1998:1).

Knowledge and skill in students do not guarantee understanding. People can acquire knowledge and routine skills without understanding their basis or when to

use them. And, by and large, knowledge and skills that are not understood do students little good (Perkins, 1993:23)! In the long term, education must aim for active use of knowledge and skills. Students gather knowledge and skills in school so that they can put them to work, in professional roles – scientist, engineer, designer, doctor, businessperson, writer artist and musician – that require appreciation, understanding and judgement. In short, we must teach for understanding in order to realise the long-term payoffs of education (Perkins, 1993:23).

4.7.1 What understanding is?

At the heart of teaching for understanding lies a very basic question: What understanding is? To draw a comparison, we all have a reasonable conception of what knowing is. When a student knows something, the student can bring it forth at will, i.e. tell us the knowledge or demonstrate the skill. But understanding something is a more subtle matter. A student might be able to regurgitate reams of facts and demonstrate a routine skill with very little understanding. Somehow understanding goes beyond knowing (Perkins, 1993: 23-24).

In a phrase, understanding is the ability to think and act flexibly with what one knows. To put it another way, the understanding of a topic is a "flexible performance capability", with emphasis on the "flexible". In keeping with this, learning for understanding is like learning a flexible performance. It shows its face when people can think and act flexibly around what they know. In contrast, when a learner cannot go beyond rote and routine thought and action, this signals a lack of understanding (Blythe *et al.*, 1998).

Understanding a topic of study is a matter of being able to perform in a variety of thought-demanding ways with the topic, for instance to explain, muster evidence, find examples, generalise, apply concepts, analogise, represent in a new way, and so on. The more thought-demanding performances the student can display, the more confident we would be that the student understands. In summary, understanding something is a matter of being able to carry out a variety of "performances" concerning the topic – performances like making predictions about the snowball fight in space that show one's understanding and, at the same time, advance it by encompassing new situations. We call such performances

"understanding performances" or "performances of understanding" (Perkins, 1993:24-25).

4.7.2 Learning for understanding

If understanding a topic means building up performances of understanding around that topic, the mainstay of learning for understanding must be actual engagement in those performances. The learners must spend the larger part of their time with activities that ask them to generalise, find new examples, carry out applications, and work through other understanding performances. And they must do so in a thoughtful way, with appropriate feedback to help them perform better.

Learning for understanding requires not just taking in what you hear, it requires thinking in a number of ways about and with what you heard – practising and debugging your thinking until you can make the right connections flexibly. In summary, typical classrooms do not give a sufficient presence to thoughtful engagement in understanding performances. To get the understanding we want, we need to put understanding up front. And that means putting thoughtful engagement in performances of understanding up front (Perkins, 1993:26-29)!

4.7.3 Teaching for understanding

Teaching for understanding is not simply another way of teaching, just as manageable as the usual lecture-exercise-test method. It involves genuinely more intricate classroom choreography. To elaborate (Perkins; 1993:26-29), here are six priorities for teachers who teach for understanding:

- i) *Make learning a long-term, thinking-centred process.* Teaching is less about what the teacher does than about what the teacher gets the students to do. The teacher must arrange for the students to think with and about the ideas they are learning for an extended period of time, so that they can learn their way around a topic
- ii) *Provide for rich ongoing assessment.* Students need criteria, feedback and opportunities for reflection in order to learn performances of understanding well. These are important functions that need to be honoured in many contexts. To learn

effectively, students need criteria, feedback and opportunities for reflection from the beginning of any sequence of instruction.

iii) *Support learning with powerful representations.* The teacher teaching for understanding needs to add more imagistic, intuitive and evocative representations to support students' understanding performances. Besides supplying powerful representations, teachers can often ask students to construct their own representations, an understanding performance in itself.

iv) *Pay heed to developmental factors.* The picture of intellectual development emerging today is less constrained, more nuanced and ultimately more optimistic regarding the prospects of education. Teachers teaching for understanding do well to bear in mind factors like complexity, but without rigid conceptions of what students can and cannot learn at certain ages.

v) *Induct students into the discipline.* Analyses of understanding emphasise that concepts and principles in a discipline are not understood in isolation. Grasping what a concept or principle means depends in considerable part on recognising how it functions within the discipline. And this in turn requires developing a sense of how the discipline works as a system of thought. For example, all disciplines have ways of testing claims and mustering proof - but the way that's done is often quite different from discipline to discipline. In science, experiments can be conducted, but in history evidence must be mined from historical record.

vi) *Teach for transfer.* Teaching for transfer is an agenda closely allied to teaching for understanding. Indeed, understanding performance virtually by definition requires a modicum of transfer, because it asks the learner to go beyond the information given, tackling some task of justification, explanation, example-finding or the like that reaches further than anything in the textbook or lecture. Moreover, many understanding performances transcend the boundaries of the topic, the discipline, or the classroom. Teachers teaching for a full and rich understanding need to include understanding performances that reach well beyond the obvious and conventional boundaries of the topic (Perkins, 1993:26-29).

4.8 Conclusion

Looking back at the historical development of the teaching of science, one realises that science teaching has always been an ever-changing educational exercise. As more and more findings in the field of the learning psychology are made, one can expect that the changes in the teaching strategies of science will continue. The ultimate objective with all these changes is to improve and to make the learning of science more effective. A question that one needs to ask is "can we at any stage arrive at an ideal teaching approach that will be completely suited to the learning patterns of all children and address all their learning problems?" The answer to this question is that the ideal teaching approach is in all practical terms not attainable. The fact is that there are teaching strategies which are better than others. However, attempts are always geared towards attaining the best possible teaching strategy. The effectiveness of any teaching strategy is not only dependent on its compatibility with the learning patterns of the child, but also on the relevance of the strategy to the times, social needs and practicality of the approach (Wesi, 1997:63).

The decision, on which teaching strategy is best, depends on the time in history during which the teaching approach is to be implemented. Its relevance also depends on the needs of the society and the objectives of science teaching as currently designed by the science and education community. It must also be noted that some teaching strategies can work effectively in one situation and yield poor results in another situation. For a teaching strategy to be effective, it must also be relevant to the situation in which it is to be implemented. Several logistic problems such as classroom sizes and teacher-pupil ratios may affect the effectiveness of some teaching strategies (Wesi, 1997:63-64).

Most important, we need to ensure that the method of fostering students' learning is "fit-for-purpose" in that it is based on a clearly thought-through rationale, that it is undertaken effectively, in a way that is appropriate for the context and the student cohort and that, in the jargon, it does what it says on the tin (Brown & Race, 2002:61)!

The next Chapter (Chapter 5) deals with educator development. In this chapter, distance learning education and in-service training of educators are discussed with

the aim of bringing to surface the difference between the two means of upgrading.
The assessment of lecturers and the procedure for doing so will also be discussed.

CHAPTER 5

TEACHER DEVELOPMENT

5.1 Introduction

Many developing countries are understandably in a great hurry to catch up and leapfrog into the industrial/technological era. Science education receives high priority as science and technology are considered keys to industrial/technological development. For these reasons many countries have carried out or are in the process of executing large, expensive, nation-wide educator education projects in science (Van den Berg, 1996:3).

5.2 Teacher development

Educators are spread across a continuum which ranges from poorly trained educators who do not sufficiently master the subject matter in the school curriculum, to professional educators with good mastery of subject matter as well as mastery of pedagogy and methods of teaching and learning science. Van den Berg (1996) quotes Bybee (1966) who conceptualised educational development as a four-stage growth process, moving from unskilled, to mechanical, routine and professional phases. Unskilled educators are those who do not sufficiently master the school subject they teach. They may be educators from other subjects who are forced to teach science or they may be people who entered the system at the times of great shortages of science educators. Mechanical educators may master the school subject matter, but may use just one dominant teaching method, which is used mechanically. The routine educator does have proper subject matter mastery, also beyond the school curriculum and mastery of a repertoire of teaching methods. However, the routine educator is not yet or not anymore in the professional phase in which educators continuously develop their repertoire of teaching methods, examples and background knowledge, or has regressed to using only a narrow band of teaching methods (Van den Berg, 1996:3-4).

In many developing countries, unskilled educators are still quite common. Schools still adhere to a large extent to a traditional way of teaching by preferentially imparting content knowledge to the pupils and emphasising comparatively less the

acquisition of "key skills" such as capabilities for problem solving, team work, design and construction, and independent investigation. For science education the issue of quality and quality assurance becomes important, especially for schools with a focus other than science. Other educators develop a view of their subject as a collection of truths to be transferred to the pupils and not as an area where knowledge is to be constructed by everyone individually from all available experiences and sources (Kühnelt *et al.*, 1997:425).

The professional growth of educators and administrators is a vital element in any formula for improving public education. The conception of new theory, the initiation of experimental research, developmental research, the development of new teaching materials and the improvement of instructional methodologies are useless if their benefits are not incorporated into classroom procedures. Consequently, it is appropriate to review, from time to time, ongoing events to search for clues that will enhance the professional expertise of practitioners. Professional development is an exceedingly complex phenomenon that can be approached from many different angles (Rubin, 1978:ix). That is, by means of distance education, in-service training, or full-time on-campus programmes.

5.3 Distance education

So-called "first generation" distance education saw the emergence of "correspondence colleges" and "correspondence education" where learning was restricted and confined to content-driven study guides, assignments and pen-and-paper examinations. Creative work was restricted and success often depended on the ability of the learner to memorise content and to record the mastery of such information in an examination (Fraser & Lombard, 2002:87).

To begin with, it is worth considering what, if any, the differences are between distance learning and open learning, given that the two terms are used on an interchangeable basis. Indeed, for much of this dissertation, little distinction is made between the two forms of learning, but sometimes it is instructive to remember that they are not quite the same thing (Monk, 2001:53-54). Monk (2001) used the following definitions offered by the UK's Employment Department for the two terms:

Distance learning is where tutor and student are separated in space and, in most cases, in time. In order to achieve this, the content of the courses needs to be packaged in some form. How this is done will depend on a number of factors. In most cases, the package is text-based, but it can include video, audio-tapes and computer assisted learning (CAL). When there is no time difference, simply a physical distances, then IT (Information Technology) systems are the most appropriate.

Open learning is a much more general term. It is very similar to flexible learning and can apply to a whole range of systems that allow the student choice as to the pace, place and time of learning. It can encompass anything from drop-in centres to stand alone multimedia systems to facilitate independent study. However, most of them require a package in order to provide the flexibility. Whatever the system, though, it normally offers some support for the student which is extra to the package.

Why individual students or employees would be interested in open or distance learning has its origins in the implicit contract theory. This theory is based on the premise that it is impossible to be explicit about every contingency that might face employees at work in their written contract of employment. Another "gloss" could be put on this view of events by suggesting that in effect, employees must take more responsibility for their development. They must be prepared to investigate what training they need and must be prepared to do it in their own time, because they realise the benefits that will accrue from such an action (Monk, 2001:58-59).

Monk (2001:59) quotes Thome, 1991, and Howard, 1993, who suggest that new training methods emphasise the role of andragogy, rather than pedagogy. Andragogy suggests that the learner is an autonomous adult who is able to take charge of his own development; part of this process means that the learner is able to "take stock" of his existing knowledge and then see where he wants to enhance his portfolio of skills or competencies. This auditing process is a useful exercise in itself, as learners have to gather evidence of their skills, regardless of whether they were gained in a formal setting (such as classroom) or an informal setting (for example, having to learn about the demands of being a parent). It is then up to the individuals to decide what open or distance learning package they need and at what level to pursue any given course. They then, of course, have to have the

discipline that is required by andragogic learning, in order to complete a given course of study, without the framework of some institutionalised setting (a certain class to be attended at a certain time each week). Equally from the individuals' perspective, one could argue that open/distance learning courses allow the freedom to decide at what pace they pursue a course and when they will do a given piece of work (Monk, 2001:59).

5.3.1 Negative aspects of distance education

Distance education practitioners have been following a first-generation mode of delivering at institutions of higher learning for many years. They have followed a highly industrialised production process in an attempt to produce large numbers of relatively cheap tutorial packages for a fast-growing and knowledge-seeking learner community. Rigidly designed reader-unfriendly readers and study guides support the notion of a predominantly positivist mechanism at work and the lack of formative assessment and a structured supporting system contribute to high student dropout and failure rates. Fraser and Nieman (1995) (as indicated by Fraser & Lombard, 2002:88) illustrated how a sample of distance learners representing major distance education institutions over-emphasised the memorisation of facts and principles, continued to identify important concepts in the text, memorised subject content and reproduced such material in assignments and examinations. They sought to work with subject information that has been set out logically and in an orderly manner. Furthermore, variables such as the successful completion of tasks and assignments and the role played by student self-confidence and regular feedback from lecturers on these achievements influence distance learning significantly (Fraser & Lombard, 2002:88)

Distance institutions are affiliated with first-generation distance learning modes of delivery. To these institutions a classical paper-based instructional policy remains the main prescribed policy of the institution. It is justifiably argued by Perraton, Creed and Robinson (2002) (as referred to in Fraser & Lombard, 2002:88) that open and distance learning are often seen as barely legitimate. According to the authors, institutions often accept student fees, give them poor service and keep their own costs down by encouraging students to drop out once they have paid all their money. As far as educator education is concerned, the dropout rate could be anything from 10% to 40%.

5.3.2 Positive aspects of distance learning

It is no longer adequate to assume that knowledge or skills acquired by students during their time at university will last the duration of their working lifetime. What is needed instead is an emphasis on self-directed study that will enable individuals to take charge of their own lifelong learning. To perpetuate a lifelong desire to update skills and knowledge, individuals need to have the necessary skills and an outlook to take charge of their own development. High-quality materials (both in the paper and electronic mode) will help facilitate such development (Monk, 2001:62).

Autonomous responsibility (genuine critical independence) should be the prime goal of education. Communication applies directly to distance education. Communicative action has to bring about "a consensus of understanding", meaning that we have to question the criteria qualifying different opinions and allow for new meaning and understanding to grow from critical dialogue. Communicative action is said to empower students to work together to solve community problems that threaten "the basis of the life-world itself". The fact that many distance learners could be defined as "extroverted", "outgoing", "people-oriented" or "socially sensitive" has been revealed by many investigations. The strong affiliation between distance students' mutual and dominant preference for external or field-dependent thinking were revealed by Fraser, Van Ede and Lombard, (2001,131) in an early investigation (as quoted by Fraser & Lombard, 2002:92).

5.4. In-service training

Henderson (1977) (as quoted by Van Niekerk, 1978:4) gives two different definitions of in-service training of educators, one according to British concepts and the other in an American concept respectively: "Any activity which a educator undertakes, after he has begun to teach which is concerned with his professional work"; and: "A program of systematised activities promoted or directed by the school system or approved by the school system that contributes to the professional or occupational growth and competence of staff members during the time of their service to the school system". The third definition is according to Porter (1975) (as quoted by Van Niekerk, 1978:4). "In-service training comprehends the whole of activities on which educators can extend their personal

education, develop their professional competence and improve their understanding of educational principles and techniques".

In-service training for educators has a long history. The taking of courses for degrees and/or professional improvement is a way of life for many classroom educators. In-service programmes have been a reliable source of income for colleges of education, and they have enabled school administrators to substitute the counting of credits for the distasteful task of judging merit. Relying on in-service study to supply the basic training for an occupation allegedly as important as teaching, reverses the relation of pre-service to in-service study that obtains in such occupations as engineering, medicine, law and accounting. In these professions the basic concepts, theories, technologies and problems of practice are part of the pre-service curriculum. Experience on the job provides familiarity with particular working situations and develops adeptness in dealing with them. In-service study is used to update personnel in theoretical and practical development (Broudy, 1978:59).

According to Harty & Enochs, (1985) science educator in-service education needs:

- ❖ Some reconstitution to cope adequately with the problems besieging it;
- ❖ To have a foundation based on validated theoretical and/or conceptual frameworks and an empirical base;
- ❖ To link more closely educator preparation to classroom instruction;

Once grounded with validated models and empirical research, future in-service preparation will have the potential to assist educators to:

- i) Develop skills to identify problems in the science classroom;
 - ii) Recognise knowledge sources, special abilities and competencies, and other resources which are available to deal effectively with these problems; and
 - iii) Apply self-directed creative behaviour involved with identifying problems and gathering available resources needed to formulate solutions.
- ❖ To consist of an integrated, interdependent and complementary mechanism in which each group and its constituents play a role and carry out particular responsibilities;
 - ❖ To be responsible for development of alternative career patterns and for promoting educator preparation as a career-long enterprise.

In-service agencies pride themselves on their flexibility, functionality and fine-tuned relevance. They are not tied to standardised courses and modes of instruction, not bound by degree requirements and the restrictions of academic bureaucracy. This freedom enables in-service offerings to utilise a variety of informal arrangements for delivery of educational services, workshops, encounter groups, field experiences, travel and mini-courses, which, like miniskirts, are thought to be instructive in proportion to their brevity. Although educators dislike the restrictions imposed by formal study, they are addicted to credits and degrees. But credits and degrees raise the troublesome problem of standards, because traditionally they (credits and degrees) certify scholastic achievement (Broudy, 1978:63-64).

In-service training could focus on simple homework assignments and how to monitor and correct them, and the same applies to tests (Van den Berg, 1996:5). According to Bolam *et al.* (1976) (as quoted by Van Niekerk, 1978:89) in-service training provides an opportunity for the student to follow his or her particular field of interest in some depth.

5.5 Evaluation of educator development programme

Developing and improving the quality of educational programmes is a current management issue of substantial concern. The object is to improve the customer experience and so to improve future sales as "Market share relates in part to perceived customer satisfaction" (Fry, 1995:69, as quoted by Kerridge, & Mathews, 1998:72). This philosophy has been espoused by the majority of higher education establishments within the increasingly competitive environment of the education marketplace (Kerridge *et al.*, 1998:72). The quality of distance learning courses is an issue that most concerns those who plan, design and develop distance learning materials. The challenge is in establishing what we mean by quality in distance learning, how we go about measuring it, what criteria should be used and how we go about using the information to maintain or improve the quality of our course materials (Van Niekerk, 1995:102).

Evaluation can be carried out for a variety of reasons. While top management might be concerned about accountability, quality, effectiveness, efficiency and competitiveness, programme managers will be concerned that the course at least covers its costs and that goals are met, while course designers and writers will be

principally concerned about the teaching effectiveness of the course ((Van Niekerk, 1995:103).

Van Niekerk, (1995) quotes Rowntree (1988), who says that course evaluation serves as a quality control tool. It enables the writer of course material to obtain feedback on issues such as the planning process, aims and objectives, course content, teaching strategies, and the materials and facilities that might be used by students. The need for and means of course evaluation are not self-evident, as is often assumed. If it were, course writers would not only be doing it more often, but also more effectively. There would be no point in evaluating, however, if we are not willing to change, even if it means that we have to change the whole course completely (Van Niekerk, 1995:103).

The two main approaches to course evaluation are formative and summative evaluation. Formative evaluation refers to the evaluation of the instructional process while it is being carried out with the aim of improving or changing the course. According to Holmberg (1989) (as quoted by Van Niekerk, 1995:103), formative evaluation does not aim at passing judgement but is to be seen as a component of development work. A function of formative evaluation is to find out whether the concepts, procedures and criteria of a subject have been made sufficiently accessible. Other functions are to determine whether the problems involved could have been presented more clearly, and whether the activities employed in the course really helped the student achieve the objectives. Formative evaluation is usually done by the course writer, is not a large-scale effort, may or may not be costly, often uses descriptive statistics, is driven by decision-making and operational constraints of the organisation, and relies on monitoring and performance indicators of short-term effects (Van Niekerk, 1995:103-104).

Summative evaluation is aimed at assessing the effectiveness of a course on completion – a type of product evaluation. It may need extra resources in terms of funding and often uses large-scale surveys and statistically based sampling and analysis methodologies. Summative evaluation is driven by the time constraints of the design and methodology chosen and initiates data gathering to reveal longer-term effects of a programme. It is a task for unbiased researchers, not for those who are engaged or have been engaged in the development of the course concerned (Van Niekerk, 1995:104).

5.6 Assessment of lecturers/tutors

The main aim of this assessment is to obtain information to reinforce existing strengths of a given lecturer and his/her repertoire of teaching skills, and suggest improvements in the instructional process. This assessment is for lecturers who are genuinely concerned about making improvements to deal with people they trust, and who do not pose a threat to their professional and career aspirations (Imenda, 1993:148). Overall, lecturers and educators need to learn ways of helping their students find their own answers. They need to learn and practise various strategies in order to develop confidence in exercising them because teaching strategies can affect students' attitudes and achievements positively or negatively (Finson, 1989:421).

5.6.1 Procedure

Within the current spirit of voluntary participation, the decision to be assessed is made by a concerned lecturer. Once a lecturer has indicated the desire to have this assessment conducted in one of his or her courses, a pre-assessment meeting between the lecturer and the assessor is arranged. The purpose of this meeting is to acquaint the lecturer with the procedure and the parameters used in the assessment. The next step involves criteria selection. In this regard the lecturer is given a battery of structured and open-ended items, all of which focus on various aspects of the instructional process, that is, on characteristics of the lecturer, i.e. the lecturer as a tutor: the use of written assignments, the use of reading assignments, the use of laboratory exercises and assignments, course organisation, the use of audiovisual media and the ability to promote various aspects of student development, such as knowledge and skills, attitudes, interest and curiosity, social skills, self-concepts and vocational skills.

The battery must also include a number of structured and open-ended items which reflect the concerns of the course in which the assessment is to be carried out. The lecturer can also be asked to add any other criteria that are relevant but which are not reflected in the battery of items provided. After the identification of relevant criteria, these are put together in the form of a questionnaire, which is then administered to the lecturer's students at an agreed time. Once the report has been completed, it is given to the lecturer to study and to prepare discussion points

for the next and final stage of the assessment process. This report is made in confidence. As such it is regarded as the exclusive property of the lecturer. The post-meeting is the final stage in the exercise (Imenda, 1993:148-149).

5.7 Strategies for programme evaluation

This kind of evaluation and procedures for evaluation can be agreed upon by all those concerned. An evaluation team is one way of achieving this. The team should resemble a small working group rather than a large committee. Obtaining information from students/customers about their experience and their opinions of a course/project is also a very important and much-needed aspect of course/project evaluation (Van Niekerk 1995:112).

Amongst a myriad of descriptions and roles is that of the students, i.e. are they customers or clients? A client can be defined as one to whom is due our best professional advice and practice, this being not necessarily what he or she may want. Customers are persons to whom we supply goods and services to satisfy their needs and/or wants. It can be argued that students, even postgraduates, do not have the ability to judge the technical content of a programme. They will know if they have already covered things before or if they seem to have been covered very poorly. Much of their evaluations may be drawn from contextual clues or from process aspects of the programme. Thus, things like comfortable seats, airy/light rooms, lack of crowding, free coffee, etc. can potentially make a substantial impact on the self-reported evaluations (Kerridge *et al.*, 1998:71-72).

5.8 Conclusion

Teacher development projects in developing countries should not provide a universal recipe for all schools and all educators but should choose different approaches, depending on educator and school backgrounds (Van den Berg, 1996:6). An assumption that can be taken for granted is that many aspects of quality in a project cannot be achieved and maintained without evaluation. Having achieved a standard of practice does not release us from the need to evaluate in future. Thorpe (1988) (as quoted by Van Niekerk, 1995:112) says that standards once reached do not maintain themselves automatically, and evaluation is the spur

to action which not only maintain standards, but improves them, thus leading towards excellence in course development (Van Niekerk, 1995:112).

The next chapter (Chapter 6) deals with the syllabus for the chemistry course offered in the SEDIBA Project. It further explains in detail the different strategies applied in the teaching of chemistry in the SEDIBA project. Results of the empirical study will be outlined and discussed in Chapter 7.

CHAPTER 6

THE SEDIBA PROJECT, THE SEDIBA CHEMISTRY SYLLABUS AND TEACHING STRATEGY FOR CHEMISTRY

6.1 Introduction

This chapter will present the situation of science teachers in the North West province of South Africa and the endeavour by the North West Department of Education in collaboration with Potchefstroom University for Christian Higher Education to alleviate the situation with regard to teacher development. Data collected by Smit *et al.*, (paragraph 6.2) will be used to determine whether science teachers in the North West Province of South Africa are classified as either un(der)qualified, unskilled, routine teachers or mechanical teachers.

6.2 Scenario in the North West Province

Research by Smit *et al.* (1997:7-8) indicates that in March 1996, 1218 teachers were teaching general science/physical science in the North West Province. The highest qualification of these 198 teachers (16% of the teacher population) was a two- or three-year certificate. 109 were in possession of a Primary Teacher's Certificate (PTC) (2 years) or a Higher Primary Teacher's Certificate (HPTC) (3 years). The entrance requirement to enrol for these certificates was only Standard 8 (Grade 10). 22 general/physical science teachers were in possession of only a matric certificate.

The total number of diplomated and non-diplomated science teachers in the North West Department of Education was 921, or 76% of the population, at the time when the survey was done (March 1996). It is alarming to deduce from departmental information that the highest qualification of about 660 general/physical science teachers (approximately 54% of the provincial population) is matriculation physical science (physics and chemistry). Some do not even have this qualification (Smit *et al.*, 1997:8)

In the North West Province, only 53 teachers had third year university physics as their highest qualification, and only 68 teachers had third year university chemistry.

The 17 teachers whose highest qualification were physics at the fourth year university level include BSc(Ed) graduates whose physics course is distributed over four years in the educational degree. The same was true for the 20 teachers whose highest qualification in chemistry was fourth year university level. The actual number of teachers who had an honours degree in physics or chemistry could not be deduced from the data available. Five teachers possessed five years of university training in physics, and four a similar training in chemistry (Smit *et al.*, 1997:8).

A study of the 1997 Standard 10 physical science results indicated that the national pass rate in physical science higher grade was 59.1%, and for standard grade it was 71.0%. In the North West Province (NWP) the pass rates were 58% and 70.6% respectively (South Africa: NDE, 1998: graph 3, Table 12). Reasons that could have directly affected the results were cited as a lack of confidence that is evident in mathematics, biology and physical science teachers and under-resourced libraries which prevented pupils from doing projects and assignments (Dilotsotlhe, 1999:2)

Given this scenario, one realises why the North West Province results in mathematics and science have been so far below the norm. This was a challenge to the Department of North West Education and the institutions within the province. The answer to this crisis was the birth of SEDIBA in-service upgrading programme, an endeavour to address the dire need of quality science teachers in the North West Province (Wesi, 1997:65)

6.3 What is the SEDIBA Project?

The SEDIBA (Setswana word for well or fountain) Project is a partnership involving the Potchefstroom University for CHE, the North West Education Department and NASCHEM – a division of DENEL, a large armaments corporation. The project is aimed at improving the quality of science and mathematics teaching by assisting science and mathematics teachers to gain mastery of their subjects and to teach them with confidence and commitment. The teaching of these subjects is of fundamental importance in the establishment of high-technology industries and wealth in the Republic of South Africa. With the consistently high failure rate amongst matriculation science pupils and in view of reports that local standards in

education, particularly those in mathematics and science, are far below the norm, the founding of the SEDIBA Project was a much needed development (Steyn & Wesi, 1998:6)

The SEDIBA programme at the PU for CHE is the only formal in-service training programme in the North West Province (Smit *et al.*, 1997:72). Upon its inception in 1996, the SEDIBA Project registered an initial group of 40 teachers in the physical science stream. At the beginning of 1997, not only did 45 new teachers enrol for the first year of the physical science course, but a new programme for upgrading the skills of mathematics teachers was introduced, with an enrolment of 37. The total enrolment of teachers in both physical science and mathematics programmes at that stage was thus 117 (Steyn & Wesi, 1998:6-7).

Up to January 2003, a higher education diploma had been conferred upon no fewer than 223 teachers of the North West Province of South Africa at graduation ceremonies held at the PU for CHE. The SEDIBA Project also made a contribution to the upgrading of teachers' qualifications in other provinces. In co-operation with the Mpumalanga Department of Education and with Billiton Development Trust as a sponsor, 28 teachers received the higher education diploma with specialisation in mathematics and physical science in 2000. During 2002 the project was also extended to the Vaal Triangle campus of the PU for CHE, where 20 mathematics teachers were enrolled for their studies with the financial aid of SASOL, Vaal Education, Old Mutual, African Cable, First Rand, Safripol and Karbochem (PUK News, 2003).

The SEDIBA Project comprises two professional development programmes for physical science teachers and mathematics teachers offered on a part-time basis. They are part-time taught courses (Race, 1999:2) because there is a limited opportunity for social interactions among students, but teaching may be similar or common to that in full-time provision. Tuition is done by means of contact teaching involving state of the art computer-aided instruction (see paragraph 6.5.4) and by means of distance learning. Lectures are offered mostly during school holidays on the campus of the Potchefstroom University. Courses are presented at the equivalent of first year university level (Steyn & Wesi, 1998:6-7).

The physical science stream consists of physics, chemistry, education, didactics of physical science and computer literacy. Practical work forms an integral part of the physical science programme (Steyn & Wesi, 1998:7).

The SEDIBA Project is reaching out to over 30 000 pupils. Feedback from subject advisors and schools indicates that there has been a marked improvement in the quality of teaching of the SEDIBAs' educators (Steyn & Wesi, 1998:8).

6.4 The SEDIBA chemistry syllabus

Chemistry is a major course and extends over two years. Topics included in the chemistry syllabus are atoms and elements, compounds and molecules, chemical reactions, reactions in aqueous solution, atomic structure, atomic electron configuration and periodicity, basic concepts of chemical bonding and molecular structure, gases and behaviour, etc. (For more detailed contents and topics refer to Table 6.1.) Each topic is introduced at grassroots level. Table 5.1 shows the contents of the SEDIBA syllabus relative to the school syllabus. A broad holistic approach is followed in the presentation of the course.

TABLE 6.1: The contents of the SEDIBA chemistry syllabus

Contents	School syllabus	SEDIBA syllabus
1. The tools of chemistry	Grade 11 - chap. 8 Basic concepts in chemistry Gr. 8 - chap. 5 Mixture Gr. 8 - chap. 6 Density of substances	1.1 The science of Chemistry 1.2 Methods of Science 1.3 Some Definitions 1.4 Units of measurement 1.5 Handling numbers 1.6 Problem solving by dimensional analysis
2. Atoms and Elements	Gr.11 - chap. 8 Basic concepts in chemistry Gr.10 - chap. 11 Basic concepts in chemistry Gr.9 - chap. 11 Atoms and molecules, symbols and formulae Gr.8 - chap. 3 Matter: properties and classification	2.1 Elements 2.2 Atoms 2.3 Isotopes 2.4 Atomic weight 2.5 The periodic table of elements 2.6 The mole

	Gr.8 - chap. 4 Classification of the elements	
3 Compounds and Molecules	Gr.10 - chap. 8 Basic concepts in chemistry Gr.9- chap. 11 Atoms and molecules, symbols and formulae Gr.8 - chap. 3 Matter: properties and classification Gr.8 - chap. 4 Classification of the elements	3.1 Compounds, molecules and molecular formulae 3.2 Elements that exist as molecules 3.3 Ions and ionic compounds 3.4 Names of compounds 3.5 Molar mass, molecular weight and formula weight 3.6 Determination of the formula of a compound
4. Chemical Reactions	Gr.10 - chap. 8 Basic concepts in chemistry Gr.9- chap. 11 Atoms and molecules, symbols and formulae	4.1 Chemical equations 4.2 Balancing chemical equations 4.3 Some common types of chemical reactions 4.4 Stoichiometry 4.5 Limiting reagents 4.6 Percent yield 4.7 Chemical equations and chemical analysis
5. Reactions in Aqueous Solution	Gr.10 - chap. 17 Ionic reactions Gr.10 - chap. 19 Calculations & ionic equations Gr.9 - chap. 12 chemical change; heating of substances Gr.8 - chap. 8 Oxygen	5.1 Properties of aqueous solutions 5.2 Balancing equations for reactions in aqueous solution: Net ionic equations 5.3 Some types of reactions in aqueous solution: Exchange reactions 5.4 Stoichiometry 5.5 Oxidation-reduction reactions
6. Atomic Structure	Gr.11 - chap. 9 Structure of the atom: Developing the atomic model Gr.10- chap. 12 the structure of the atom	8.1 Electromagnetic radiation 8.2 The quantization of energy 8.3 The photoelectric effect and Albert Einstein 8.4 Atomic line spectra and Niels Bohr

		8.5 The wave properties of the electron 8.6 Schrödinger, Heisenberg and quantum mechanics 8.7 The wave mechanical view of the atom
7. Atomic Electron Configuration and Periodicity	Gr.11 - Chap. 10 Atomic structure - a wave model Gr.11 - chap. 12 Periodicity of chemical properties. Gr.10 - chap. 11 the periodic table Gr.10 - chap. 13 A modern view of electron structure	9.1 Electron spin 9.2 The Pauli exclusion principle 9.3 Atom orbital energies and electron assignments 9.4 Atom electron configurations 9.5 Ion orbital energies and electron configurations 9.6 Atomic properties and periodic trends 9.7 The energy required to form common monoatomic ions and its chemical consequences
8. Basic Concepts of Chemical Bonding and Molecular Structure	Gr.11 - chap. 13 Covalent bonding Gr.11 - chap. 14 Ionic and metallic bonding Gr.10 - chap. 14 Chemical bonding of atoms	10.1 Valence electrons 10.2 Chemical; bond formation 10.3 Ionic bonding 10.4 Covalent bonding 10.5 Bond properties 10.6 Molecular shape 10.7 Molecular polarity
9. Gases and their Behaviour	Gr.11 - chap. 15 Gases Gr.9 - chap. 8 Pressure Gr.9 - chap. 9 Pressure in liquids Gr.9 - chap. 10 Gas pressure Gr.8 - chap. 7 Particle model of matter	12.1 The properties of gases 12.2 The Gas Laws: the experimental basis 12.3 The Ideal Gas Law 12.4The Gas Laws and Chemical reactions 12.5 Gas mixtures and partial pressures 12.6 Kinetic molecular theory of gases 12.7 Graham's law of diffusion and effusion 12.8 Non-ideal gases

10. Inter-molecular Forces, liquids and solids	Gr.11 - chap. 16 Liquids and solids (intermolecular forces)	13.1 Phases of matter and the kinetic molecular theory 13.2 Intermolecular forces 13.3 Properties of liquids 13.4 Solids 13.5 The special properties of liquid and solid water 13.6 Phase changes
11. Solutions and their behaviour	Gr.11 - chap. 17 Solutions Gr.8 - chap. 7 Particle model of matter	14.1 Units of concentration 14.2 The solution process 14.3 Colligative properties 14.4 Colloids and colloidal dispersions
12. Chemical Equilibria	Gr.12 - chap. 9 Chemical reactions and equilibrium	16.1 The nature of the equilibrium state 16.2 The equilibrium constant 16.3 The reaction quotient 16.4 Some calculations with the equilibrium constant 16.5 External factors affecting equilibria
13. Precipitation Reactions		19.1 Solubility of salts 19.2 The solubility product 19.3 Determining K_{sp} from experimental measurements 19.4 Estimating salt solubility from K_{sp} 19.6 The common ion effect, p.796 (qualitative) 19.10 Separation of ions by selective precipitation, p.805 (qualitative)
14. The Chemistry of Acids and Bases	Gr.12 - chap. 11 Acids and Bases Gr.10- chap. 15 Acids, bases and salts Gr.9 - chap. 14 Chemical change: reaction of acids	17.1 Water, the hydronium ion and auto-ionization 17.2 The Bronsted concept of acids and bases 17.3 Water and the pH scale 17.4 Strong acids and bases 17.5 Weak acids and bases 17.6 The Lewis concept of acids and bases

15. Reaction between Acids and Bases		18.1 Acid-base reactions 18.2 The common ion effect and buffer solutions 18.3 Acids-base titration curves 18.4 Acid-base indicators
16. Electrochemistry: The Chemistry of Oxidation-Reduction reactions	Gr.12 - chap. 12 Oxidation, reduction and electrochemical cells Gr.10- chap. 16 Chemical reactions and electricity Gr.9 - chap. 12 Chemical change: combustion Gr.9 - chap. 13 Chemical change; heating of substances Gr.8 - chap. 8 Oxygen	21.1 Chemical change leading to electric current 21.2 Electrochemical cells and potentials 21.3 Voltaic cells at non-standard conditions 21.4 Common batteries and storage cells 21.5 Electrolysis: Chemical change from electrical energy 21.6 Electrical energy 21.7 The commercial product of chemicals by electrochemical methods 21.8 Corrosion: An example of oxidation-reduction reactions.
17. The Chemistry of the Non-metals: Group 5A - 7A, Rare Gases	Gr.11 - chap 18 Sulphur and its compounds (24.2) Gr.11 - chap. 19 Nitrogen and its compounds (24,1) Gr.11 - chap. 20 Halogens ND Halides (24.3) Gr.10-chap. 10 The reactions of non-metals	24.1 The chemistry of group 5A elements 24.2 The chemistry of group 6A elements 24.3 The chemistry of group 7A elements 24.4 The chemistry of rare gases (just a summary)
18. Organic Chemistry: Introduction, Functional groups, Common classes of Organic compounds, Unsaturated compounds, Alcohols, Alkyn halides, Carbonyl compounds, Carboxylic acids and	Gr.12 - chap. 13 Organic chemistry	26.1 Some preliminaries: Structural formulas and bonding 26.2 The alkanes 26.3 Functional groups and common classes of organic compounds 26.4 Alcohols, ROH

Esters, Petroleum and refinery processes. Polymer: Natural and Synthetic Macromolecules		26.5 Ethers, ROR 26.6 Unsaturated compounds: Alkenes and alkynes 26.7 Benzene and aromatic compounds 26.8 Alkyl halides 26.9 Carboxylic acids and esters 26.10 Carbonyl compounds: aldehydes and ketones 26.12 Petroleum and refinery processes 27.5 Synthetic polymers: plastics, fibres and elastomers
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6.5 Teaching strategy for the SEDIBA chemistry syllabus

The teaching strategies that directly impact on the affective domain are those that are geared towards the outcomes-based education approach. This is a holistic approach based on the notion that the learning is driven by outcomes where learners are able to provide evidence that critical, specific and final outcomes were met (Olivier, 2001:33). When asked what OBE is, most teachers defined OBE by reference to certain common practices. For example, learner-centred instruction, activity-based learning, group work, learning by discovery, less direct teaching and more teacher facilitation, less of a focus on content coverage, learning by doing, etc. In other words, teachers certainly held and expressed a very practical and elaborated idea of what constitutes OBE (Jansen, 1999:207-208).

The effective chemistry classroom appears to be one in which students are kept aware of instructional objectives and receive feedback on their progress towards these objectives. They are given the opportunities to interact physically with instructional materials and engage in varied kinds of activities. Alteration of instructional material or classroom procedure occurs where it is thought that the change might be related to increased impact (Trowbridge et al., 1996:201).

The chemistry lecturers of the SEDIBA Project place *Science as Inquiry* very high on science teachers' instructional agenda. The standards of inquiry focus science teachers' attention on developing students' abilities to use observations and knowledge as they construct scientific explanations. The standards incorporate the traditional processes of science with instructional strategies that require students to use scientific knowledge and evidence from their investigations to formulate scientific explanations. The standards shift instructional emphasis towards empirical criteria, critical thinking about evidence, and scientific reasoning in the construction of explanations (Trowbridge *et al.*, 1996:201).

Students learn to construct their own understanding and assume responsibility for establishing their own knowledge base. Science, in turn, has been described as both knowledge of the natural world and a procedure used to obtain that knowledge. Inquiry teaches models in science. In an inquiry classroom, students are allowed to experience the processes of science. They learn to question their own observations, as well as those made by past researchers. Students deal with the frustrations of experimental error, missing data and uncontrolled variables. They learn that theories can never be proven, only disproved (Damnjanovic, 1999:71).

Use of inquiry activities has been shown to enhance some students' interest in science, as well as their motivation to continue studying science (Damnjanovic, 1999:71).

Various science councils advise that the classroom should incorporate group activity because it influences how students learn and reinforces the collaborative nature of the scientific enterprise. This emphasis on student-centred instruction marks a shift from the traditional instruction-centred paradigm, which provides few opportunities for students to become actively engaged in the learning process. In contrast, students working in small groups have opportunities to negotiate meaning and construct conceptual understanding in a community of learners. Small group instructional methods have been implemented in undergraduate science, mathematics, engineering and technology (SMET) education. Students experience positive interdependence as they work through problems in a collaborative setting. Meta-analyses of the impact of small-group learning in undergraduate SMET have

demonstrated significant positive effects on students' achievement, attitudes, and persistence (Tien *et al.*, 2002:606-607)

Even though discovery, co-operative learning and inquiry are top on the list, several instructional models are explored. Lecturers do not stick to one specific approach because some teaching strategies can work effectively in one situation and yield poor results in another situation. For teaching strategy to be effective, it must also be relevant to the situation in which it is to be implemented (Wesi, 1997:64).

The dedicated SEDIBA staff support the importance of models as outlined in paragraph 4.6.1. This is evident in the preparation of all teaching-learning material that is used for this program. Below is the discussion of materials used by the SEDIBA staff members in their presentation of science.

1. Study manuals: The course is offered on a part-time basis and comprises of both distance and contact teaching. It is for this reason that the manuals developed for students are user-friendly (refer to Appendix 9). Teachers use well thought-out study manuals that have been developed using outcomes-based education as a criterion. The study manuals elaborate further what is prescribed for the course. The outcomes of each unit are clearly stated at the beginning of each unit and chapter. Also enclosed is a concept map which enhances conceptualisation. This results in students' studies being outcomes-based. Questions and icons are used throughout the material to guide the educators and to indicate further references (refer to appendix 9).

2. Laboratory manuals: The format of the design of the laboratory material used at the SEDIBA Project is based on thorough research done by the staff of the SEDIBA Project. The student's ability to extract and process information from laboratory manuals is facilitated by these characteristics of the manual: stating clearly what is preliminary or peripheral, using simple and precise language, directing students to practise the necessary skills before they are used in investigative activities, sequencing procedures into steps, and including drawings of equipment and apparatus (Dechsri *et al.*, 1997:892).

Although pictures (refer to Appendix 1) are expensive, they are included in the SEDIBA Projects' laboratory manual because of their effective results in promoting and facilitating information processing of laboratory instructions. Visual information aids consisting of pictures integrated with text in the design of chemistry laboratory manuals help students perform better in the cognitive, affective and psychomotor domain. Important laboratory activity outcomes can be assessed in all three domains by using an achievement test (cognitive), an attitude towards chemistry laboratory survey (affective) and a manipulative skills observation checklist (psychomotor). Visual information-processing assistance provided by pictures and diagrams integrated with text in chemistry laboratory manuals reduce the information load passing through students' working memories and help them gain more from their laboratory experiences (Dechsri *et al.*, 1997:901).

Dechsri *et al.*, (1997:892) quote Reid and Miller stating that pictures, which represent visible images such as persons, objects, scenes and diagrams, composed of both an image and explanation, have been accepted as useful ways to communicate information. The ease with which words are recalled depends on their ability to stimulate a sensory image in the subject's mind. Thus, pictures are more effortlessly recalled than words that describe easily visualised concrete phenomena, which are in turn more easily recalled than abstract words. A visual image can act as an easily recalled conceptual peg for abstract concepts or complicated procedures. In addition, a picture of a piece of equipment or diagram of a procedure presents information in a meaningful context, with spatial arrangement of apparatus or chronology of procedural steps explicitly shown (Dechsri *et al.*, 1997:892-893).

The laboratory learning outcomes in SEDIBA's laboratory manuals are categorised into three domains: cognitive, affective and psychomotor (refer to Appendix 1). In the manual, letters are used to indicate what domain or field is being tested (refer to Appendix 10). Appendix 10 explains in detail what each letter represent and how effectively can the educator and the learner make use of the manual. Within a laboratory context, the cognitive relates to intellectual abilities such as recalling, applying and evaluating scientific information, and planning and devising experimental investigations to seek solutions to scientific problems. Affective outcomes include student attitudes towards and interest in science and the study of science, science-related beliefs and values, and student attitudes towards

ethical judgements and interpersonal relationships. Psychomotor outcomes relate to manipulative skills and abilities. These include skills in handling and manipulating materials and apparatus in the context of scientific investigations, as well as the ability to follow instructions and make accurate observations (Kemp, 1985 as in Dechsri *et al.*, 1997:893).

3. **Textbook:** Paragraph 4.6 puts forward problems encountered by learners in visualising concepts in chemistry. Because of thorough research done by SEDIBA staff, "Chemistry and chemical reactivity", (Kotz & Treichel, Jr., 1999), is recommended and is provided to the SEDIBA science students for free. Among others, the textbook is selected for the following reasons:

- It brings a new organisation to the theme of "*Chemistry and chemical reactivity*": the close relation between the macroscopic observations they make of chemical and physical changes, the symbols they use to describe those changes, and the way they view those changes at the atomic and molecular levels.
- In addition to a fresh viewpoint on chemistry, it conveys a sense of chemistry as a field that not only has a lively history, but also one that is currently dynamic, with important new developments on the horizon.
- Furthermore, it provides some insight into the chemical aspects around us (i.e.: What materials are important to our economy? What chemical reactions are taking place in plants and animals and in our environment? What role do chemists play in protecting the environment?).
- It is constructed in such a way that students enjoy reading it and offer, at a reasonable level of rigor, chemistry and chemical principles in a format and organisation typical of college and university courses.
- It conveys the utility and importance of chemistry by introducing the properties of elements, their compounds, and their reactions as early as possible and by focusing the discussion as much as possible on these subjects.
- It is offered with the *Saunders Interactive General Chemistry CD-ROM*. The incorporation of *ActivChemistry*, software that allows one to design and perform simulated laboratory experiments will be available in an expanded version of the CD-ROM.
- Additionally, special sections called *Current Perspectives* and a *Closer Look* bring relevance and perspective to a study of chemistry (Kotz & Treichel, Jr., 1999:xiii-xviii).

6.5.1 Multimedia instruction

Like writing systems and the printing press, a computer as a tool for multimedia instruction gives the teacher and the learner more and more powerful new ways to organise, store, retrieve and transform information. Thus, at SEDIBA, computer tutors are used to teach concepts of chemistry by applying programs and by teaching cognitive skills by modelling the processes that students are expected to learn. These take place in modern computer centres. The use of interactive multimedia (IMM) is of great assistance to students, especially in facilitating conceptual change regarding scientific processes. Students can also access useful sites on the World Wide Web (WWW), especially the *Saunders* website (<http://wwwsaunderscollege.com>). They can also make use of the *Saunders Interactive General Chemistry* CD-ROM which they receive along with the prescribed textbook.

6.5.2 Laboratory methods

Practical work, which forms an integral part of the chemistry course, includes all experiments prescribed by the current syllabus from Grade 10 to 12, a number of enrichment experiments not included in school syllabi and some experiments drawn from first year university level. Teachers use well-designed worksheets that have been developed using outcomes-based education as a criterion (See Appendix 1). Educators work through these experiments individually or in small groups. The apparatus used by the teachers are the Student Lab Small Scale Chemistry laboratory (a small scale lab developed at SSMTE and which is patented). The apparatus are manufactured and distributed by Sangari Company.

The Student Lab provides a wonderful opportunity for individual students to gain practical experience and understanding through an interactive learning process. The versatility of the Student Lab enables it to be used in a variety of environments and situations promoting accessibility of information, life-long learning and equal opportunities for the learner. There are numerous advantages that the Student Lab Small Scale Chemistry laboratory can provide in an educational environment. It allows a unique way for students to be involved in hands-on practical work at a fraction of the cost of installing a traditional laboratory (Sangari, 2002)

6.5.3 Lecture method

The course is presented in English by members of SEDIBA staff experienced in teaching of high school chemistry and is fully committed to improve the quality of education in the North West Province and South Africa. The course is presented in modern lecture halls and well-equipped laboratories at the Potchefstroom University. The tuition is enriched by computer aided instruction during presentation in a modern computer centre (refer to paragraph 6.5.2). In addition to these "high tech" aspects, participating teachers are trained to adapt their knowledge to their teaching environment. Lectures are supplemented with overheads to illustrate scientific concepts and ideas. In essence, lectures are used for the purposes elaborated in paragraph 4.6.4. Lecturers use different approaches in their presentation (refer to paragraph 6.5). Educators are introduced to the use of low cost equipment and the handling of equipment available at schools to achieve understanding of scientific principles.

It is out of this context that the SEDIBA Project's approach to chemistry and chemistry teaching is taking the route explained in paragraph 6.5. These has proven to be highly successful because when asked about the success of the project, Prof. Smit, the director, simply answered that its success may be ascribed to the unique presentation method of the programme. The project boasts a sustained pass rate of almost 80%. Through the interaction of participating teachers with colleagues, a positive attitude towards mathematics and science education is also promoted among them (PUK News, 2002)

6.6 Quality assurance in the SEDIBA project

"Market share relates in part to perceived customer satisfaction" Fry, 1995:69 (as quoted by Kerridge *et al.*, 1998:72). This philosophy has been espoused by the management of the SEDIBA Project establishment within the increasingly competitive environment of the education market place. Because management is concerned about accountability, quality, effectiveness, efficiency and competitiveness, there is continuous evaluation going on within the project. Evaluation enables the management to obtain feedback on issues such as the planning process, aims and objectives, course content, teaching strategies and

materials and facilities that are used by students. Evaluation is formative and summative (refer to paragraph 5.5).

Evaluation of the SEDIBA Project is a task for unbiased researchers who are not engaged or have been engaged in its development. Evaluation is done at the beginning of the year and at the end of each contact session. It takes the form of open-ended questions, comments and recommendations, and statements (refer to Appendix 8). Some of the responses and results of this evaluation will be used to support the results of this research.

6.7 Conclusion

The initiatives since 1996 by the SEDIBA Project, the PU for CHE and the Department of Education North West have contributed enormously to Grade 12 results for the North West province. The National Report on the Performance of individual schools in the 2001 Senior Certificate Examinations indicates that the total pass rate in the North West Province for physical science in 2000 was 65.1%, whereas the 2001 pass rate was 67.9%. Moreover, there has been a continuous production of science teachers by SEDIBA project since its inception in 1996 (see Table 6.2). This means that there has been a continuous increase in the numbers of well-qualified and capable educators.

Table 6.2 Enrolment and diplomas awarded to the SEDIBA science students.

Year	Enrolment	Diplomas awarded
1996	39	30
1997	45	35
1998	50	34
1999	45	28
2000	39	27
2001	29	26
2002	36	24
TOTAL	280	194

The empirical study and the discussion of results will be dealt with in Chapter 7.

CHAPTER 7

EMPIRICAL STUDY AND DISCUSSION OF RESULTS

7.1 Introduction

In this chapter the methodological procedure and the results of the study are discussed. The discussion is based on the impact of the SEDIBA programme on the attitude of educators participating in chemistry and chemistry teaching.

7.2 Aims of empirical study

In Chapter 2 attitude formation and factors influencing science-related attitudes were discussed. The role of attitude towards science teaching and learning, factors contributing to attitude exchange and procedures for attitude exchanges were discussed in Chapter 3. The empirical study that is reported in this chapter is an in-depth and comprehensive study of the first-year SEDIBA Project students' attitude towards chemistry and chemistry teaching. The main purpose was to determine the impact of the SEDIBA programme on the educators participating in chemistry and chemistry teaching.

The following aims of the dissertation were addressed in the empirical study:

1. Educators' perception of the science curriculum
2. Educators' perception of science
3. Educators' attitude towards science
4. Educators' attitude towards science teaching
5. Educators' attitude towards chemistry teaching
6. Quality assurance

7.3 Data assembling

An availability sample of educators in the North West Province of South Africa attending an upgrade course for science teachers was used in the empirical study. Data was collected by means of questionnaires. Resulting from the requirements of the aims of the study, one questionnaire was designed. A pre-test and post-test

were administered to the first year educators of the SEDIBA Project in January and April 2003. A pre-test was administered at the beginning of the educators' first contact session, prior to any instruction in any course.

The same questionnaire was administered in the post-test but this time the order of the items was changed. The post-test was administered on the last day of the educators' second contact session. A detailed description of the questionnaires is provided in subparagraphs 7.3.1 and 7.3.2.

7.3.1 Compilation of questionnaire

A Likert-type science attitude scale was developed as discussed in paragraph 1.5.3 to measure educators' attitudes towards chemistry and chemistry teaching. The questionnaire administered consisted of 80 items (or statements) and was divided into two sections. Section A consisted of 15 items that sought the demographic information of the educators. Section B consisted of 65 items that covered all the sub-scales indicated in Table 7.1 and Appendix 4. It consisted of 23 negative and 42 positive statements to which educators responded with one of six Likert intervals. The response intervals were 1 (totally disagree), 2 (do not agree), 3 (undecided), 4 (agree with reservations), 5 (agree) and 6 (completely agree). Section B of the questionnaire itself is not divided into sub-scales but the items of the sub-scales are randomly distributed (see appendix 3).

7.3.2 Aspects investigated in questionnaire

Chapter 2 and 3 explain attitude, factors influencing attitude towards science and how attitude can be changed. The items of the questionnaire were structured in such a way that they cover the three aspects of attitude (cognitive, affective and action) in every sub-scale (appendix 4, subscale A-F). Table 7.1 summarises the aspects of attitude per sub-scale. Even though the distribution is not equal in each sub-scale, the author tried to cover all the aspects in the whole questionnaire.

Table 7.1: Aspects investigated in the questionnaire

Sub-scale	Cognitive	Affective	Action
B. Science curriculum	25; 68	16; 32; 43; 48; 55; 61; 78;	38
C. Perception of science	31; 39; 47; 54; 66;	60	18; 23; 64; 77
D. Attitude towards science	26	19; 24; 29; 34; 41; 45; 50; 59; 62; 65	22; 37; 53; 56
E. Attitude towards science teaching	20; 44; 49; 57; 63; 72; 74	33; 36; 40; 52; 69; 76	28; 30
F. Attitude towards chemistry and chemistry teaching	17; 21; 42; 67; 70; 71; 73; 75; 79; 80.	27; 46; 51; 58.	35

7.4 Processing of data

7.4.1 Statistical analysis

7.4.1.1 Introduction

The data was processed statistically by the Statistical Consultation Service of the PU for CHE by means of the SAS statistical program (SAS Institute Inc., 1999).

Since random sampling was not performed, the results could not be generalised. What was determined was whether the change in attitude between the pre-test and post-test was *practically* significant. The educators participating in the project differed in background and working environments (see paragraph 6.3). Although the course was designed for disadvantaged educators, they came from rural and urban environments. The results can therefore be regarded as important indicators of what impact the SEDIBA programme has on the attitude of participating educators. It cannot be generalised for example that all the educators who participated in this project had a negative attitude towards chemistry.

A brief overview of the statistical tests and techniques used to interpret results are provided in the next paragraph. Additional information on the statistical procedures can be found in publications such as Cohen (1988) and Anastasi (1988).

7.4.2 Effect size and practical significance

Instead of only reporting descriptive statistics in cases where small populations (obtained from available samples) were studied, effect sizes can be determined. Practical significance can be understood as a large enough difference to have an effect in practice.

A natural way to comment on practical significance is to use the standardised average increase between pre-test and post-test in the population, i.e. the mean increase divided by the estimate for standard deviation. Steyn (2000:3) indicates that a measure that is called the effect size, which not only makes the difference independent of units and sample size but relates it also with the spread of the data, is introduced (for more information, the reader is referred to Steyn, 2000).

The influence of the factors was determined by means of effect sizes (d-values). Sub-scales B–F (see Appendix 6) indicates the results for the difference between pre-test and post-test. Only the mean increase and the standard deviation are shown.

To determine the relative effect on the attitude of educators per sub-scale, the d-values (effect size) of each sub-scale was calculated. The d-values were calculated to determine whether effects between the pre-test and the post-test were small, medium or large. The d-value is the ratio of the increase between the average increase ($\bar{x}_{\text{diff}}$) in the sub-scale (pre and post) and the standard deviation s_{diff} , i.e.

$$d = \frac{\bar{x}_{\text{diff}}}{s_{\text{diff}}}.$$

Table 7.2 provides the interpretation of the d-values (Cohen, 1988).

Table 7.2: Effect sizes indicated by ranges in d-values

<u>Effect size (d-values)</u>	
$.20 \leq d < .50$	small effect
$.50 \leq d < .80$	medium effect
$d \geq .80$	large effect

In a case where $d \geq .80$, the difference is regarded as practically significant.

For the interpretation of the results, the effect sizes for each sub-scale will be used, but not that of each item. It should be stated that reversal of numerical values for all negative statements provided consistency in a positive direction.

7.4.3 Cronbach's Alpha Coefficient

To find the effect sizes, interrelated items are summed to obtain an overall score for each participant and each sub-scale. Cronbach's alpha coefficient estimates the reliability of this type of scale by determining the internal consistency of the test or the average correlation of items within the test. When a value is recorded, the observed value contains some degree of measurement error.

Two sets of measurements on the same variable for the same individual may not have identical values. However, repeated measurements for a series of individuals will show consistency. Reliability measures internal consistency from one set of measurements to another. Therefore, the reliability coefficient of a measurement test is defined as the squared correlation between the observed value Y and the true value T . That is

$$\begin{aligned}\rho^2(Y, T) &= \frac{\text{cov}(Y, T)^2}{\text{var}(Y) \text{var}(T)} \\ &= \frac{\text{var}(T)^2}{\text{var}(Y) \text{var}(T)} \\ &= \frac{\text{var}(T)}{\text{var}(Y)}\end{aligned}$$

The larger the overall alpha coefficient, the more likely that the items contribute to a reliable scale. Scales with a Cronbach's coefficient alpha value larger than 0.50, will be considered as reliable.

For this research, the Cronbach's coefficient alpha was used to determine the reliability of each sub-scale. Items 25, 38 and 61 were deleted in order to make sub-scale B reliable. The table below shows the reliability coefficient values for each sub-scale:

Table 7.3: The Cronbach's alpha reliability coefficients

SUB-SCALE	DELETED ITEMS	ALPHA
B Science curriculum	25;38 and 61	0.59
C Perception of science		0.56
D Attitude towards science		0.82
E Attitude towards science teaching		0.577
F Attitude towards chemistry and chemistry teaching		0.57

NB: A Cronbach's coefficient alpha value larger than 0.50 will be considered reliable.

It can therefore be said that the alpha values for the sub-scale presented in table 7.3 above are reliable for use with educators in determining the attitude objects of chemistry and chemistry teaching.

7.5. Demographic information of participating educators

The main aim of the project is to upgrade the qualifications of science and mathematics teachers in the North West Province of South Africa, but due to its impact, it has already included educators from other provinces (see paragraph 6.2). According to the educators' responses (Appendix 5, sub-scale A, item 1, responses 1 + 2 + 3 + 4 + 5), 67.57% of the educators were from regions within

the North West Province, while 32.43% were from other provinces in South Africa, namely Gauteng, Free State and Limpopo.

The highest qualification possessed by 94.41% (Appendix 5, sub-scale A, item 2) of these educators was a three-year teachers' diploma obtained from teacher training colleges in the former Bophuthatswana homeland and former South African Department of Education and Training (DET) colleges. Only 5.41% (Appendix 5, sub-scale A, item 2) were in possession of a four-year qualification. This group of educators was more or less balanced in terms of gender (Appendix 5, sub-scale A, item 3), with 59 males and 41 females. More than half of these educators were under 30 years of age and most of those who were above 30 years, were not over 35 years. Only 21.63% were above 35 years of age (Appendix 5, sub-scale A, item 4). Almost all the participating educators had training in science up to third year college level, with only 5.41% who had training up to Grade 12, and almost all were teaching physical science to Grades 10-12, with the exception of only two, who were teaching biology in the higher grades (Appendix 5, sub-scale A, item 5).

By the time of this research, the Department of Education's teacher-learner ratio was 1:35. According to the data, about half of the educators' classes were overcrowded, a problem the Department of Education is generally faced with. 40.54% had teaching experience of three years, 21.62% between three and six years and the rest (21.6 + 10.81 + 5.41) over six years (Appendix 5, sub-scale A, item 8).

According to the collected data, 56.76% (Appendix 5, sub-scale A, item 9) of the educators had facilities for practical work in chemistry and physics and 91.89% (Appendix 5, sub-scale A, item 10) had electricity at school. Only 4 educators did not have running water at school (Appendix 5, sub-scale A, item 11).

Almost all schools were incapable of buying their own science apparatus and chemicals (Appendix 5, sub-scale A, item 12). Of the participating educators, 59.46% (Appendix 5, sub-scale A, item 13) were provided with the micro-kits of Somerset by the Department of Education. 48.65% (Appendix 5, sub-scale A, item 14) did not have training in outcomes-based education. A few who did have

training, had it for a period of three days to over a month (Appendix 5, sub-scale A, item 15).

7.6 Discussion of results

Educators' responses to the questionnaire are tabulated in appendix 5, Sub-scales B–F (see Appendix 6). The frequency distribution of each item per sub-scale is indicated with its percentages. Note should be taken that the "missing frequencies" (respondents who left some of the questions blank, didn't choose any of the six options or who indicated their responses by highlighting 7) are not included in the frequencies and percentages of such specific items. However, the total number of the subjects (designated by (N)) who responded to the items or questions are indicated respectively. Where there is no indication, it should be taken that all the 37 educators responded to the item.

Discussion of the results is based on the effect sizes of each sub-scale (see Appendix 7, Table 12). However, during the discussion, in some cases reference was made to a specific item's effect sizes (see Appendix 6, Table 7-11) within a sub-scale. Appendix 8 shows the results of the evaluation of the SEDIBA Project administered to the physical science year 1 group of 2003, the same subjects that were used in the research under discussion. It should be noted that the results obtained in the project evaluation will be used to support the results of the research. Most of the items of the questionnaire that were administered for the project evaluation were, coincidentally, similar to those of the research. The difference is that the post-test for the project evaluation was administered nine months after the pre-test, while in the research it was administered three months after the pre-test. An evaluation of the project was done by Mrs. Du Toit, an independent researcher under the conditions mentioned in paragraph 5.7.

7.6.1 Discussion of result: sub-scale B (science curriculum)

This sub-scale dealt with the issues surrounding the science curriculum in secondary schools. The aim of this section was to establish educators' attitudes towards the present curriculum as adopted by the Department and the impact that the project would have on their understanding of the science curriculum. Most of the items were directed at determining the disposition towards outcomes-based

education and its broad generic cross-curricular outcomes, prescribed in the Constitution of the country and adopted by the South African Qualification Authority (SAQA).

However, according to the educator's responses, the effect size of the sub-scale was 0.16 (appendix 7, Table 12), a very low effect. This means that there was almost no practical change in the educators' attitudes towards the present curriculum. Nonetheless, it should be noted that at this stage of the course, the subject didactics of natural sciences do not deal with the issues of OBE in detail. The only section of OBE that is treated in this course is assessment, and that is done during the last year. This section of the school curriculum (i.e. OBE) is only dealt with in detail at a higher level (i.e. B.Ed. Hons. for Natural Sciences). Appendix 5, item 15, shows that most of the educators did not attend training courses in OBE. Therefore, because of a lack of knowledge in this regard, educators' understanding of OBE is affected. It should be noted that the environment plays an important role in development. If the conditions at school are not conducive to positive development, the educators' attitude towards the curriculum will also be affected. Management support and departmental innovations are vital to the equipping of educators with OBE skills and in-depth knowledge of what the OBE curriculum involves.

Contrary to the results of the research, a different picture emerges during the evaluation of the project (appendix 8). When responding to the question: "Did the SEDIBA course meet your expectations?" one student supported his/her answer by saying: "I now have a clear picture about OBE" (refer to appendix 8, number 3). Item 38 (appendix 6, table 7): "I need guidance in practical work (experiments) in science;" shows a medium effect. 81% of the students answered "yes" to the statement: "After this session I feel more confident to do experiments in my classes (appendix 8, number 2.4). Item 43 (appendix 6, table 7) is augmented by the statement: "... more confident to teach physical science at school," to which 93% of the students answered "yes" (appendix 8, number 2.1). This is an indication that, even though OBE itself is not taught to the educators, the approach to science teaching applied by lecturers is in line with the demands of science teaching. Furthermore, the approach enhanced their knowledge not only of OBE, but also of science teaching in general. Therefore, the SEDIBA programme has a

positive impact on the attitude of participating educators towards the science curriculum.

7.6.2 Discussion of result: sub-scale C (perception of science)

The aim with the items of sub-scale C was to probe respondents' information regarding their perception of science (i.e. what they believe science to be). The effect size for this sub-scale is 0.22 (appendix 7, table 12), which indicates a small effect.

Even the effect sizes of individual items indicate a small to medium effect (appendix 6, table 8). Hart (2002:4-5) indicates that, in order to change teachers' practices, teachers' beliefs need to be considered. However, beliefs are difficult to change, the beliefs teachers' espouse are not always consistent with the way they teach, and changing teachers' beliefs takes time since most beliefs are formed through experience over time. The small effect is due to the fact that, the post-test was administered after a very short space of time (i.e. within three months). Since there is a positive effect, it can be reasoned that the longer the educators are exposed to the project, the more positive their perception of science will be. This is supported by the results of the project evaluation (appendix 8). For example, the effect size for item 60 is 0.059 (appendix 6, table 8). This statement is similar to the statement: "... positive to physical science as subject", to which 95% responded by saying "yes" (appendix 8, number 2.7). Items 23, 47 and 77 (appendix 6, table 8) are rated over 81% (appendix 8 number 2.2). Items 54 and 66 that deal with teaching strategies (appendix 6, table 8) are rated 93%, the statement of which is: ".... motivated to try different methods of teaching" (appendix 8, number 2.6). Therefore, the SEDIBA project has a positive impact on participating educators' perception of science.

7.6.3 Discussion of result: sub-scale D (attitude towards science)

Sub-scale D deals with the attitude of educators towards science. The effect size for this sub-scale is 0.77 (appendix 7, table 12). This is a large effect which is practical significant for this research. These results are supported by the response in the evaluation of the project to the statement: "... positive to physical science as subject," to which 95% of educators answered "yes" (appendix 8, number 2.7). It

means that the attitude of the participating educators towards science has improved since they started attending classes at the University. A number of educators have this to say: "It has motivated and encouraged me to teach physical science as a subject", when responding to the question: "Did this SEDIBA course meet your expectations?" (appendix 8, number 3). As a science teacher, you need to show interest in the subject and also make your students enjoy science and to be able to go out there and teach it (Palmer, 2001:133). A teacher's attitude towards science is reflected in the time the teacher spends teaching science, and in the manner in which it is taught (Koballa, Jr. & Crawley, 1985:228-229).

This is confirmed by the responses of educators to items 22, 24, 26 and 34, to mention but a few (appendix 6, table 9). Item 22 has an effect size of 0.56 (appendix 6, table 9). The project evaluation (Appendix 8, number 3) had a similar statement that reads as follows: "I will use the knowledge I am equipped with to improve my teaching strategies and above all to produce good results". The response to this statement indicates a medium effect. This means that the educators' approach to teaching science has improved within a short space of time. This may be owing to the different approaches lecturers follow in the presentation of different courses. The reader is referred to paragraph 5.6 of this dissertation.

Also, one should make mention of the constructivist approach to science teaching and learning, a topic that is discussed in detail in the subject didactics course of the SEDIBA Project's first year (paragraph 4.4). Item 26 (appendix 6, table 9) also confirms the positive impact of the project on the attitude of educators towards science, even though the effect is 0.465, very close to a medium effect. After some time, 80% of the same educators answered "yes" to a similar statement that goes: "... that I have a better understanding of my pupils' problems" (appendix 8, number 2.8). This indicates that the SEDIBA Project has a positive impact on the attitude of participating educators towards science.

7.6.4 Discussion of result: Sub-scale E (Attitude towards science teaching)

Items of sub-scale E was aimed to probe participating educators' information regarding their attitude towards science teaching. The effect size for this sub-scale is 0.32 (appendix 7, table 12), a small effect. The items of this sub-scale also

reflect the small effect (appendix 6, table 10). Item 30 and 69 has an effect size of 0.278 and 0.366 respectively, indicating a small shift in a positive direction (appendix 6, table 10). Relative to such statements is the response to a statement that goes: "... more confident to do experiments in my classes", where 81% of the subjects answered "yes" (appendix 8, number 2.4). Item 72's d-value is 0.138 (appendix 6, table 10). To exactly the same statement, 63% of educators chose "totally disagree" as a response (appendix 8, number 4.3). Even though most educators perceived science teaching to be difficult (item 63, appendix 6, table 10), 62% of them answered "yes" to the statement: "... master of the subject" (appendix 8, number 2.3). To the same statement (item 63, appendix 6, table 10), 38% were negative (appendix 8, number 2.3). The positive shift in the attitude of educators towards science teaching may be ascribed to the fact that they were engaged in hands-on experiments with the Student Lab small-scale kit (see paragraph 6.5.3). This is an affirmation that the SEDIBA Project has a positive impact on the attitude of participating educators towards science teaching.

7.6.5 Discussion of result: sub-scale F (attitude towards chemistry and chemistry teaching)

Sub-scale F has an effect size of 0.58 (appendix 7, table 12), a moderately positive effect which indicates a positive effect on the attitude of educators. This is supported by statements in the project evaluation such as: "Physical science as a subject is interesting", "Physical science can be applied in everyday life", "Physical science helps me understand nature", to which educators' "yes" percentages were 98%, 98%, and 93% respectively (Appendix 8, number 4.1, 4.5 and 4.7). This could mean that educators did gain in positive attitude towards chemistry and this has positively increased their attitude towards chemistry teaching. Paragraph 6.5 explains in details the teaching procedures and strategies that are followed in the presentation of the chemistry syllabus. The explanation given in paragraph 6.5, correlates positively with the results regarding the change in attitude towards chemistry and laboratory experiences.

7.7 Discussion of results: quality control

The SEDIBA Project management is concerned over the quality of the project and the service it provides. In order to maintain its quality, a continuous evaluation of the project is carried out. Appendix 8 contains the results of the evaluation of the project given by the participating educators. It is evident from the result that all the important facets of the project are rated positively by almost all the educators (appendix 8, October; Evaluation of the whole course, Physical science: Year 1). It should be mentioned that, of the 39 educators, more than 30 categorically rated the chemistry course more than positively. Content, workbooks, textbook, practicals, presentation, assignments, number of contact hours and assessment were rated positively by 37, 30, 35, 30, 30, 15, 13 and 27 respectively, (appendix 8, October; Evaluation of the whole course, Physical science: Year 1). Not only courses are rated, even the administration is assessed and educators are given the opportunity to comment or make suggestions. 33 of the educators responded positively in their answers to the question: "How did you benefit from SEDIBA courses?" (appendix 8, administration).

7.8 Findings

In summary, there was an overall positive attitude shift in almost every item from pre-test to post-test, as well as in each sub-scale. This exploratory study generated evidence that suggested that an activity-centred science content course patterned after these SEDIBA Project programmes is influential in promoting positive attitudes towards chemistry and chemistry teaching among participating educators.

This evidence supports the results of studies previously done by different researchers:

- i) Hall (1992), who found that activity-centred, process-approach instruction, characterised by inquiry and discovery, promoted positive attitudes.
- ii) Lowery (1994), who emphasised that learning takes place best via first-hand, direct-inquiry experiences and progresses to depth and abstraction through representation and narrative or expository tasks.

iii) Cukrowska, Staskun & Schoeman,(1999:13), who found that positive perceptions of chemistry are a major factor in students' success.

iv) Hart (2002:4-5), who indicated that, in order to change teachers' practices; teachers' beliefs need to be considered. However, beliefs are difficult to change, the beliefs teachers' espouse are not always consistent with the way they teach, and changing teachers' beliefs takes time since most beliefs are formed through experience over time. The results of the evaluation of the project give a very good indication that attitude cannot be changed effectively within a short space of time.

The reason for the improvement in attitude can also be attributed to the engagement of educators in hands-on experiments with the Student Lab small-scale kit (see paragraph 6.5.3).

According to the research, attitude statements that generated the most positive responses in this study suggested that subjects in general:

- were of the opinion that the teaching method they use will allow learners to explore and discover new scientific concepts on their own;
- hoped to enjoy manipulating science equipment;
- acknowledged that the chemical industry plays a vital role in promoting national health;
- were satisfied that their training in science teaching was adequate to teach learners up to grade 12;
- did not experience greater disciplinary problems in their classes;
- thought children were curious about scientific matters;
- did not think teaching science took too much time and effort; and
- thought they would enjoy the laboratory period in the science courses they teach.

Because of exposure to hands-on practical, the results further confirm the findings by Cukrowska *et al.* (1999), Du Toit, Lachman & Nel,(1992) and Hall (1992), who argue that hands-on chemistry practical work:

- ❖ was effective in causing a change in the attitude of students;
- ❖ increased learning;
- ❖ increased motivation to learn;

- ❖ increased enjoyment of learning;
- ❖ increased skill proficiency, including communication skills;
- increased independent thinking;
- ❖ enhanced decision-making based on direct evidence and experiences; and
- ❖ increased perception and creativity.

7.9 Conclusion

The real effect of the programme on the attitude of the educators towards chemistry can be interpreted as the decrease in the number of the initially less positive educators who were influenced to respond in a positive way in the post-test. It should be noted that attitude change does not take place in a short space of time but rather after long exposure to an attitudinal object. The report by Du Toit (2003) supports this. The author does not take it for granted that this observed change will be permanent, but it does indicate that good and interesting presentation can influence educators (Du Toit *et al.*, 1991:51). This work adds to the body of evidence that attitude towards science influences achievement, with the additional idea that a hands-on laboratory programme influences the attitude towards science of educators and influences their achievement in science knowledge. The results and conclusion of this investigation add to the evidence supporting the Schibeci and Riley model (as indicated by Freedman, 1997:353-354).

The next chapter (Chapter 8) gives a summary of the study and recommendations based on the results of the study.

CHAPTER 8

SUMMARY AND RECOMMENDATION

8.1 Introduction

This Chapter gives a summary of the different chapters of the dissertation, and some recommendations. The recommendations are based on the results of the study. In support of the results, there are the results of the report of the project evaluation. It is envisaged that when applied appropriately, these recommendations will be helpful in alleviating problems associated with the attitude of educators towards chemistry and chemistry teaching. Emerging from the research, exposure to the programme alleviates problems associated with strategies in science teaching and attitude towards science and practicals.

8.2 Summary

This study was aimed at investigating the impact of the SEDIBA programme on the attitude of participating educators towards chemistry and chemistry teaching. The study was motivated by a number of factors. According to the results obtained by a number of researchers (Hart, 2002; Gilbert, 1991; Yore, 1991; Hofstein *et al.*, 1990; Koballa, Jr., & Crawley, 1985; Hall, 1992; Altun & Kaya, 1996; Levitt, 2001) not only students, but also educators have a negative attitude towards chemistry and chemistry teaching. The indications are that, after the birth of the SEDIBA Project, there has been an improvement in matric results of SEDIBA alumni in the North West Province of South Africa. Summaries of different chapters of this study are presented in 8.2.1 - 8.2.7. These summaries are in line with the objectives in 1.4.

8.2.1 Chapter 1

Chapter 1 presents an orientating introduction. It analyses various studies conducted on the different attitude-related factors affecting the teaching of chemistry in secondary school and the impact of the SEDIBA programme on the attitude of educators, which prompted the execution of this research. A

comprehensive motivation for conducting this study is presented, which includes the hypothesis, the objectives of this study and the envisaged methodology.

8.2.2 Chapter 2

An overview is given in this chapter of the literature study conducted on attitude and attitude changes. The attitude-related variables surveyed include definitions of attitude, theories of attitude, attitude formation, and factors influencing science-related attitudes, attitude measurement and standard attitude scales.

8.2.3 Chapter 3

Chapter 3 elaborates in detail on factors contributing to attitude change, the roles of attitude towards teaching and learning of science, attitude change and procedures for attitude exchange.

8.2.4 Chapter 4

This chapter is concerned with purposeful teaching and learning. It elaborates on topics such as the theory of science learning, learning science, constructivism and understanding of science. It is in this chapter where the objectives of outcomes-based education are discussed, as well as aspects of visualisation in science teaching and learning.

8.2.5 Chapter 5

Chapter 5 discusses teacher development programmes, with special emphasis on distance education and in-service training. It further explores assessment of lecturers and the best procedure for quality assurance within development programmes.

8.2.6 Chapter 6

A detailed explanation of what the SEDIBA is and what is being done in the project is given in this chapter. It further gives the aims and objectives of the SEDIBA Project, how SEDIBA was started and how it operates. The SEDIBA Project

chemistry syllabus is discussed, as are the teaching strategies implemented in the SEDIBA chemistry syllabus. An elaboration on the Student Lab small-scale kit is also given.

8.2.7 Chapter 7

This Chapter 7 consists of the empirical study and results. The aims of the empirical study are outlined, and the method followed in the compilation of a questionnaire is set out. A discussion is also given of how data were gathered and processed using the SAS program. The result of the research is also discussed in Chapter 7, with special reference to the report on the evaluation of the SEDIBA science course. It is evident from the discussion of the empirical study that the SEDIBA programme has a positive impact on the attitude of educators towards chemistry and chemistry teaching. This confirms the hypothesis of this study that *the SEDIBA programme has a positive impact on the attitude of participating educators towards chemistry and chemistry teaching.*

8.3 CONSTRAINTS OF RESEARCH

The research was completed within a shorter space of time than had been envisaged, namely within three months. The intention was to administer a similar questionnaire to educators every contact session for a period of a year. Due to a lack of co-operation, unfaithfulness and bias, the research was terminated. These factors became evident when the questionnaire was administered for the third time in July 2003. Eighty percent of the educators responded by saying: "undecided" to almost all the items. This questionnaire was thus nullified.

A few statements which were not complete also caused some problems. Fortunately the researcher was able to save the situation. Most of the educators did not understand the importance of research in general. They assume that it benefits the researcher and not the community. Failure to understand the purpose of research brings about conflict between the researcher and the subjects.

8.4 RECOMMENDATIONS

The findings presented in this study support the recommendations made by Hall (1992), who argues that the strategies and methods featured in his research be incorporated into the college science courses for secondary school science teachers. A similar recommendation applies to the SEDIBA Project. During incorporation, a hands-on laboratory technique must be emphasised as part of the science curriculum because it offers a prescriptive method for raising achievement levels and promoting positive attitudes towards science among science educators. The programme proposed here appears to be effective with educators of diverse backgrounds. Therefore it will be beneficial to society in both the North West Province and South Africa for instilling and sustaining a positive attitude towards chemistry and science in general.

8.5 INTERVENTION STRATEGIES

Negative attitudes towards science and science teaching, particularly among science teachers, could have a serious and long-lasting impact on student and teacher performance within the province. Thus a primary goal in teacher education programmes should be to design and to implement specific courses, strategies and methods that promote attitude towards science and science teaching among educators (Hall, 1992).

Attitudes are not easily changed. In order to change teachers' practices, teachers' beliefs need to be considered. However, beliefs are difficult to change, the beliefs teachers espouse are not always consistent with the way they teach, and changing teachers' beliefs takes time, since most beliefs are formed through experience over time. This increases the importance of the development of a positive attitude towards chemistry and chemistry teaching in colleges of education. Perhaps equally important is alerting educators to negative attitudes and to their likely effects ("forewarned is forearmed").

8.6 RECOMMENDATIONS FOR FURTHER RESEARCH

Further studies to investigate the generality of the findings presented above are recommended, but the researcher believes they are sufficiently indicative of the impact of the SEDIBA programme on the attitude of educators towards chemistry and chemistry teaching. Perhaps some components of these attitudes might even be traced to experiences in science instruction in primary schools.

8.7 CONCLUSION

It is clear from the research that the SEDIBA Project is capable of changing the attitude of participating educators from a negative attitude towards chemistry and chemistry teaching to a positive attitude. Efforts to improve the attitudes of vulnerable educators should certainly be considered, perhaps through continuous workshops, support groups and counselling by the subject advisors. It is evident from the research that the SEDIBA programme has a positive impact on the attitude of participating educators towards chemistry and chemistry teaching.

BIBLIOGRAPHY

- AIKEN, D.R. & AIKEN, L.R., Jr. 1969. Recent research on attitudes concerning science. *Science education*, 53(4):295-303.
- AJZEN, I. 1996. Attitudes (*In Concise encyclopaedia of psychology*, 1:75-76.)
- ALTUN, E. & KAYA, S. 1996. Measurement of the confidence, attitudes, and self-image of Turkish student-teachers in relation to chemistry education. *International journal of science education*, 18(5):569-567.
- ANASTASI, A. 1988. Psychological testing. 6th ed. New York : Macmillan.
- ANDERSON, L.W. 1994. Attitudes, measurement of. (*In International encyclopaedia of education*, 1:380-390).
- APPLE, M.W. 1992. Educational reform and educational crisis. *Journal of research in science teaching*, 29(8):779-789.
- BELL, B. & GILBERT, J. 1996. Teacher development: A model from science education. London : Falmer Press
- BLYTHE, T. & ASSOCIATES. 1998. The teaching for understanding guide. San Fransisco : Jossey-Bass. [Web] <http://learnweb.havard.edu/alps/tfu/info3f.cfm>. [Date of access: 6 May 2003].
- BROUDLY, H.S. 1978. In-service teacher education: Paradoxes and potentials. (*In* _Rubin, J. ed., The in-service education of teachers: Trends, processes, and prescriptions. London : Allyn and Bacon, Inc. p.58-67)
- BROWN, R. & RACE, P. 2002. Lecturing: A practical guide. London : Kogan Page.

- CAVALLO, A.M.L. & SCHAFER, L.E. 1994. Relationships between student's meaningful learning orientation and their understanding of genetics topics. *Journal of research in science teaching*,31(4):393-418.
- CAMPBELL, B., KAUNDA, L., ALLIE, S., BUFFLER, A., & LUBBEB, F. 2000. The communication of laboratory investigations by university entrants. *Journal of research in science teaching*, 37(8):839-853,
- CHIN, C. & BROWN, D.E. 2000. Learning in science: A comparison of deep and surface approaches. *Journal of research in science teaching*, 37(2):109-138.
- COHEN, J. 1988. Statistical power analysis for the behavioral sciences. 2nd ed. New Jersey : Hillsdale.
- COTTON, J. 1995. The theory of learning: An introduction. London : Kogan.
- CRONIN-JONES, L & SHAW, E.L., Jr. 1992. The influence of methods instruction on the beliefs of pre-service elementary science teachers: preliminary comparative analyses. *School science and mathematics*,92(1):14-22,Jan.
- CUKROWSKA, E., STASKUN, M.G. & SCHOEMAN. 1999. Attitudes towards chemistry and their relationship to student achievement in introductory courses. *South African journal of chemistry*,52(1):8-14, Dec.
- DAMNJANOVIC, A. 1999. Attitude towards inquiry-based teaching: Differences between pre-service and in-service teachers. *School science and mathematics*,99(2):71-76, Feb.
- DAVIS, D. & OSTROM, T. 1996. Attitude measurement. (In Concise encyclopaedia of psychology, 1:72-73).
- DeBEAR, R.S. 1988. Performance indicators. [Web:] <http://yesican.yorku.ca/home/overview.html>. [Date of access: 5 April. 2002].

DECHSRI, P., JONES, L.L. & HEIKKINEN, H.W. 1997. Effect of laboratory manual design incorporating visual information-processing aids on student learning and attitudes. *Journal of research in science teaching*,34(9):891-904,

De CORTE, E. & WEINERT, E.F. 1996. Attitudes and values, acquiring. Britain : Pergamon.

DéSAUTELS, J. & LAROCHELLE, M. 1998. About the epistemological posture of science teachers. [Web:] <http://pluslucis.univie.ac.at/ICPE/D3.html>. [Date of access: 25 April.2002].

DILOTSOTLHE, K.E. 1999. The role and functions of the physical science subject advisor in the North West Province. Potchefstroom : PU for CHE.

DOLO, R.T. 2000. The implication of computer-assisted learning in the teaching of chemical change. Potchefstroom : Potchefstroom University for Christian Higher Education.

DRIVER, R., GUESNE, E. & TIBERGIE, A. 1985. Children's ideas in science. Milton Keynes : Open University Press.

DU TOIT, S.C. 2003. Evaluation of the whole course, Physical science. (Report submitted to the management of SEDIBA project at the PU for CHE on 7 November 2003.) Potchefstroom. 15p (Unpublished.)

DU TOIT, C.J., LACHMANN, G., NEL, S.J., VREKEN, N.J. & VAN SCHALKWYK, P. 1991. Survey of the influence of a demonstration programme on the attitude of high-school students towards chemistry. *South African journal of education*, 11(2):49-54, May.

DU TOIT, C.J., LACHMANN, G., NEL, S.J. 1992. Survey of factors influencing the attitude of Afrikaans-speaking high school and university student towards chemistry. *South African journal of education*,12(3):261-266.

DYKSTRA, D.I. Jr., BOYLE, F.C., & MONARCH, A.I. 1992. Studying conceptual change in learning physics. *Science education*, 76(6):615-652.

EDWARDS, A.L. 1983. Techniques of attitude scale construction. New York : Irvington

ELLIS, R.S. 1993. Impacting the science attitudes of minority high school youth. *School science and mathematics*,93(8):400-407,Dec.

FINSON, K.D. 1989. Assessment of a pilot program for in-service teachers. *Science education*,73(4):419-431, Jul.

FISHBEIN, M. & AJZEN, I. 1975. Beliefs, attitude, intention and behavior: An introduction to theory and research. Philippines : Addison-Wesley, Inc.

FRASER, B. & LOMBARD, E. 2002. Prominent paradigms of performance and the dilemma of distance education to deliver. *Perspectives in education*, 20(3):85-100, Sep.

FREEDMAN, M.P. 1997. Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of research in science teaching*,34(4):343-357.

GALLARD, A.J. & GALLAGHER, J.J. 1994. A case study of a national science curriculum and teacher conflict. *International journal of science education*,16(6):639-648.

GILBERT, S.W. 1991. Model building and a definition of science. *Journal of research in science teaching*, 28(1):73-79,

GIL-PEREZ, D. & CARVHALHO, A. M.P. 1998. Physics teachers training: analysis and proposals. [Web:] <http://pluslucis.univie.ac.at/ICPE/D4.html>. [Date of access: 25 April. 2002].

GUNSTONE, R. F. & WHITE, R.T. 1998. Teachers' attitudes about physics classroom practice. [Web:] <http://pluslucis.univie.ac.at/ICPE/D1.html>. [Date of access: 25 April. 2002].

- HALL, D.A. 1992. The influence of an innovative activity-centered biology program on attitudes towards science teaching among pre-service elementary teachers. *School of science and mathematics*,92(5):239-243, May/Jun.
- HALLORAN, J.D. 1967. Attitude formation and change. Leicester University Press
- HART, L.C. 2002. Pre-service teachers' beliefs and practice after participating in an integrated content/methods course. *School of science and mathematics*,102(1):4-11, Jul.
- HARTY, J. & ENOCHS, L.G. 1985. Towards reshaping the in-service education of science teachers. *School science and mathematics*,85(2):125-135, Feb
- HESSE, J.J.III., & ANDERSON, C.W. 1992. Students' conceptions of chemical change. *Journal of research in science teaching*,29(3):277-299,
- HODSON, D. 1998. Teaching and learning science. (Towards a personalized approach). Buckingham. Philadelphia : Open University Press.
- HODSON, D. 1996. Practical work in school science: exploring some directions for change. *International journal of science education*,18(7):755-760.
- HOFSTEIN, A., BEN-ZVI, R., & WELCH, W.W. 1981. Some aspects of scientific curiosity in secondary school students. *Journal of science education*,65(2):229-235.
- HOFSTEIN, A. MAOZ, N. & RISHPON, M. 1990. Attitudes toward school science: comparison of participants and non-participants in extra-curricular science activities. *School science and mathematics*,90(1)13-22, Jan.
- HOUTZ, L.E. 1995. Instructional strategy change and attitude and achievement of seventh- and eighth-grade science students. *Journal of research in science teaching*,32(6):629-648.

IMENDA, N.S. 1993. Assessment of lecturer performance. *Sajhe/Satho*,7(3):148-151

JACOBS, M., GAWE, N. & VAKALISA, N.C.G. 2002. Teaching-Learning Dynamics: A participative approach for OBE. 2nd ed. Johannesburg : Heinemann

JANSEN, J.D. 1999. Setting the scene: Historiographies of curriculum policy in South Africa. (In Jansen, J. & Christie, P., eds., *Changing curriculum: Studies on outcomes-based education in South Africa*, Kenwyn: Juta & Co, Ltd. p3-18).

JANSEN, J.D. 1999. "A very noisy OBE: The implementation of OBE in Grade 1 classroom. (In Jansen, J. & Christie, P. eds., *Changing curriculum: Studies on outcomes-based education in South Africa*, Kenwyn: Juta & Co, Ltd. p203-217).

JONES, S. 1997. Values and attitudes. [Web:]
[http://management.canberra.edu.au/lectures/administudies/sem97/Values and attitudes.html](http://management.canberra.edu.au/lectures/administudies/sem97/Values_and_attitudes.html). [Date of access: 26 March 2002].

KEOGH, B. & NAYLOR, S. 1996. Teaching and learning in science: a new perspective. [Web:] <http://www.leeds.ac.uk/educol/documents/000000115.html>. [Date of access: 13 Feb. 2003].

KERRIDGE, J.R & MATHEWS, B.P. 1998. Student rating of courses in HE: further challenges and opportunities. *Assessment & evaluation in higher education*,23(1):71-82, Mar.

KOBALLA, T.R., Jr. 1992. Persuasion and attitude change in science education. *Journal of research in science teaching*,29(1):63-80.

KOBALLA, T.R., Jr. 1989. Research matters - to the science teacher. [Web:] <http://www.educ.sfu.ca/narstsite/research/attitude.html>. [Date of access: 24 Aug. 2002].

KOBALLA, T.R., Jr. & CRAWLEY, F.E. 1985. The influence of attitude on science teaching and learning. *School of science and mathematics*,85(3):222-231.

- KÖLLER, O.; BAUMERT, J. & SCHNABEL, K. 2001. Does interest matter? The relationship between academic interest and achievement in mathematics. *Journal for research in mathematics education*,32(5):448-470
- KOTZ, J.C. & TREICHEL, P. Jr. 1999. Chemistry and chemistry reactivity. 4th Ed. Florida : Saunders College Publishing.
- KÜHNELT, H. & STADLER, H. 1997. Combined updating on science and pedagogy for experienced teachers. *Research in science education*, 27(3):425-444,
- LEVITT, K. 2001. An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Journal of science education*,86:1-22.
- LINN, C.M. 1992. Science education reform: Building on the research base. *Journal of science teaching*,29(8):821-840
- LOWERY, L.F. 1994. Inquiry: the emphasis of a bold, new science curriculum. *Science-study and teaching; educational technology*, 21(8)50(2p), March. [In EBSCOHost: Academic Search Premier, Full display: <http://www.sa.ebsco.com>] [Date of access: 22 June 2002].
- MALCOLM, C. 1994. Structures, force and stability. Design a playground (Year 6). (In Fensham, P., Gunstone, R. & White, R., eds., The content of science, London : Falmer. p59-79.)
- MEICHTRY, J.Y. 1993. The impact of science curricula on student views about the nature of science. *Journal of research in science teaching*,30(5):429-443
- MESTRE, J.P. 1994. Cognitive aspects of learning and teaching science [Web:] <http://umperg.physics.umass.edu/PhysicsEdResearch/ReviewPaper>. [Date of access: 13 Feb. 2003].
- MONK, D. 2001. Open/distance learning in the United Kingdom. Why do people do it here (and elsewhere)? *Perspectives in education*,19(3):53-66,Oct.

- NICHOLS, J.D. & MILLER, R.B. 1994. Cooperative learning and student motivation. *Educational psychology*, 19(1):167-178.
- NOLEN, S.B. & HALADYNA, T.M. 1990. Motivation and studying in high school science. *Science teaching*, 27(2):115-126.
- NOVAK, J.D. 2002. Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. *Science education*, 86:548-571,
- NOVODSVORSKY, I. 1997. Constructing a deeper understanding. *The physics teacher*, 35:242-245.
- OLIVIER, C. 2001. Let's educate, train and learn outcomes-based: A 3D experience in creativity. Ifafi. OBET Pro.
- OSTROM, T. 1996. Attitude theory. (In Concise encyclopaedia of psychology, 1:73-75).
- PALMER, D.H. 2001. Factors contributing to attitude exchange amongst pre-service elementary teachers. *Science teacher education*, 86:122-138.
- PASELK, R.A. 1994. Visualization of the abstract in general chemistry. *Journal of chemical education*, 71(3):225, Mar.
- PENDLEY, B.D., RICHARD, L.B., & NOVAK, J.D. 1994. Concept maps as a tool to assess learning in chemistry. *Journal of chemical education*, 71(1):9-16, Jan.
- PERKINS, D. 1993. Teaching for understanding. American educator: *The professional journal of the American federation of teachers*, 17 (3): 23-35. [Web:] <http://www.exploratorium.edu/IFI/resources/workshops/teachingforunderstanding.html>. [Date of access: 6 May 2003].

- PUK NEWS. 2002. Programme addressed nationwide: Education crisis. Potchefstroom : PUK for CHE. [Web]
<http://www.puk.ac.za/nuus/eng/news23.html>. [Date of access: 13 May 2003]
- PUK NEWS. 2003. Community service. Potchefstroom : PUK for CHE. [Web]
<http://www.puk.ac.za/oorsig/eng/ikateleng.html>. [Date of access: 13 May 2003]
- RACE, P. 1999. 2000 tips for lecturers. London: Kogan Page.
- ROKEACH, M. 1972. Beliefs, attitudes, and value: A theory of organization and change. San Francisco : Jossey-Bass.
- RUBIN, L. 1978. Preface. (*In* Rubin, J. ed., The in-service education of teachers: Trends, processes, and prescriptions. London : Allyn and Bacon, Inc. p ix-xv).
- SANGARI. 2002. Student Lab: Overview. [Web :]
<http://www.sangari.co.za/www.studentlab.co.za/overview.htm>. [Date of access: 19 May. 2003]
- SAS Institute Inc., 1999. The SAS System for windows release 8.02 TS Level 02M0
- SCHOLL, R.W. 2000. Attitude and attitude change. [Web:]
<http://www.cba.uri.edu/Scholl/Notes/Attitudes.htm>. [Date of Access: 26 March.2002].
- SHE, H. & FISHER, D. 2002. Teacher communication behavior and its association with students' cognitive and outcomes in science in Taiwan. *Journal of research in science teaching*,39(1):63-78.
- SHUELL, T.J. & MORAN, K.A. 1994. Learning theories: Historical overview: (*In* *International encyclopedia of education*,(6):3340-3345)
- SHUSTERMAN, G.P. & SHUSTERMAN, A.J. 1997. Teaching chemistry with electron density models. *Journal of chemical education*,74(7):771-776, Jul.

SHYMANSKY, J.A., KYLE, Jr. W.C. & ALPORT, J.M. 1983. The effects of new science curricula on student performance. *Journal of research in science teaching*,20:387-404.

SHYMANSKY, J. A. & KYLE, W.C., Jr. 1992. Establishing a research: Critical issues of science curriculum reform. *Journal of research in science teaching*,29(8):749-778.

SHYMANSKY, J. A. & KYLE, W.C., Jr. 1992. Overview: Science curriculum reform. *Journal of research in science teaching*,29(8):745-747.

SMIT, J.J.A. 1995. Models in physics: perceptions held by final-year prospective physical science teachers studying at South African universities. *International journal of science education*,17(5):621-634.

SMIT, J.J.A. *project leader*. 1997. The training of physical science teachers in the North West Province. (Report of a study undertaken by the University of Potchefstroom and North West, in cooperation with the North West Education Department, for the Foundation for Research Development. Potchefstroom : Potchefstroom University for CHE.). *South African journal of chemistry*,52(1):8-14, Dec.

SOUZA BARROS, S. & ELIA, M. F. 1998. Physics teacher's attitudes: How do they affect the reality of the classroom and model for change? [Web:] <http://pluslucis.univie.ac.at/ICPE/D2.html>. [Date of access: 2 April. 2002].

STEYN, H.S., jr. 2000. Practical significance of the difference in means. *Journal of industrial psychology*,26(3):1-3.

STEYN, P. & WESI, R.P. 1998. Project Sediba: a programme for upgrading physical science and mathematics teachers in South Africa. *Chemistry international*,20(1):6-9.

- TIEN, L.T., ROTH, V. & KAMPMEIER, J.A. 2002. Implementation of peer-led team learning instructional approach in an undergraduate organic chemistry course. *Journal of research in science teaching*, 39(7):606-632.
- TRIANDIS, H.C. 1971. Attitude and attitude change. New York : John Wiley & Sons, Inc
- TROWBRIDGE, L.W. & BYBEE, R.W. 1996. Teaching secondary school science: strategies for developing scientific literacy. 6th Ed. New Jersey : Merrill.
- TRUNFIO, P., BERENFELD, B., KREIKEMEIER, P., MORAN, J. & MOODLEY, S. 2003. Molecular modeling and visualization tools in science education. Symposium presented at the 2003 annual meeting of the National Association of Research in Science Teaching (NARST) in Philadelphia, March. [Web:] <http://polymer.bu.edu/narst2003/>. [Date of access: 6 Nov. 2003]
- TSAI, C.-C. 1999. "Laboratory exercise help me memorize the scientific truths": A study of eighth graders' scientific epistemological views and learning in laboratory activities. *Science education*, 83: 654-674,
- UVAROV, E.B. & ISAACS, A. 1993. The penguin dictionary of science. 7th Ed. New Zealand :Penguin
- VAN DRIEL, J., DE JONG, O. & VERLOOP, N. 2002. The development of pre-service chemistry teachers' pedagogical content knowledge. *Journal of science teacher education*, 86(4):572-590.
- VAN DEN BERG, E. 1996. Science teacher development in developing countries. *Science education international*, 7(3):3-8, Sept.
- VAN NIEKERK, D. 1995. Course evaluation in distance learning education. *Prograssio*. 17(1) 102-125.
- VAN NIEKERK, R.J. 1978. Indiensopleiding van onderwyser, teorie en praktyk met toespitsing op ontwikkelende lande. Bloemfontein : Universiteit van die Oranje-Vrystaat, Des.

WESI, P.R. 1997. Conceptualization of core concepts in electricity by physical science teachers. Potchefstroom : PU for CHE. (Dissertation – MEd.)

WHITE, R.T. 1996. The link between the laboratory and learning. *International journal of science education*,18(7):761-774,

WHITE, R.T. 1988. *Learning science*. Oxford : Blackwell

WOOD, W. 2000. Annual review of psychology: Attitude change: Persuasion and social influence. [Web:]
http://www.findarticles.com/cf_dls/m0961/2000_Annual/61855636/print.jhtml.
[Date of access: 10 Sept. 2002].

YORE, L.D. 1991. Secondary science teachers' attitudes toward and beliefs about science reading and science textbooks. *Journal of research in science teaching*,28(1):55-72.

ZEMBYLAS, M. 2002. Constructing genealogies of teachers' emotions in science teaching. *Journal of research In science teaching*,39(1):79-103,Jul.

APPENDIX 1

Example of worksheets used by SEDIBA students

EXPERIMENT 3 (Grade 10)

PROBLEM QUESTION

Which one of the following metal oxides, lead(IV) oxide, copper(II) oxide, and magnesium oxide will lose the bonded oxygen the easiest when heated?

1. OUTCOMES

General:

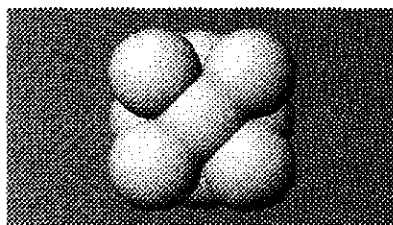
- Learners should be able to give the **scientific explanation** for the phenomena that fall within their field of study.
- ♦ The learner should develop the ability to **observe** carefully and to **solve problems** by applying the scientific method of reasoning and scientific procedures.

Specific:

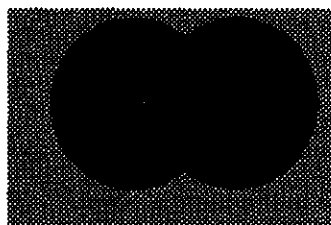
- ♦ The learner should be able to **decompose metal oxides** into their components.
- ♦ The learner should understand the concept of **chemical bonding**.

2. BACKGROUND KNOWLEDGE

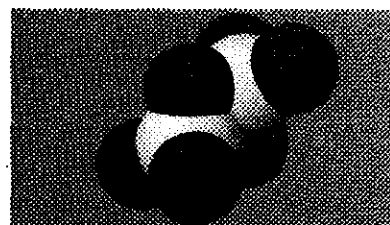
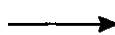
(i) The breaking and forming of chemical bonds is an inherent part of a chemical reaction. Consider the following reaction:



2Al +



3Br_2



Al_2Br_6

The aluminium atoms must break away from the aluminium metal and the chemical bond between the bromine atoms in the bromine molecule must break before a new molecule, aluminium bromide, can form

When lithium (a metal) reacts with oxygen the chemical bond between the lithium atoms is broken to produce independent lithium atoms. The covalent bond between the two oxygen atoms in the oxygen molecule is broken to

produce two independent oxygen atoms. The lithium atoms then react with the oxygen atoms to form a new and different type of chemical bond, an ionic bond.

(ii) Give the chemical equation for the formation of lithium oxide in words and as a formula. Remember to balance the equation.

(i)

Reaction equation in words	<i>Lithium + oxygen $\longrightarrow$ lithium oxide</i>
Reaction equation as a formula	<i>$4\text{Li(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{Li}_2\text{O(s)}$</i>

(iii) Can the metal oxide again be decomposed into the metal and oxygen by heating (give a motivation for your answer)?

(k)

Yes, if the bonds that formed between the atoms are not too strong. If the bonds are too strong you will need "better" methods to break them again

(iv) The more vigorously the metal and the oxygen react, the stronger the bond between the metal and the oxygen will be and the more difficult it will be to decompose the metal oxide into metal and oxygen by heating. In Experiment 1 you reacted lithium with oxygen, and every day you see iron reacting with oxygen; which metal oxide will be the easiest to decompose? (k)

Iron oxide

Inversely the greater the difficulty with which a metal oxide decomposes (gives off the oxygen) the more vigorously it originally reacted with oxygen. It can be determined how vigorously a metal will react with oxygen by heating its metal oxide.

(v) What do you think can be done to encourage the metal oxide to decompose when it is heated? (i)

Heat the metal oxide more strongly at a higher temperature

Use an extra substance to encourage the bonds between the metal and the oxygen to break more easily

If the metal oxide cannot be decomposed by heating, the metal oxide can be mixed with carbon and then be heated. The carbon reacts with the oxygen in the metal oxide, and the pure metal is obtained.

Read the problem question once more. The given metal oxides must be decomposed by heating or by mixing the metal oxide with carbon, and the subsequent heating of the mixture. Finally you have to make a conclusion regarding the relative strength of the ionic bonds in the three metal oxides.

(v) How will you go about testing whether oxygen was liberated (formed) in the reaction? (k)

***Insert a glowing toothpick into the heated test tube containing the metal oxide.
If the glowing toothpick ignites, oxygen was given off during the
heating process***

(vi) Which of the three metal oxides do you think will release the bonded oxygen the easiest? (i)

Any one of the three given metal oxides

3. EXECUTION OF AN EXPERIMENT TO ANSWER THE PROBLEM QUESTION

Apparatus:

1x student lab apparatus stand, 1x spatula, 4x test tubes, microburner, 3x toothpicks, 1x test tube holder (clothes peg).

Chemicals:

Solids: copper(II) oxide (CuO), magnesium oxide (MgO), lead(IV) oxide (PbO₂) and carbon(s)

Liquids: 4 cm³ limewater {Ca(OH)₂} (see preparation of solutions for the technique to prepare limewater).

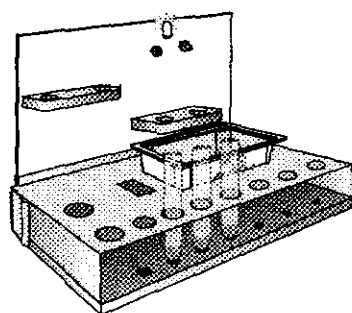
WARNING

- Calcium hydroxide is an irritant and can do serious damage to eyes. Do not breathe in the dust and avoid contact with skin. In case of contact rinse with plenty of water.
- Lead(IV) oxide is toxic and harmful by inhalation and if swallowed. Avoid exposure. (Restricted to professional users.)
- Lead may cause lead poisoning. Wash your hands thoroughly after working with lead.
- Copper(II) oxide is harmful if swallowed. Do not breathe in the dust.
- Copper is not a hazard.
- Magnesium oxide is not completely harmless, do not breathe in the dust.
- Magnesium is highly flammable and contact with water liberates extremely flammable gases.

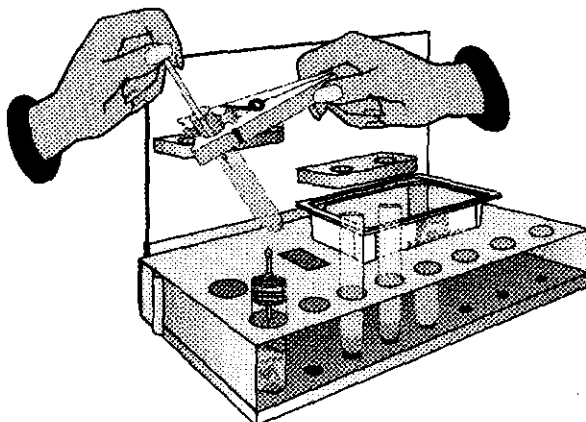
Method 1

Heating of metal oxides without carbon

1. Set up the apparatus as shown in the sketch. (M)



2. Add one spatula of each of the metal oxides: lead(IV) oxide (PbO_2), copper(II) oxide (CuO) and magnesium oxide (MgO) into three different test tubes. (M)
3. A hot flame is needed for the experiment. Pull out approximately 10 mm of the wick of the burner to obtain a bigger flame, and insert the burner into the front burner opening.
4. Use the test tube holder (clothes peg) to hold the test tubes and heat each of the test tubes in the flame of the microburner. (M)
5. Test each of the three test tubes for the liberation of oxygen during the heating process, as shown in the sketch. **It is important** to get your test procedure (v) ready before you start heating the oxide otherwise all the oxygen will be gone (if any is released) before you can test for the presence of oxygen! (M)



6. Carefully note whether changes in colour or any other visual property occurs. (o)
7. Complete the following table as a summary of your results: (r)

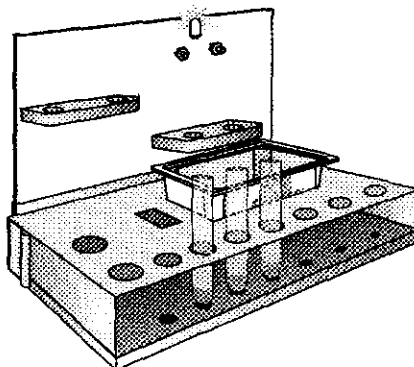
Metal oxides	Observations during heating	Reaction equation
Lead(IV) oxide	<i>Oxygen is liberated.</i>	$2\text{PbO}_2 \longrightarrow 2\text{PbO} + \text{O}_2$
	<i>Metal oxide changes from brown</i>	
	<i>(PbO_2) to yellow (PbO).</i>	
Copper(II) oxide	<i>No oxygen is liberated.</i>	<i>None</i>

	No colour change is observed.	
Magnesium oxide	No oxygen is liberated	None
	No colour change is observed	

Method 2

Heating of the metal oxides mixed with carbon

1. Set up the apparatus as shown in the sketch. (M)



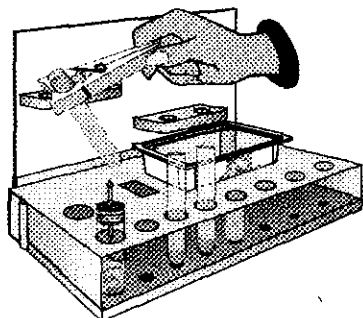
2. Add two spatulas of each of the metal oxides: lead(IV) oxide (PbO_2), copper(II) oxide (CuO) and magnesium oxide (MgO) into three different test tubes. (M)
3. Add one spatula of carbon to each of the test tubes and mix the content with the spatula (be careful to wipe the spatula clean after stirring the content of each test tube). (M)
4. In step 9 you will be heating each of the test tubes very strongly with the microburner. You will also test the gas given off if the metal oxide decomposes. Do you think the gas liberated in this case will be oxygen, or will it be another gas? Remember carbon was added to enhance the decomposition of the metal oxide by having it react it with the oxygen. (i)

CO_2 is given off in these reactions.

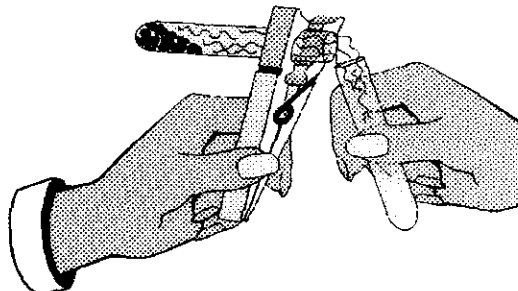
5. To test whether carbon dioxide is given off (liberated) during the heating process, you have to follow the following procedure: (M)

Put 1 cm³ of limewater in a test tube. Place the test tube in the COR.S₃ apparatus stand. Use the clothes peg to hold the test tube and heat the test tube containing the lead(IV) oxide (PbO_2) and carbon mixture strongly (use a large flame) for 4 minutes. Try to keep the test tube upright while heating it in the flame (note sketch A). Note any changes to the mixture in the test tube while heating it. Remove the test tube from the flame and "pour" the gas, if any, into the test tube containing the limewater (sketch B).

SKETCH A



SKETCH B



Use the finger protection device and shake the test tube containing the limewater and added gas.

6. Does the limewater change colour? Give an explanation for your observations.

(o)(i)

The limewater turns milky. Reason: CO_2 was liberated, the CO_2 reacts with the limewater and it turns milky.

7. In step 5 you had to keep the test tube upright while heating the content, and then you had to "pour" the gas from the first test tube into the other test tube containing the limewater. Which property of carbon dioxide is utilised in this activity?

(i)

Carbon dioxide is heavier than air and accumulates in the bottom part of the test tube.

8. Did you observe anything while heating the lead(IV) oxide (PbO_2) + carbon mixture?

(o)

The mixture developed a red glow after a few minutes of intense heating.

9. Allow the test tube with the lead(IV) oxide (PbO_2) + carbon mixture to cool and investigate the product. What is your observation?

(o)

Lead metal was formed in the test tube.

10. Your next step is to heat the carbon + copper(II) oxide (CuO) and carbon + magnesium oxide (MgO) mixtures in the same way as described above. Use the same procedure to test the gas liberated, if any.

(M)

11. Complete the following table as a summary of your results:

(r)

Metal oxide + carbon	Observation during heating	Reaction equation
Lead(IV) oxide + carbon	Carbon dioxide is liberated (formed) Metal oxide changes from brown PbO_2 to Pb metal.	$\text{PbO}_2(\text{s}) + \text{C}(\text{s}) \longrightarrow \text{Pb}(\text{s}) + \text{CO}_2(\text{g})$

Copper(II) oxide + carbon	Carbon dioxide is liberated (formed)	$2\text{CuO(s)} + \text{C(s)} \longrightarrow 2\text{Cu(s)} + \text{CO}_2\text{(g)}$
	Copper(II) oxide changes to Cu metal.	
Magnesium oxide + carbon	No carbon dioxide is formed.	None
	Magnesium oxide undergoes no	
	Colour change.	

12. Study the two tables in steps 7 and 14 and answer the problem question. Compare your answer to your prediction in question (iv), based on your background knowledge. (i)

Of the three metal oxides, lead(IV) oxide loses the bonded oxygen the easiest.

13. In which of the three metal oxides is the oxygen bonded the strongest, and in which is the ionic bond the strongest? (i)

Magnesium oxide

Library assignment:

14. Most metals are found in the earth's crust as metal ores. In these ores the metal atoms are bonded to oxygen or other atoms. How did the people of ancient times (5000 years ago) manage to produce pure metal from ores? (iv)

5 000 years ago people found that they could get pure metal simply by heating certain ores. With other ores, carbon in the form of charcoal or coke had to be mixed with the ore first. This method is still used today.

15. In South Africa, ISCOR produces thousands of tons of iron each year. Explain the method used by ISCOR to convert the impure ore to pure iron. (iv)

ISCOR produces thousands of tons of iron metal every year by mixing carbon with various ores of iron and heating the two together.

ISCOR makes iron from its ore by heating (mainly) iron(III) oxide in a blast furnace.

The iron(III) oxide is reduced to iron and molten iron runs out of the bottom of the furnace. (Reduced in this process means the oxygen is removed from the

ore.)

16. A method in which the metal ore is not heated, but in which an electric current is used to purify the metal, is also used. Describe the basics of this method in a few sentences. (iv)

Metals can also be removed from ores by an electrical process: electrolysis.

Electrolysis is the process of passing an electrical current through a liquid or solution. You have two electrodes in the same solution, connected to the two different poles of a battery or cell. Electrical energy is changed into chemical energy and causes a chemical change. The battery causes a flow of charge which results in the one electrode becoming negatively charged and the other electrode becoming positively charged. In a salt solution the negative ions will move towards the positively charged electrode and the positive ions will move towards the negatively charged electrode.

The positive ions will receive electrons at the electrode and form metals and the negative ions, non-metal ions, will release electrons to the positive electrode.

In the external circuit the current flows from the one electrode to the other.

Clean-up time



Student Lab apparatus	WASTE DISPOSAL
Wash and clean apparatus according to instructions.	Solutions and solids containing heavy metals must be placed in container E (if it is available). Otherwise dilute with the rest of the waste materials.
Wash test tubes with test tube brush and rinse well. Dry or place upside down in apparatus stand.	Dilute all waste with lots of water before disposing of the waste in the outside drain or on the ground.
Close lids of chemicals properly and put back in the correct place. NB!	
Pack apparatus set according to packing instructions.	

💧 **WASH HANDS on completion of experiments!!**

Tips:

- ☺ You can find a similar experiment in Physical Science 2000 standard 8, Heyns, De Villiers *et al.*, Nasou, 1995, page 168.
- ☺ Remember 1 cm³ is equal to 1 ml.
- ☺ The decomposition of oxides on heating is not a good method for comparing the reactivity of the elements involved. Too many other factors play a role in the strength of bonds between oxygen and the metals. You can only decide on two groups: those which release oxygen when they are heated and those which do not release oxygen.

EXPERIMENT 3 (grade 10)

Which one of the following metal oxides: lead(IV) oxide, copper(II) oxide, and magnesium oxide will lose the bonded oxygen the easiest when heated?

Learner self-evaluation

The learner must complete the following table on conclusion of the practical.

6 – agree completely; 5 – agree; 4 – agree with reservations; 3 – undecided; 2 – don't agree; 1 – definitely don't agree.

	6	5	4	3	2	1
I cannot determine charges of atoms in compounds or ions.						
My background knowledge was sufficient to answer the background knowledge questions.						
I had difficulty in assembling the apparatus and in following the experimental procedures.						
I take trouble to do research to find answers to difficult questions.						
I could easily do the experimental observations.						
It was difficult to reach conclusions from the experimental results.						
I could easily give scientific explanations for the experimental results in this experiment.						
Working with the Student Lab set improved my manipulating skills in handling the apparatus.						
This experiment changed my attitude positively about experimental work in chemistry						
This experiment taught me something about metal oxides that I did not know before.						
I understand the concept of chemical bonding and the breaking of bonds to form new compounds.						

Facilitator evaluation

The Facilitator must complete the following table on conclusion of the practical.

1 – poor; 2 – awkward, clumsy; 3 – needs practice; 4 – reasonable; 5 – good; 6 – very good.

	Observation (o)	Measuring (m)	Recording (r)	Manipulating (M)	Inference (i)	Procedure (p)	Investigation (iv)	Evaluation (e)	Knowledge (k)
Question number	1.6, 2.6, 2.8, 2.9		1.7, 2.11	1.1-1.5, 2.1-2.3, 2.5, 2.10	ii, vi, x, 2.4, 2.6, 2.7, 2.12, 2.13,		2.14, 2.15, 2.16		iii, iv, ix,
Mark									
								Total Max.	

Name of learner	
Grade	
School	
Date	

APPENDIX 2: LETTER REQUESTING PERMISSION

PU for CHE
SEDIBA Project (Internal box 533)
Private Bag X6001
Potchefstroom
2531
7 January 2003

The Director
PU for CHE
School of Science, Mathematics and Technology Education
SEDIBA Project
POTHCEFSTROOM

Sir

RE: Permission to administer questionnaires to SEDIBA Student

I am currently researching the topic "The impact of SEDIBA Programme on the attitude of participating educators towards chemistry and chemistry teaching" for an M.Ed. degree in science education at North West University, Potchefstroom Campus.

Your permission is humbly requested to allow me to administer questionnaires on your first-year science students.

Thank you for your anticipated co-operation.

Yours faithfully

Morabe, Olebogeng N.

Student

Prof. Nel, S.J.

Supervisor

APPENDIX 3

ATTITUDE QUESTIONNAIRE SEDIBA PROJECT

Dear Educator

We are busy with research to determine the impact of the SEDIBA programme on the attitude of educators towards science and science teaching. The idea of this questionnaire is to obtain information from you so that we can develop a programme that will be useful to us in order to help you effectively. Please be honest when responding to the items of this questionnaire.

Read the following instructions carefully:

- (i) Write your surname and initials on the response sheet
- (ii) If you don't have a student number, write your date of birth as follows:
yyyymmdd
- (iii) Use only an HB pencil
- (iv) Colour only the inside of the circle of your choice that corresponds with the number of the item in the questionnaire.
- (v) Erase faulty marks thoroughly

SECTION A (Item 1–15)

DEMOGRAPHIC INFORMATION

Carefully read the following questions and then colour the answer according to your choice against the correct item number on the answer side of the response sheet.

1. In which Region is your school situated?

1	2	3	4	5	6
BRITS	MMABATHO	POTCHEFSTROOM	RUSTENBURG	VRYBURG	OTHER

2. What is your highest qualification in teaching?

1	2	3
M + 3	M + 4	OTHER

3. Gender

1	2
MALE	FEMALE

4. Age

1	2	3	4	5
20 - 25	25 - 30	30 - 35	35 - 40	40 - 50

5. What is your highest training in science/chemistry?

1	2	3	4	5	6
GRADE 10	GRADE 12	FIRST YEAR COLLEGE	SECOND YEAR COLLEGE	THIRD YEAR COLLEGE	OTHER

6. Present teaching assignment.

1	2	3	4	5
GENERAL SCIENCE	BIOLOGY	CHEMISTRY	PHYSICS	PHYSICAL SCIENCE

7. The average number of learners in my science class is:

1	2	3	4	5	6
10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70

8. For how long have you been teaching?

1	2	3	4	5
1 - 3	3 - 6	6 - 10	10 - 15	15 - 20

9. Do you have facilities for practical work in chemistry and physics?

1	2
YES	NO

10. Is electricity available at your school?

1	2
YES	NO

11. Is running water available at your school?

1	2
YES	NO

12. Do you have enough money available to buy science apparatus and chemicals?

1	2
YES	NO

13. The micro-kits of Somerset Educational are available in my school for learners

1	2
YES	NO

14. Do you have training in OBE?

1	2
YES	NO

15. For how long did you have training in OBE?

1	2	3	4	5	6
NOT AT ALL	<3 DAYS	1 WEEK	2 WEEKS	3 WEEKS	MOTH +

SECTION B

(ITEMS 16 - 80)

Carefully read the following statements and then respond in terms of one of the following possibilities on the given computer response sheet:

Scheme for answers:

Choose 1 if you totally disagree

Choose 2 if you do not agree

Choose 3 if you are undecided

Choose 4 if you agree with reservations

Choose 5 if you agree

Choose 6 if you completely agree

16. Do you feel confident in applying OBE?

1	2	3	4	5	6
---	---	---	---	---	---

17. Chemistry is bad for the environment

1	2	3	4	5	6
---	---	---	---	---	---

18. Teaching science takes a lot of effort.

1	2	3	4	5	6
---	---	---	---	---	---

19. I enjoy the lab period in the science courses that I teach.

1	2	3	4	5	6
---	---	---	---	---	---

20. In the presentation of my classes I follow the recitation method

1	2	3	4	5	6
---	---	---	---	---	---

21. Working with chemicals is bad for your health

1	2	3	4	5	6
---	---	---	---	---	---

22. The teaching method I use allows my learners to explore and discover new scientific concepts on their own

1	2	3	4	5	6
---	---	---	---	---	---

23. I enjoy manipulating science equipment.

1	2	3	4	5	6
---	---	---	---	---	---

24. Science would be one of my preferred subjects to teach if I were given a choice.

1	2	3	4	5	6
---	---	---	---	---	---

25. I need guidance in preparation of science lessons

1	2	3	4	5	6
---	---	---	---	---	---

26. My learners are able to communicate ideas and information in a variety of ways

1	2	3	4	5	6
---	---	---	---	---	---

27. The chemical industry plays a vital role in promoting national health

1	2	3	4	5	6
---	---	---	---	---	---

28. I regularly do demonstrations

1	2	3	4	5	6
---	---	---	---	---	---

29. I try to present my lessons in such a way that my learners are inspired to love science.

1	2	3	4	5	6
---	---	---	---	---	---

30. In the classroom, I fear science experiments won't turn out as expected.

1	2	3	4	5	6
---	---	---	---	---	---

31. I have difficulty in understanding science.

1	2	3	4	5	6
---	---	---	---	---	---

32. If I have the opportunity I will leave teaching.

1	2	3	4	5	6
---	---	---	---	---	---

33. I experience science teaching as a challenge.

1	2	3	4	5	6
---	---	---	---	---	---

34. We have discussion groups for science teachers in our area.

1	2	3	4	5	6
---	---	---	---	---	---

35. I cannot learn anything by doing chemical experiments when I already know the result I am supposed to get.

1	2	3	4	5	6
---	---	---	---	---	---

36. I try to present my lesson in such a way that my learners are encouraged to develop a positive attitude towards science.

1	2	3	4	5	6
---	---	---	---	---	---

37. I hope to be able to excite my students about science.

1	2	3	4	5	6
---	---	---	---	---	---

50. I am committed to being a good science teacher.

1	2	3	4	5	6
---	---	---	---	---	---

51. It is not necessary to learn chemistry to be a good citizen.

1	2	3	4	5	6
---	---	---	---	---	---

52. The learners and community have a higher opinion of me as science teacher than of my other colleagues.

1	2	3	4	5	6
---	---	---	---	---	---

53. I am willing to spend time setting up equipment for a lab.

1	2	3	4	5	6
---	---	---	---	---	---

54. In the presentation of my classes I follow the recitation method.

1	2	3	4	5	6
---	---	---	---	---	---

55. When my learners finish matric (Grade 12), I am satisfied with the knowledge they have obtained.

1	2	3	4	5	6
---	---	---	---	---	---

56. I enjoy helping students construct science equipment.

1	2	3	4	5	6
---	---	---	---	---	---

57. I am not looking forward to teaching science in my secondary classroom.

1	2	3	4	5	6
---	---	---	---	---	---

58. I would never consider marrying a chemist.

1	2	3	4	5	6
---	---	---	---	---	---

59. My learners are able to appreciate and hold acceptable attitudes to the environment.

1	2	3	4	5	6
---	---	---	---	---	---

60. Learning science is boring.

1	2	3	4	5	6
---	---	---	---	---	---

61. I am satisfied with the in-service training I received during 2002 from the Education Department.

1	2	3	4	5	6
---	---	---	---	---	---

62. I feel comfortable with the science content in the secondary school curriculum.

1	2	3	4	5	6
---	---	---	---	---	---

63. Teaching science is difficult.

1	2	3	4	5	6
---	---	---	---	---	---

64. I would be interested in working in an experimental science curriculum.

1	2	3	4	5	6
---	---	---	---	---	---

65. My learners regularly participate in the annual EXPO.

1	2	3	4	5	6
---	---	---	---	---	---

66. I follow the same teaching style as my science teacher in secondary school.

1	2	3	4	5	6
---	---	---	---	---	---

67. I would rather have someone show me the solution to a difficult chemistry problem than work it out myself.

1	2	3	4	5	6
---	---	---	---	---	---

68. I try to integrate science into other subject areas.

1	2	3	4	5	6
---	---	---	---	---	---

69. I am not afraid to demonstrate science phenomena in the classroom.

1	2	3	4	5	6
---	---	---	---	---	---

70. I see chemistry as a subject I rarely use in my daily life.

1	2	3	4	5	6
---	---	---	---	---	---

71. To do well in chemistry requires a student to study hard.

1	2	3	4	5	6
---	---	---	---	---	---

72. Science can be learned without performing experiments.

1	2	3	4	5	6
---	---	---	---	---	---

73. Chemistry is a difficult science to understand.

1	2	3	4	5	6
---	---	---	---	---	---

74. I dread teaching science.

1	2	3	4	5	6
---	---	---	---	---	---

75. Chemistry has benefited mankind enormously

1	2	3	4	5	6
---	---	---	---	---	---

76. Science teaching is interesting.

1	2	3	4	5	6
---	---	---	---	---	---

77. Doing science experiments is boring.

1	2	3	4	5	6
---	---	---	---	---	---

78. Experience as science teacher has improved my confidence in science teaching.

1	2	3	4	5	6
---	---	---	---	---	---

79. I find the terminology of chemistry difficult to learn.

1	2	3	4	5	6
---	---	---	---	---	---

80. The pharmaceutical industry plays a vital role in promoting national health.

1	2	3	4	5	6
---	---	---	---	---	---

APPENDIX 4

Sub-scales of Items

SECTION. A

DEMOGRAPHIC INFORMATION

1. In which region is your school situated?
2. What is your highest qualification in teaching?
3. Gender
4. Age
5. What is your highest training in science/chemistry?
6. Present teaching assignment.
7. The average number of learners in my science class is:
8. For how long have you been teaching?
9. Do you have facilities for practical work in chemistry & physics?
10. Is electricity available at your school?
11. Is running water available at your school?
12. Do you have enough money available to buy science apparatus and chemicals?
13. The micro-kits of Somerset Educational are available in my school for learners
14. Do you have training in OBE?
15. For how long did you have training in OBE?

SECTION B

SCIENCE CURRICULUM/ EDUCATION SYSTEM

16. Do you feel confident in applying OBE?
25. I need guidance in preparation of science lessons.
38. I need guidance in practical work (experiments) in science.
55. When my learners finish matric (Grade 12), I am satisfied with the knowledge they have obtained.
43. I am satisfied that my training in science teaching is adequate to teach learners up to grade ...
61. I am satisfied with the in-service training I received during 2002 from the Education Department.
32. If I have the opportunity I will leave teaching.
68. I try to integrate science into other subject areas.
48. I experience great disciplinary problems in my science classes.
78. Experience as science teacher has improved my confidence in science teaching.

SECTION C

PERCEPTION OF SCIENCE (NOS)

18. Teaching science takes a lot of effort.
39. Science is as important as the 3 Rs
64. I would be interested in working in an experimental science curriculum.
23. I enjoy manipulating science equipment.
60. Learning science is boring.
31. I have difficulty in understanding science.
77. Doing science experiments is boring.
47. Science is difficult.
54. In the presentation of my classes I follow the recitation method.
66. I follow the same teaching style as my science teacher in secondary school.

SECTION D

ATTITUDE TOWARDS SCIENCE

- 19. I enjoy the lab period in the science courses that I teach.
- 26. My learners are able to communicate ideas and information in a variety of ways.
- 56. I enjoy helping students construct science equipment.
- 24. Science would be one of my preferred subject to teach if given a choice.
- 37. I hope to be able to excite my students about science.
- 41. Children are not curious about scientific matters.
- 65. My learners regularly participate in the annual Expo.
- 53. I am willing to spend time setting up equipment for a lab.
- 34. We have discussion groups for science teachers in our area.
- 50. I am committed to being a good science teacher.
- 59. My learners are able to appreciate and hold acceptable attitudes to the environment.
- 22. The teaching method I use allows my learners to explore and discover new scientific concepts on their own.
- 29. I try to present my lessons in such a way that my learners are inspired to love science.
- 45. I often organize my learners' activities in science in such a way they have to do it at home to get their parents involved.
- 62. I feel comfortable with the science content in the secondary school curriculum.

SECTION E

ATTITUDE TOWARDS SCIENCE TEACHING

- 20. In the presentation of my classes I follow the recitation method
- 40. Teaching science takes too much time.
- 44. The teaching of science processes is important in the secondary classroom.
- 69. I am not afraid to demonstrate science phenomena in the classroom.
- 30. In the classroom, I fear science experiments won't turn out as expected.
- 49. I need guidance in the theory of science.
- 72. Science can be learned without performing experiments.
- 33. I experience science teaching as a challenge.
- 74. I dread teaching science.
- 57. I am not looking forward to teaching science in my secondary classroom.
- 28. I regularly do demonstrations.
- 76. Science teaching is interesting.
- 52. The learners and community have a higher opinion of me as science teacher than of my other colleagues.
- 36. I try to present my lesson in such a way that my learners are encouraged to develop a positive attitude towards science.
- 63. Teaching science is difficult.

SECTION F

ATTITUDE TOWARDS CHEMISTRY TEACHING

- 17. Chemistry is bad for the environment.
- 21. Working with chemicals is bad for your health.
- 58. I would never consider marrying a chemist.
- 73. Chemistry is a difficult science to understand.
- 79. I find the terminology of chemistry difficult to learn.
- 42. For some reason, even though I teach it, chemistry seems unusually difficult for me.
- 71. To do well in chemistry requires a student to study hard.
- 46. I don't understand why some people spend so much time on chemistry and seem to enjoy it.
- 67. I would rather have someone show me the solution to a difficult chemistry problem than work it out myself.
- 35. I cannot learn anything by doing chemical experiments when I already know the result I am supposed to get.
- 75. Chemistry has benefited mankind enormously.
- 27. The chemical industry plays a vital role in promoting national health.
- 80. The pharmaceutical industry plays a vital role in promoting national health.
- 70. I see chemistry as a subject I rarely use in my daily life.
- 51. It is not necessary to learn chemistry to be a good citizen.

APPENDIX 5

RESPONSES TO THE PRE- AND POST-TESTS

In this table, a presentation is made of participating educators as they responded to the questionnaires, i.e. pre-test and post-test. The frequency distribution of each item per sub-scale is indicated with their percentages. Note should be taken that the "missing frequencies" (respondents who left some of the questions blank, didn't choose any of the six options or who indicated their responses by highlighting 7) are not included in the frequencies and percentages of such specific items. However, the total number of the subjects (designated with an (N)) who responded to the items or questions are indicated. Where there is no indication, it should be taken that all the 37 educators responded to the item.

DEMOGRAPHIC INFORMATION

Table 1: Sub-scale A

ITEMS	N=37	1	2	3	4	5	6
V1	F	5	6	4	5	5	12
	%	13.51	16.22	10.81	13.52	13.51	32.43
V2	F	31	2				
	%	94.41	5.41				
V3	F	22	15				
	%	59.46	40.54				
V4	F	1	19	9	6	2	
	%	2.70	51.35	24.32	16.22	5.41	
V5	F		2			35	
	%		5.41			94.59	
V6	F	2		3		32	
	%	5.41		8.11		86.49	
V7	F	4	6	9	12	4	2
	%	10.81	16.22	24.32	32.43	10.81	5.41
V8	F	15	8	8	4	2	
	%	40.54	21.62	21.62	10.81	5.41	
V9	F	21	16				
	%	56.76	43.24				
V10	F	34	3				
	%	91.89	8.11				
V11	F	33	4				
	%	89.19	10.81				
V12	F	2	35				
	%	5.41	94.59				
V13	F	22	15				
	%	59.46	40.54				
V14	F	19	18				
	%	51.35	48.65				
V15	F	17	5	6	4	3	2
	%	45.95	13.51	16.22	10.81	8.11	5.41

SCIENCE CURRICULUM
Table 2: Sub-scale B

ITEMS		PRE-TEST						POST-TEST					
		1	2	3	4	5	6	1	2	3	4	5	6
V16	F	5	5	10	10	5	2	6	12	7	10	2	
	%	13.51	13.51	27.03	27.03	13.51	5.41	16.22	32.43	18.92	27.03	5.41	
V25	F	2	1		10	15	9	5	4	3	10	13	2
	%	5.41	2.70		27.03	40.54	24.32	13.51	10.81	8.11	27.03	35.14	5.41
V32	F	6	12	7	5	2	5	(36) 9	7	1	7	6	6
	%	16.22	32.43	18.92	13.51	5.41	13.51	24.32	18.92	2.70	18.92	16.22	16.22
V38	F		3		7	11	16	(36) 3	5		10	11	6
	%		8.11		18.92	29.73	43.24	8.33	13.89		27.78	30.56	16.67
V43	F	2	2	2	3	3	23		1		4	7	25
	%	5.71	5.71	5.71	8.57	8.57	65.71		2.70		10.81	18.92	67.57
48	F	4	18	1	9	5		13	19		3		2
	%	10.81	48.65	2.70	24.32	13.51		35.14	51.35		8.11		5.41
55	F(36)	2	3	3	7	14	7		2	5	10	12	8
	%	5.56	8.33	8.33	19.44	38.89	19.44		5.41	13.51	27.03	32.43	21.62
61	F(32)	15	9		3	1	4	9	8	6	5	1	8
	%	46.88	28.13		9.38	3.13	12.50	24.32	21.92	16.22	13.51	2.70	21.62
68	F	1		3	4	21	8	(36)	1		3	21	11
	%	2.70		8.11	10.81	56.76	21.62		2.70		8.11	56.76	29.73
78	F			5	2	13	17		1	1	3	15	16
	%			13.51	5.41	35.14	45.95		2.70	2.70	8.11	40.54	43.24

PERCEPTION OF SCIENCE

Table 3: Sub-scale C

ITEMS		PRE-TEST						POST-TEST					
		1	2	3	4	5	6	1	2	3	4	5	6
V18	F	2	2		2	14	17	(36) 4	5		4	14	9
	%	5.41	5.41		5.41	37.84	45.95	10.81	13.51		10.81	37.84	24.32
V20	F	13	16	3	3	2		23	7	2	3	1	1
	%	35.14	43.24	8.11	8.11	5.41		62.16	18.92	5.41	8.11	2.70	2.70
V23	F		8	4	5	14			4	3	4	16	10
	%		21.62	10.81	13.51	37.84			10.81	8.11	10.81	43.24	27.03
V31	F	7	23	1	3	2	1	(36) 13	13	2	6	1	1
	%	18.92	62.16	2.70	8.11	5.41	2.70	35.14	35.14	5.41	16.22	2.70	2.70
V39	F	1		2	4	15	15	2			3	13	19
	%	2.70		5.41	10.81	40.54	40.54	5.41			8.11	35.14	51.35
V47	F	15	10	2	8	1	1	19	10	1	4	2	1
	%	40.54	27.03	5.41	21.62	2.70	2.70	51.35	27.03	2.70	10.81	5.41	2.70
V60	F	23	11		1		2	27	7		1		2
	%	62.16	29.73		2.70		5.41	72.97	18.92		2.70		5.41
V64	F		1	3	2	16	15			1	3	15	17
	%		2.70	8.11	5.41	43.24	40.54			2.70	8.11	40.54	45.95
V66	F	14	11	1	6	5		18	12		5	1	1
	%	37.84	29.73	2.70	16.22	13.51		48.65	32.43		13.51	2.70	2.70
V77	F	24	92	2				27	7	1		1	1
	%	64.86	24.32	5.41	5.41			72.97	18.92	2.70		2.70	2.70

ATTITUDE TOWARDS SCIENCE

Table 4: Sub-scale D

ITEMS		PRE-TEST						POST-TEST					
		1	2	3	4	5	6	1	2	3	4	5	6
V19	F		3	1	11	14	8		2	2	4	16	13
	%		8.11	2.70	29.73	37.84	21.62		5.41	5.41	10.81	43.24	35.14
V22	F	1	3	4	8	15	6			1	9	17	10
	%	2.70	8.11	10.81	21.62	40.54	16.22			2.70	24.32	45.95	27.03
V24	F		2	2	3	7	23	(36)			2	7	27
	%		5.41	5.41	8.11	18.92	62.16				5.41	18.92	72.97
V26	F	2	4	5	12	12	2	1	2	2	14	14	4
	%	5.41	10.81	13.51	32.43	32.43	5.41	2.70	5.41	5.41	37.84	37.84	10.81
V29	F			1	1	18	17	(36)	1		1	15	18
	%			2.70	2.70	48.65	45.95		2.70		2.70	40.54	48.65
V34	F	11	11	1	2	9	3	(36) 7	7		3	12	7
	%	29.73	29.73	2.70	5.41	24.32	8.11	19.44	19.44		8.33	33.33	19.44
V37	F		1	1	2	14	19	(36)	1		1	16	18
	%		2.70	2.70	5.41	37.84	51.35		2.70		2.70	43.24	48.65
V41	F	5	8	6	8	9	1	6	11	5	12		3
	%	13.51	21.62	16.22	21.62	24.32	2.70	16.22	29.73	13.51	32.43		8.11
V45	F	2	5	1	15	9	5	1	4	1	13	12	6
	%	5.41	13.51	2.70	40.54	24.32	13.51	2.70	10.81	2.70	35.14	32.43	16.22
V50	F			1	1	6	29				2	5	28
	%			2.70	2.70	16.22	78.38				5.41	16.22	75.68
V53	F			1	3	18	15	(35)			4	18	13
	%			2.70	8.11	48.65	40.54				11.11	50.00	36.11
V56	F	1	2	2	6	19	7	(36)	1	1	7	15	12
	%	2.70	5.41	5.41	16.22	51.35	18.92		2.70	2.70	18.92	40.54	32.43
V59	F		3	7	11	14	2		3	3	10	19	2
	%		8.11	18.92	29.73	37.84	5.41		8.11	8.11	27.03	51.35	5.41
V62	F	1	6	1	5	14	10	(36) 1		1	4	16	13
	%	2.70	16.22	2.70	13.51	37.84	27.03	2.70		2.70	10.81	43.24	35.14
V65	F	6	14	2	4	7	4	8	11	2	6	3	7
	%	16.22	37.84	5.41	10.81	18.92	10.81	21.62	29.73	5.41	16.22	8.11	18.92

ATTITUDE TOWARDS SCIENCE TEACHING

Table 5: Sub-scale E

ITEMS		PRE-TEST						POST-TEST					
		1	2	3	4	5	6	1	2	3	4	5	6
V28	F		5		13	16	3	1	5	3	8	16	4
	%		13.51		35.14	43.24	8.11	2.70	13.51	8.11	21.62	43.24	10.81
V30	F	4	12	2	8	10	1	(36) 6	16		8	5	1
	%	10.81	32.43	5.41	21.62	27.03	2.70	16.22	43.24		21.62	13.51	2.70
V33	F	1	3		6	16	11	(36) 2	1		4	13	15
	%	2.70	8.11		16.22	43.24	29.73	5.41	2.70		10.81	35.14	40.54
V36	F		1		2	17	17	(36)			1	13	21
	%		2.70		5.41	45.95	45.95				2.70	35.14	56.76
V40	F	2	6	1	10	13	5	(36) 6	6	2	12	6	4
	%	5.41	16.22	2.70	27.03	35.14	13.51	16.22	16.22	5.41	32.43	16.22	10.81
V44	F	2	4	4	2	13	12	(36) 2	3		2	12	15
	%	5.41	10.81	10.81	5.41	35.14	32.43	5.4	8.11		5.41	32.43	40.54
49	F	1	2	1	9	16	8	(36) 4	4	1	8	13	5
	%	2.70	5.41	2.70	24.32	43.24	21.62	11.11	11.11	2.70	22.22	36.11	13.89
V52	F	1	1	11	5	14	5	(36) 3	2	7	7	11	6
	%	2.70	2.70	29.73	13.51	37.84	13.51	8.11	5.41	18.92	18.92	29.73	16.22
V54	F	10	12	3	8	3	1	19	12		4	2	
	%	27.03	32.43	8.11	21.62	8.11	2.70	51.35	32.43		10.81	5.41	
V57	F	20	8	1	4	3	1	22	8	1	1	1	4
	%	54.05	21.62	2.70	10.81	8.11	2.70	59.46	21.62	2.70	2.70	2.70	10.81
V63	F	14	17	2	2	1	1	19	11		5	2	
	%	37.84	45.95	5.41	5.41	2.70	2.70	51.35	29.73		13.51	5.41	
V69	F	2	3	2	5	17	8	(36)	3		4	14	14
	%	5.41	8.11	5.41	13.51	45.95	21.62		8.33		11.11	38.89	38.89
V72	F	14	16		5	2		18	7		9	2	1
	%	37.84	43.24		13.51	5.41		48.65	18.92		24.32	5.41	2.70
V74	F	10	12	5	3	5	2	12	10	6	4	3	2
	%	27.03	32.43	13.51	8.11	13.51	5.41	32.43	27.03	16.22	10.81	8.11	5.41
V76	F			1	4	10	22	(36)			3	10	23
	%			2.70	10.81	27.03	59.46				8.11	27.03	62.16

ATTITUDE TOWARDS CHEMISTRY AND CHEMISTRY TEACHING

Table 6: Sub-scale F

ITEMS		PRE-TEST						POST-TEST					
		1	2	3	4	5	6	1	2	3	4	5	6
V17	F	13	14		6	2	2	(36) 9	9	4	13		1
	%	35.14	37.84		16.22	5.41	5.41	24.32	24.32	10.81	35.14		2.70
V21	F	2	8	4	15	6	2	(36)2	7	4	16	5	2
	%	5.41	21.62	10.81	40.54	16.22	5.41	5.41	18.92	10.81	43.24	13.51	5.41
V27	F	1	3	2	10	9	12	(36)	3	1	4	10	17
	%	2.70	8.11	5.41	27.03	24.32	32.43		8.11	2.70	10.81	27.03	45.95
V35	F	13	14	4	3	2	1	(36)14	17	2	2	1	
	%	35.14	37.84	10.81	8.11	5.41	2.70	38.89	47.22	5.56	5.56	2.78	
V42	F	4	14	2	9	6	2	9	15	2	8	3	
	%	10.81	37.84	5.41	24.32	16.22	5.41	24.32	40.54	5.41	21.62	8.11	
V46	F	7	11	8	5	3	2	9	12	7	5	4	
	%	19.44	30.56	22.22	13.89	8.33	5.56	24.32	32.43	18.92	13.51	10.81	
V51	F	5	11	8	7	1	5	(36)14	10	2	4	4	2
	%	13.51	29.73	21.62	18.92	2.70	13.51	38.89	27.78	5.56	11.11	11.11	5.56
V58	F	12	11	10			3	18	10	2	4	1	2
	%	33.33	30.56	27.78			8.33	48.65	27.03	5.41	10.81	2.70	5.41
V67	F	4	6	3	8	10	6	11	13		8	4	1
	%	10.81	16.22	8.11	21.62	27.03	16.22	29.73	35.14		21.62	10.81	2.70
V70	F	10	11	1	2	10	3	20	5	3		5	4
	%	27.03	29.73	2.70	5.41	27.03	8.11	54.05	13.51	8.11		13.51	10.81
V71	F				4	13	20	(36)	1		4	13	18
	%				10.81	35.14	54.05		2.70		10.81	35.14	48.65
V73	F	16	16	2		1	2	20	13		3	1	
	%	43.24	43.24	5.41		2.70	5.41	54.05	35.14		8.11	2.70	
V75	F		1	2	2	15	17	2			6	17	12
	%		2.705	5.41	5.41	40.54	45.95	5.41			16.22	45.95	32.43
V79	F	9	21	2	2	2	1	18	12	2	3	1	1
	%	24.32	56.76	5.41	5.41	5.41	2.70	48.65	32.43	5.41	8.11	2.70	2.70
V80	F			3	4	13	17	(36) 1		2	5	8	20
	%			8.11	10.81	35.14	45.95	2.70		5.41	13.51	21.62	54.05

APPENDIX 6

Comparison of educators' mean and standard deviation of pre and post tests results

SCIENCE CURRICULUM

Table 7: Sub-scale B

ITEMS	PRE-TEST		POST-TEST			EFFECT SIZE <i>d</i>
	Mean	Std. dev.	Mean		Std. dev.	
V16	3.2972973	1.3917388		2.7297297	1.1937022	0.39835
V25	4.6756757	1.2484224		3.7567568	1.5166741	0.59194
V32	3.0000000	1.6158933		3.4324324	1.9513605	0.26609
V38	5.0000000	1.1785113	(36)	4.1944444	1.6003472	0.50745
V43 (35)	5.0571429	1.5707409		5.4864865	0.9012837	0.42122
V48	2.8108108	1.3088977		1.9729730	1.0925629	0.52120
V55 (36)	4.3611111	1.4172968		4.5135135	1.1455620	0.089490
V61 (32)	2.3125000	1.7677670		3.1351351	1.8583470	0.27554
V68	4.8378378	1.0411936		5.1891892	0.8445195	0.38214
V78	5.1351351	1.0317774		5.2702703	0.9617302	0.12463

PERCEPTION OF SCIENCE

Table 8: Sub-scale C

ITEMS	PRE-TEST		POST-TEST			EFFECT SIZE <i>d</i>
	Mean	Std. dev.	Mean		Std. dev.	
V18	5.0270270	1.3841661		4.3513514	1.7574473	0.30724
V20	2.0540541	1.01290592		1.7837838	1.2938988	0.23579
V23	4.1621622	1.4242642		4.6756757	1.2704779	0.38145
V31	2.2702703	1.1937022		2.3513514	1.5314520	0.051066
V39	5.0810811	1.0898108		5.2162162	1.2049697	0.12463
V47	2.2702703	1.4072954		2.0000000	1.3944334	0.19767
V60	1.6486486	1.2296390		1.5405405	1.2381571	0.059320
V64	5.1081081	1.025398		5.3783784	0.7941226	0.21807
V66	2.3783784	1.4785757		1.9729730	1.3225919	0.24708
V77	1.5135135	0.8373776		1.4864865	1.0959932	0.019249

ATTITUDE TOWARDS SCIENCE

Table 9: Sub-scale D

ITEMS	PRE-TEST		POST-TEST			EFFECT SIZE <i>d</i>
	Mean	Std. dev.	Mean		Std. dev.	
V19	4.6216216	1.1143347		4.9729730	1.0925629	0.24435
V22	4.3783784	1.2769615		4.9729730	0.7988355	0.55771
V24	5.2702703	1.1702006		5.7297297	0.6077577	0.40131
V26	3.9189189	1.2775493		4.3513.514	1.1109610	0.46539
V29	5.3783784	0.6811490		5.4864865	0.8699177	0.11545
V34	2.8918919	1.8224493	(36)	3.7500000	1.9179602	0.42749
V37	5.3243243	0.9145143		5.4324324	0.8346836	0.088625
V41	3.2972973	1.4694078		2.9459459	1.4326732	0.22417
V45	4.0540541	1.3732756		4.3243243	1.2704779	0.19205
V50	5.7027027	0.6610121		5.7567568	0.5965366	0.094049
V53	5.2702703	0.7321448	(36)	5.3055556	0.7099072	0.030531
V56	4.6486486	1.1835966		5.0540541	0.9984974	0.32130
V59	4.1351351	1.0583573		4.3783784	1.0097126	0.19363
V62	4.4864865	1.4836446		5.1891892	1.1014596	0.39192
V65	3.1081081	1.7124347		3.1621622	1.8486258	0.035839

ATTITUDE TOWARDS SCIENCE TEACHING

Table 10: Sub-scale E

ITEMS	PRE-TEST		POST-TEST		EFFECT SIZE <i>d</i>	
	Mean	Std. dev.	Mean	Std. dev.		
V28	4.3243243	1.1068989		4.2162162	1.3151919	0.070956
V30	3.2972973	1.5067416		2.9189189	1.6051718	0.27798
V33	4.7837838	1.2722494		5.1081081	1.3699916	0.25099
V36	5.3243243	0.8183335		5.6486486	0.6331674	0.36704
V40	4.1081081	1.4488268		3.5945946	1.7071656	0.28953
V44	4.5135135	1.5744774		5.0540541	1.5625113	0.29960
V49	4.6486486	1.1835966	(36)	4.1388889	1.6414763	0.37268
V52	4.2162162	1.2502252		4.1621622	1.5368350	0.027421
V54	2.5945946	1.4425953		1.8648649	1.2055926	0.44851
V57	2.0540541	1.4897044		2.0000000	1.6666667	0.032130
V63	1.9729730	1.1663449		1.9189189	1.2556180	0.032780
V69	4.5135135	1.4067619	(36)	5.0833333	1.1801937	0.36633
V72	2.0540541	1.2006005		2.2702703	1.5392756	0.13808
V74	2.6486486	1.5673087		2.5135135	1.5206289	0.067492
V76	5.4324324	0.8007129		5.5945946	0.6855436	0.22306

ATTITUDE TOWARDS CHEMISTRY AND CHEMISTRY TEACHING

Table 11: Sub-scale F

ITEMS	PRE-TEST		POST-TEST			EFFECT SIZE <i>D</i>
	Mean	Std. dev.	Mean		Std. dev.	
V17	2.3513514	1.5132051		2.8108108	1.5062433	0.29523
V21	3.5675676	1.3025731		3.6756757	1.3754606	0.085491
V27	4.5945946	1.3633997		5.1621622	1.2804841	0.32606
V35	2.1891892	1.3088977	(36)	1.8611111	0.9607372	0.19337
V42	3.1351351	1.4937306		2.4864865	1.3043010	0.39632
V46 (36)	2.7777778	1.4364860		2.5405405	1.3037253	0.16334
V51	3.0810811	1.5523885	(36)	2.4444444	1.6291004	0.34071
V58 (36)	2.2777778	1.3858697		2.0810811	1.4601822	0.082455
V67	3.8648649	1.6357493		2.5675676	1.5191471	0.66812
V70	3.0000000	1.8257419		2.3783784	1.8760383	0.32136
V71	5.4324324	0.6888211		5.3513514	0.9194266	0.085000
V73	1.9189189	1.2775493		1.7027027	1.0237422	0.15476
V75	5.2162162	0.9756803		4.9459459	1.1772365	0.20068
V79	2.1891892	1.1980966		1.9189189	1.2556180	0.17356
V80	5.1891892	0.9380191		5.2432432	1.1880284	0.041225

APPENDIX 7

Comparison of the Pre-post-test results standard deviation (per sub-scale)

Table 12

SUB-SCALE (Variable)	MEAN	STD. DEV.	EFFECT SIZE <i>d</i>
B	-0.0958816	0.5846273	0.16400
C	0.1243243	0.5649019	0.22008
D	0.3366795	0.4388952	0.76711
E	0.1526384	0.4763888	0.32041
F	0.2773884	0.4805851	0.57719

Education should not be for examination purpose (1)
 Chemistry lecturer should be better prepared (1)
 Increase time for computer studies (1)

2. Answer YES or NO to each of the following questions:

After this session I feel:

		YES	NO
2.1	More confident to teach physical science at school	93%	7%
2.2	Better equipped to use teaching aids	77%	23%
2.3	Master of the subject	62%	38%
2.4	More confident to do experiments in my classes	81%	19%
2.5	Equipped to set question papers	81%	19%
2.6	Motivated to try different methods of teaching	93%	7%
2.7	Positive to physical science as subject	95%	5%
2.8	That I have a better understanding of my pupils' problems	80%	20%

3 Did this SEDIBA course meet your expectations?

YES	NO
85%	15%

Reasons for Yes

It has broadened and improved my knowledge (9)
 I feel confident in teaching science now (6)
 It has motivated and encouraged me to teach physical science as a subject (3)
 The things I thought were difficult are now becoming easier (3)
 I will use the knowledge I am equipped with to improve my teaching strategies and above all to produce good results (3)
 They have shown me different teaching methods (2)
 Learning to use the computer was exciting (2)
 Some of the problems I am experiencing in class are being cleared (1)
 I developed a love for the subject (1)
 Labs are well equipped and the institution is very clean (1)
 I gained a lot of experience (1)
 The use of teaching aids and practicals (1)
 I now have a clear picture about OBE (1)

Reasons for No

I did not acquire the knowledge that I had expected, especially in chemistry and education (1)
 In some classes we were lost and didn't have direction and understanding of what to do (1)
 I thought I was going to be confident when doing chemistry experiments, but I am still blank like I came here (1)

4. A number of statements follow. Please cross one number in the given blocks according to the following scale:

Choose 5 if you strongly agree
 Choose 4 if you agree
 Choose 3 if you are neutral
 Choose 2 if you disagree
 Choose 1 if you totally disagree

		1	2	3	4	5
4.1	Physical Science as subject is interesting	-	-	2%	33%	65%
4.2	Physical Science as subject is difficult	20%	46%	22%	7%	5%
4.3	Physical Science can be learned without performing experiments	63%	14%	5%	14%	4%
4.4	The use of Mathematics simplifies	5%	2%	12%	49%	32%

	Physical Science					
4.5	Physical Science can be applied in everyday life	-	2%	-	22%	76%
4.6	Physical Science experiments confuse me	30%	28%	23%	16%	3%
4.7	Physical Science helps me understand nature	-	2%	5%	48%	45%
4.8	Practicals enhance the understanding of Physical Science	2%	-	-	23%	75%

October2003: Evaluation of the whole course
PHYSICAL SCIENCE: YEAR 1
STUDENTS: 39

Chemistry Course

Remarks	Positive	Neutral	Negative
Content	37	1	1
Relevant to the school syllabus; it makes it easy for us to understand the content so that we can help our learners			
Of great standard			
Satisfactory and to the point			
Informative, although a little bit difficult			
Workbooks	30	3	6
Well arranged and helpful			
Well planned, with simple explanations and very informative			
Not very understandable			
Not effective, but informative			
Textbook	35	3	1
One of the best in the world			
Of high quality and standard			
Very good; we can even use it at school and when doing research			
Practicals	30	1	8
Entertaining, challenging and interesting			
It could be still better if we have apparatus in our schools			
I can in no doubt say that I have no problems any more			
Time frame was too short, but I gained a great deal			

Too much work in a short time			
Presentation	30	-	9
Excellent tutors			
Very good			
Still learning as a teacher; first term was not good, but other terms were wonderful			
Only reading through the transparencies			
Assignments	15	1	23
Good assignments and covers all topics			
Tricky but informative			
Long tedious assignments with no feedback			
Some are difficult to understand			
They interfere with our workload at school; if possible to be reduced; too many for the year			
Number of contact hours	13	16	10
Appreciated; enough			
Too long and tiring as well as strenuous			
Assessment	27	4	8
Well done			
Very good, because through them we can assess ourselves			
Difficult; at some stage questions need to be graded			
Some of the tests are long and don't test understanding			
Too much scope for little marks			

Physics Course

Remarks	Positive	Neutral	Negative
Content	36	3	-
Relevant to the school syllabus			
Enjoyable and covers all the topics that one should know			
Good and very informative			

Workbooks	36	3	-
Well developed/structured; up to standard			
Covering all topics			
Well designed and understandable			
Easy to approach, but please hand it out earlier (April workbook handed out in January)			
Textbook	33	6	-
Highly informative			
Good source of information			
Very interesting and excellent			
Of good quality			
Practicals	37	2	-
Helps a lot; I gained a lot of knowledge from the practicals			
Excellently handled and informative			
Excellent; one can now have confidence in class			
Very good and enjoyable; well done!			
Excellent and very easy to understand, especially the worksheets			
Presentation			
Excellent. I understand physics better now	35	3	1
The content is well presented and I like my physics lecturer very much. By the way she is presenting a lesson, I have really learnt a lot			
Absolutely priceless; more than superb performance			
Excellent; Dr Lemmer is very good			
Well done and outstanding; satisfies all my needs in the subject			
Assignments	28	8	3
Challenging and good for further understanding			
Difficult but developing			
Too difficult sometimes, but they do give us some exercise			
The September contact session should not have assignments			
Number of contact hours	13	17	9
Reasonable			
Too long			
Assessment	31	4	4
Fine and helpful			
Easy to understand			
Fair and motivating			
Reduce the number of tests written			

Subject Didactics

Remarks	Positive	Neutral	Negative
Content	21	9	9
Informative; relevant to our work experience			
I did enjoy it, especially at this last session			
Not so easy to understand			
Confusing; more clear notes needed			
Workbooks	18	11	10
Well prepared			
Very good and informative			
Not understandable; difficult to learn			
Textbook			
Not applicable			
Presentation	26	8	5
Excellent; good			
Confusing due to different lectures throughout the contact session			
Assignments			
Not applicable			
Number of contact hours	11	20	8
Enough			
Too long			
Assessment	17	16	6
Well done and satisfactory			
Well understood			
Not enough; unclear to me			

Computer Literacy

Remarks	Positive	Neutral	Negative
Content	29	8	2
Excellent; marvellous; impressive			
Good and relevant			
Very good and enjoyable			
Not so easy since it is new			
Not really understandable, because we have to rush through the learning content			
Workbooks	27	7	5
Well understood			
Very useful; clear with enough information			
Not clear and not easy to understand			
Textbook			
Not applicable			
Presentation	31	6	2
Mrs Breedt is excellent!			
Very entertaining			
Sometimes not clear			
Assignments	26	8	5
Very interesting and educating			
Most of the time practical			
Sometimes difficult due to the lack of computers			
Not clear as they need computer usage, but I do not have any access to one			
Number of contact hours	8	17	14
Enough			
The contact hours are very few, because some of us do not have computers			
Assessment	23	11	5
Done well; well structured			
OBE style			
Too tricky for us			

Administration

Remarks	Positive	Neutral	Negative
Notices	26	10	3
Fine because all information reaches us in time			
Accurately administered			

Excellent handled			
Well done			
More information should be given about courses and bursaries			
General administration	23	12	4
Very co-operative			
Very human and fair			
Impressive; handled by professional people			
The participation marks are calculated in a confusing manner			
Accommodation in the Annex residence is too expensive			
How did you benefit from the Sediba course?	33	6	-
I thank Sediba for giving me a chance to be here and learn so much with them; practicals are very interesting. Thanks			
Gained a lot of information that is also useful to my learners at school			
Before I came to Sediba I had a problem with practicals and some of the physics concepts, but now I understand better. Thanks to Sediba. You are doing a wonderful job			
Physical science experiments are no longer nightmares			
Physics has actually boosted my confidence and I am not afraid to stand in front of anyone to do a presentation in any topic			
Any other comments or suggestions?	14	15	10
Chemistry workbook should be handed out during the previous contact session so that pre-study can be made			
I would like to suggest that the sponsors must continue to introduce Sediba for B.Ed. Honours. Then Sediba will have good science teachers			
Ask the sponsors to supply materials for school practicals			
We enjoy Dr Lemmer's lessons very much. Increase the contact time			
Try to make more time for computers; we need the knowledge!			
Please make contact session during school holidays			
Accommodation should be subsidized			

SEDIBA

Research Questionnaire:

Activities of 2003

Physical Science:

Year 1

This is the last contact session for 2003. Please write down your impressions of the SEDIBA course you attended during this year concerning the following aspects:

(Positive or negative comments and recommendations on how to improve courses in future would be appreciated)

1. Chemistry course:

Content:.....

.....

Workbooks:.....

.....

Textbook:.....

.....

Practicals:.....

.....

Presentation:.....

.....

Assignments:.....

.....

Number of contact hours:.....

.....

Assessment:.....

.....

.....

2. Physics course:

Content:.....

.....

Workbooks:.....

.....

Textbook:.....

.....
Practicals:.....

.....
Presentation:.....

.....
Assignments:.....

.....
Number of contact hours:.....

.....
Assessment:.....

3. Subject didactics:

Content:.....

.....
Workbooks:.....

.....
Textbook:.....

.....
Practicals:.....

.....
Presentation:.....

.....
Assignments:.....

.....
Number of contact hours:.....

.....
Assessment:.....

4. Computer literacy:

Content:.....

.....
Workbooks:.....

.....
Textbook:.....

.....
Presentation:.....

.....
Assignments:.....

.....
Number of contact hours:.....

.....
Assessment:.....

5. Administration:

Notices (e.g. about courses, assignments, etc.).....

.....
.....
.....

General administration:.....

.....
.....
.....

6. How did you benefit from the Sediba project?.....

.....
.....
.....
.....
.....

7. **Any other comments or suggestions:**.....
.....
.....
.....
.....

SEDIBA- QUESTIONNAIRE
PHYSICAL SCIENCE
Year 1 - January 2003

Please answer the following questions:

1. What were your impressions of the past course?

1.1 Positive features:

.....

.....

.....

1.2 Negative features:

.....

.....

.....

1.3 Suggested improvements:

.....

.....

.....

2. Answer YES or NO to each of the following questions:
 After this session I feel:

		YES	NO
2.1	More confident to teach physical science at school		
2.2	Better equipped to use teaching aids		
2.3	Master of the subject		
2.4	More confident to do experiments in my classes		
2.5	Equipped to set question papers		
2.6	Motivated to try different methods of teaching		
2.7	Positive to physical science as subject		
2.8	That I have a better understanding of my pupils' problems		

3. Did this SEDIBA course meet your expectations?

YES	NO

Reasons:.....

.....

.....

.....

4. A number of statements follow. Please cross one number in the given blocks according to the following scale: Choose 5 if you strongly agree
Choose 4 if you agree
Choose 3 if you are neutral
Choose 2 if you disagree
Choose 1 if you totally disagree

4.1	Physical Science as subject is interesting	1	2	3	4	5
4.2	Physical Science as subject is difficult	1	2	3	4	5
4.3	Physical Science can be learned without performing experiments	1	2	3	4	5
4.4	The use of Mathematics simplifies Physical Science	1	2	3	4	5
4.5	Physical Science can be applied in everyday life	1	2	3	4	5
4.6	Physical Science experiments confuses me	1	2	3	4	5
4.7	Physical Science helps me to understand nature	1	2	3	4	5
4.8	Practicals enhance the understanding of Physical Science	1	2	3	4	5

APPENDIX 9

EXAMPLE OF SEDIBA'S STUDY MANUAL

CHAPTER 3 MOLECULES AND COMPOUNDS

~ (KT3, p.101 - 154)(KT4, p.99 - 146)

⊕ CD 3,4



Chemical Puzzler:

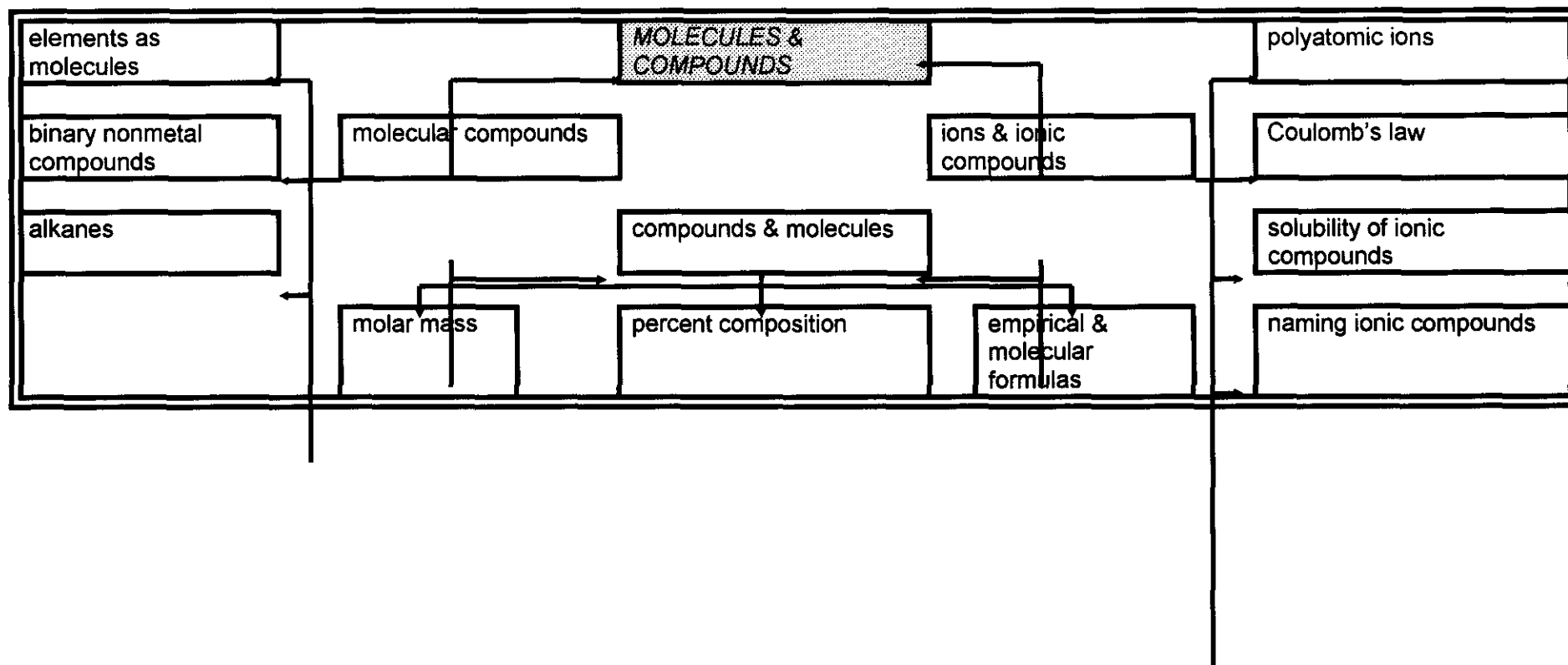
You write a secret message with hydrated cobalt chloride and water. When you heat it the message becomes visible. What happened chemically? ($\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$)

- What happens to a virtually colourless substance to make it change so suddenly?
- What properties of this substance makes the change in colour possible?
- Can other substances act as "invisible ink"?

At the end of this chapter you should be able to:

- Interpret molecular formulae and structural formulae (3.1)
- Define allotropes (3.0)
- List elements that exist as diatomic molecules (3.0)
- Recognize that metal ions form cations and nonmetal ions form anions (fig. 3.5)
- Recognize that the charge on metal ions of the main groups are equal to the group number (3.3)
- Recognize that the charge on nonmetal ions are given by $n = 8 - \text{group number}$ (3.3)
- Give the names or formulas of polyatomic ions (3.3)
- Write the formulas for a number of ionic compounds (3.4)

Chapter concept map



- Describe the properties of ionic compounds (3.4)
- Name ionic compounds and binary compounds of the nonmetals (3.5)
- Understand that the molar mass of a compound is the mass in gram of Avogadro's number of molecules of the compound; formula mass for ionic compounds (3.6)
- Calculate the molar mass of a compound (3.6)
- Calculate moles from mass (3.6)
- Express molecular composition in terms of percent composition (3.7)
- Use percent composition to determine the empirical formula of a compound (3.7)
- Use experimental data to calculate the number of water molecules in a hydrated compound (3.8)

3.0 INTRODUCTION

~ (KT3, p.102)(KT4, p.100)



Give everyday examples of *chemical compounds*.

Clothes: wool, cotton, polyester, nylon composed of C, H, O and other elements
Sugar, starch, salt: $C_{12}H_{22}O_{11}$; Aspartame (diet sugar) C, H, O, N; Table salt NaCl
Rocks and minerals: Si, O, and metals like Na, Al, Be, Fe; Limestone Ca, C, O = $CaCO_3$
Colours: pelargonidin the red colour in geraniums and strawberries



Name all the elements in your body.

O = 64,6 %	P = 1,1 %	Mg = 0,03 %
C = 18,0 %	Cl = 0,4 %	Fe = 0,005 %
H = 10,0 %	K = 0,36 %	Zn = 0,002 %
N = 3,1 %	S = 0,25 %	Cu = 0,0004 %
Ca = 1,9 %	Na = 0,11 %	I = 0,0001 %

Total = 99,8 %



What is chemistry all about?

Chemistry is about compounds you find all around you: their physical and chemical properties. Creating new compounds with new properties.



Study:

- Composition of compounds
- How compounds react with one another
- The shape and structure of compounds
- The forces holding compounds together
- How compounds interact with their environment
- Major types of chemical compounds and their chemical and physical properties

ELEMENTS THAT EXIST AS MOLECULES

(KT3, p.102 - 108) (*extra to KT4*)

⊕ CD 3.2 (*good*)



How many elements are known and isolated?

111 elements are known and isolated

- **Metals:**
Most elements are metals.
Most metals are solids.
In solid state, metals consist of atoms packed closely together.
- **Nonmetals:**
Nonmetals are gases, liquids or solids consisting of free atoms or molecules
Group 8A, rare gases, are uncombined atoms in nature.



Give all the elements that exist as diatomic molecules.

H₂, N₂, O₂ and group 7A elements. ("*brinclhof*")



Give all the elements that exist as polyatomic molecules.

Elements that exist as molecules with more than two atoms are one form of elemental phosphorus P₄, and sulphur S₈, O₃, C₆₀



Some elements can exist in different physical forms called *allotropes*. Name the elements and describe their shape and characteristics.

oxygen

- colourless gas O₂,
- unstable blue gas with odour O₃

phosphorus

- white phosphorus P₄ molecules
- red phosphorus P₄ units bonded together in a chain
- black phosphorus, more complex networks of phosphorus atoms

sulphur

- lemon yellow form of sulphur, crown-shaped S₈ molecules, ortho-rhombic crystals (below 150 °C)
- needle-shaped monoclinic crystals, rings break to form S₈ chains (above 150 °C)
- plastic sulphur, orange red, forms when melted sulphur is poured into water

carbon

- Pure carbon is found in two well-known forms:
- diamond and
- graphite, and
- a new form, a carbon cage called "buckyball"

All are extended networks of carbon atoms.



Explain the differences between all the carbon allotropes and give their characteristics and practical uses.

(a) *graphite*

Atoms of carbon arranged in flat sheets of interconnected, hexagonal rings, each *carbon atom* connected to *three* others in the same layer. Sheets of rings cling only weakly to one another, one layer can easily slip over another.

graphite = soft, good lubricant, pencil "lead"

Chemists and engineers form sheets into fibres – extraordinarily strong composite materials – used in tennis rackets, fishing rods, masts for sailing boats.

(b) *diamonds*

Carbon atoms are arranged in six-sided rings.

Each *carbon atom* is connected to *four* others, surrounding the central carbon atom at the corners of a tetrahedron.

Consequences

(1) atoms connected throughout the solid

(2) carbon rings (layers) cannot be flat

Structure makes diamond extremely hard and denser than graphite (3,51 to 2,22 g/cm³)

Chemically even less reactive than graphite, and excellent conductor of heat (*not electricity*).

(c) *diamond films*

Recent exciting chemistry development.

Ability to grow diamond films – coat other materials with extraordinarily hard film that conducts heat but not electricity (greatest advance since plastic)

(d) *carbon cage C₆₀ molecule (buckyball)*

Beautifully regular structure - spherical cage of carbon atoms - resembles hollow soccer ball.

Five-membered rings linked to six-membered rings – official name of allotrope is buckminsterfullerenes.

C₆₀, C₇₀, C₂₄₀, C₅₄₀, C₉₆₀

Buckyballs are found in carbon soot.

Extraordinary properties - e.g. microscopic ball bearings ("*Swiss army knife of a molecule*")



Exercise 3.1 (KT3, p. 108)

How is the microscopic structure of graphite related to its macroscopic properties?

3.1 MOLECULES AND COMPOUNDS

⌚ (KT3, p.108 - 111)(KT4, p.100 - 103) ⊕ CD 4.2;3.3,4



- Interpret molecular formula and structural formula (3.1)

Compounds are pure substances that can be decomposed into two or more different pure substances.



Give Dalton's definition of a compound

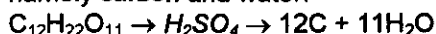
Compounds form by the combination of atoms in the ratio of small whole numbers.



Give the definition of a molecule

The smallest unit of a compound that retains the chemical characteristics of the compound is a molecule, represented by a *molecular formula*.

The compound of pure sugar is decomposed into two or more *different* pure substances, namely carbon and water.



molecule

atoms molecules



What happens to the characteristics of the compound (sugar) when it is decomposed?

When compounds are formed directly from the elements or from other compounds, the *characteristics of the constituent elements* (or compounds) are lost.



What happens to the physical and chemical characteristics of iron and sulphur in the formation of a new compound iron sulphide (or Al and Br₂ to form Al₂Br₆)?

FeS (new compound) will not have the same characteristics as Fe (element) or as S.



Use examples to indicate how to write molecular formulas. What information does the molecular formula provide?

Red phosphorus reacts violently with bromine (*fig.3.8, KT3, p.118*)

Formula of resulting compound is PBr₃

4 atoms per molecule = 1 atom phosphorus + 3 atoms bromine

Subscript indicates number of atoms of element in molecule. *Subscript omitted means one.*

Molecular formula provides information on the composition of the molecule.

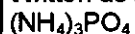


Give the molecular formula of ammonium phosphate, a common fertilizer

Written in *alphabetical* order:



Written as *functional groups*:



Two different chemical "units"

NH₄ and PO₄ in the ratio 3:1

Polyatomic (many atom) unit

- *Simplest* molecule consists of two atoms:
CO carbon monoxide
- *Complex* molecule consists of many atoms:
haemoglobin
2952C, 4664H, 832O, 812N, 4Fe, 8S atoms



Give a definition of organic compounds.

Compounds containing carbon and hydrogen and may also contain O, N, S, P.



There are several ways to write the formulas of organic compounds. Name them.

- *Alphabetical order* with subscript indicating the total number of atoms of that type in the molecule.
- *Structural formulas* showing how atoms are grouped together in the molecule
- *Functional groups*, indicating the point of attack when molecules react with each other.

ethanol

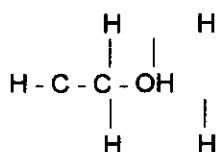
C_2H_6O

CH_3CH_2OH
-OH

alphabetical

structural

functional group



structural formula



example 3.1 (KT3, p.111)(KT4, p.103)

exercise 3.1 (3.2, KT3, p.111)(KT, p.103)

3.2 MOLECULAR MODELS

~ (KT3, p.112 - 113)(KT4, p.103 - 106) @ CD 3.4(good)



- Interpret molecular formula and structural formula (3.2)

- Visualizing the structures of molecules is important to chemists.
- Molecular structure of a substance is essential in explaining its physical and chemical properties.



How does the structure of ice explain its properties (fig.3.3, KT4, p.104)?

- *shape of ice crystals*
The six-fold symmetry of the macroscopic crystals also appears at particulate level, in the form of six-sided rings involving hydrogen and oxygen atoms.
- *density of ice; less dense than water*
Molecules of water are packed more tightly together than the open weave of the ice molecules.

APPENDIX 10

ASSESSMENT GUIDELINE

Dear Facilitator

Small Scale Chemistry Set was developed to meet the following criteria:

The learners should:

- ♦ observe, by discovering for themselves, the changes which elements and compounds can undergo;
- ♦ construct the correct visual images necessary for the forming of concepts by observation;
- ♦ develop manipulation skills by experimenting on their own;
- ♦ develop a positive attitude towards Chemistry and the Natural Sciences as a result of their experimentation, observation and interpretation;
- ♦ become conscious of the use and misuse of Chemistry by studying elements and compounds with the Student Lab.

In order to achieve the above, you as a facilitator should give the learners full opportunity to make discoveries on their own by using the Student Lab. The ideal is that every learner should have his own apparatus set and chemical set. However, where this is not financially viable, it is recommended that two learners share an apparatus set and four share a chemical set.

A few notes:

- ♦ In case of time constraints long worksheets can be shortened according to the facilitator's own discretion (in compliance with the problem question) by leaving out some of the numbers of the worksheet.
- ♦ the worksheets are developed with Outcomes Based Education as our criteria, and as such encourage greater learner -, parent - and community involvement
- ♦ class time can be conserved by letting learners do "safe" experiments at home, e.g. electrochemical experiments.
- ♦ self responsibility, critical and creative thinking and life long learning will also be improved by greater responsibility when doing chemical experiments in school and at home.
- ♦ the Student Lab is an excellent tool in teaching Science by inquiry. It gives sufficient guidance to learners to ensure direction and success in discovering scientific concepts and principles.
- ♦ Please take special note of all safety requirements, especially special safety techniques and waste disposal regulations.
- ♦ The assessment sheets at the end of each experiment simplify assessment. Learner self evaluation is done according to a six point scale (6. agree completely; 5. agree; 4. agree with reservations 3. undecided; 2. don't agree; 1. definitely don't agree).

- ♦ Facilitator evaluation is also done according to a six point scale (1 – poor; 2 – awkward, clumsy, 3 – needs practice, 4 – reasonable, 5 – good, 6 – very good). The six point scale prevents learners and facilitators from choosing the safe middle mode.
- ♦ There are alphabet letters at the end of the questions or actions in the worksheets to simplify the facilitator evaluation. For example observation is tested in questions 4, 7, 10 and 14 of a worksheet. In compliance with the answers to these questions and the facilitator's own observation in class, the facilitator can evaluate the learner for observation according to the six point scale on the table provided at the end of the worksheet. Nine fields of assessment are continuously evaluated namely: observation, measuring, recording, manipulating, inference, procedure, investigation, evaluation and knowledge.

Facilitator evaluation

(6-very good, 5-good, 4-reasonable, 3-needs practice, 2-awkward, clumsy, 1-poor)

	Observation (o)	Measuring (m)	Recording (r)	Manipulating (M)	Inference (i)	Procedure (p)	Investigation (iv)	Evaluation (e)	Knowledge (k)
Question number	4, 7, 10, 14		19	1, 2, 3, 5, 6, 8, 13	1, 9, 11, 12, 15, 16, 17, 18, 20, 21	Experiment		16, 17	1
Mark	3		4	3	4	4		4	4
Consider all the answers on the questions relating to, for example, observation and give the average mark. In this case 3 marks mean the learner needs more practice in observation skills. Seven skills were tested (in this experiment) for which a maximum of 6 marks each can be awarded, so the maximum marks total is $7 \times 6 = 42$ marks.								Total (7x6) Max. 42	26

Assessment guidelines

Assessment fields	Explanation
Observational skills	Observations of changes during chemical reactions, e.g. colour, smell, and development of gas, temperature- and volume changes, and precipitation. Classification of types of reactions, e.g. acid base and redox reactions. Comparison between different observations.
Measurement skills	Correct units for common measurements, e.g. length, volume, pressure and temperature. Correct reading of scales and measuring instruments, e.g. pipette, measuring cylinder, and thermometers. Making of rough estimates during a measurement. Precision and accuracy in measurements.
Recording skills	Correct recording and ordering of data, e.g. in tables. Correct graphic representation and interpretation of data. Correctly labeled scientific drawings. Correct deductions and conclusions.
Manipulative skills	Demonstrate fine motor control in confidently using apparatus and chemicals.
Skills of inference	Making correct calculations from collected data. Recognition of data patterns. Recognition of the difference between observations and the interpretation of observations. Making possible and plausible

	generalizations and the relation between various observations.
Experimental procedural skills	Identification of all component parts of apparatus and chemicals. Setting up of apparatus and the execution of experimental procedures. The correct adherence to and application of security procedures during the execution and completion (correct waste disposal) of experiments.
Investigative/ research skills	Identify researchable aspects of a problem. Demonstrate insight into related concepts. Suggestion of possible strategies and procedures to adopt in further investigations. Insight into the correct use of scientific method (hypothesis, literature survey, experimentation, laws and theories).
Evaluative skills	Identification and prevention of possible danger with regard to experimental procedures and chemicals. Awareness of the fact that results and conclusions may be incomplete and inadequate. Offering constructive criticism of the design and procedure of the experiment or the use of the apparatus.
Knowledge	Demonstrate good insight in handling chemical concepts and the integration of prior and newly acquired knowledge.

If you have any ideas for the improvement of the set, we would like to hear from you. It is our wish, as the developers of the set, that your teaching of chemistry will gain a new dimension as a result of the creation of a positive class room climate and a positive attitude among your learners.

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