DEMONSTRATIONS AS A TEACHING - LEARNING TECHNIQUE IN NATURAL SCIENCE

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ABSTRACT

The use of teaching techniques opens many exciting possibilities for learning in a classroom. The methods that teachers use in teaching new information has been identified as critical to how learners learn new scientific skills. Demonstrations as a teaching and learning technique has been central to this assertion It has been found that little or nothing has been done to bring about reform in teaching methods since curriculum reform, resulting in teachers clinging to the lecture method and demonstrations to be their only source of images and concept formation.

Some teachers believe that demonstrations are passive in nature and most overdo demonstrations. To verify this statement, research was carried out to investigate the teachers' knowledge of and insight into demonstrations and to identify what benefits, if at all, and constrains do teachers associate with the use of demonstrations. The results show that teachers are still experiencing problems with the concept demonstration and many are yet still no using the technique as a teaching method. A conclusion is that teachers are not yet conversant with the benefits and alternative ways through which demonstrations can be implemented.

OPSOMMING

Die gebruik van onderrigtegnieke bring verskeie opwindende moontlikhede vir onderrig in die klaskamer. Die wyse waarop onderwysers onderrig is as krities geïdentifiseer vir die manier waarop leerders nuwe wetenskaplike vaardighede aanleer. Demonstrasie as 'n onderrig- en leertegniek, staan sentraal in hierdie aanname. Daar is gevind dat niks of baie min al gedoen is om hervorming in onderrigtegnieke aan te bring sedert die instelling van die nuwe kurrikulum wat daartoe gelei het dat onderwysers nog vasklou aan die lesingmetode en demonstrasie as hulle enigste bron van beeld- en konsepvorming. Sommige onderwysers is van mening dat 'n demonstrasie passief van aard is en die meeste oordoen dit. Om hierdie stelling te verifieer is 'n studie gedoen om die onderwysers se kennis van en insig in die demonstrasiemetode te ondersoek ten einde die voordele, indien enige, en beperkinge te identifiseer wat onderwysers met die gebruik van demonstrasies assosieer. Die bevindinge toon dat onderwysers nog steeds probleme ondervind met die begrip 'demonstrasie' en baie gebruik nog steeds nie die tegniek in die onderrig nie. Die gevolgtrekking is dat onderwysers nog nie vertroud is met die voordele sowel as die alternatiewe maniere waarop demonstrasies geïmplimenteer kan word nie.

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CHAPTER 1

ORIENTATIVE INTRODUCTION

1.1 Problem statement and background

Today South Africa is facing a crucial need to protect its investment in teachers and its education. In the midst of this need the standards of science teaching remains marginally low (Howie, 2001:11). Wesi (2003:1) in support of this statement holds that the teaching standards in South Africa are generally below the norm. Not a single proposal for reform suggests that education can survive, much less succeed without excellence in teaching (Trowbridge & Bybee, 1990:173). Everybody expects quality results from our education system yet very few ask the question, does our education system have the necessary capacity to produce desired outcomes?

At present, schools in developing communities, including those in the South African context do not provide a sufficient number of learners in the field of technology and other related professions (Van der Linde *et al.*, 1994:49). This non-achievement of results is evident in matric examinations (Department of Education, 2002:9; Nyamane, 2002:17) and is further revealed by Howie (2001:38) that even at Grade 8, the threat of poor performance exists. A shortage of suitable teachers has been assumed by many researchers as contributing to the problem (Howie, 2001: 25; Van der Linde *et al.*, 1994:50).

The teaching of Physical Science has not achieved the desired goals (Nyamane, 2002:17) even in the present reform into an Outcomes-Based model of education. This is a matter of concern because many teachers believe that the Outcomes- Based Education curriculum is the best model that South Africa has ever had. Howie (2001:38) gives an account of the situation. She claims that teachers who are not suitably qualified contribute to the situation. Most of such teachers have not even passed a second level of their university education specialising in natural sciences. This is genocitic to the learners. This statement is furthermore supported by Wesi (2003:1) by stating that many physical science teachers did not specialise in the subject. The lack of suitably qualified teachers who can handle the subject matter in a proficient manner is cited as one of the recurrent problems of lack of interest in science subjects (Bradley & Stanton, 1986:538).

This situation has led to South Africa being rated amongst the lowest achieving countries in the world for its results in Mathematics and Science tests (Howie, 2001:38). An in depth scrutiny of this results single out natural sciences results as unacceptably low (Nyamane, 2002:17). As a measure of intervention research points to the following indicators as a cause for concern;

- Lack of suitably qualified teachers (Wesi, 2003:1).
- Short sight on the upgrading of serving teachers through in-service training programmes (Mkhize & Gouden, 1988:2).
- Lack of appropriate teaching methods (Van der Linde *et al.*, 1994:50; Prawat, 1992:388).

In an attempt to find the best appropriate techniques for teaching, several methods were put to research. Over the past decades the demonstration as a teaching technique has been at the core of the research. Brophy (1986) discovered that demonstrations do influence learners' attitude towards science in a positive way. Jenkinson and Fraiman (1999:283) reported that demonstrations open many exciting opportunities for teachers in their delivery of information. Watson (2000:51) asserts that practical work is seen as a hallmark of science and many teachers argue that teaching science without demonstrations fail to reflect the nature of scientific activity. His report shows that many teachers believe that demonstrations provide an essential feature for understanding scientific concepts. Practical work as described by Van der Linde *et al.*, (1994:49) includes all types of investigation or experiments by learners on their own or in groups as well as demonstrations by teachers. This study will only focus on demonstrations done by teachers in a classroom situation.

This study aims to investigate how teachers use demonstrations in a classroom situation and to determine the extent of their knowledge on the concept, demonstrations as a teaching-learning technique. Secondly this study will also focus on how demonstration can be effectively used to enhance learning and the academic achievement of learners. Specific attention will be on demonstrations in natural sciences.

1.2 Research aims and objectives

1.2.1. The aims of the research

The aim of this investigation is to determine the teachers' knowledge of and insight into demonstrations in the teaching and learning of natural science. The study will further investigate how well trained are teachers in the use of demonstrations as a teaching-learning technique.

1.2.2. Research Objectives

The research aims will be achieved by means of the following objectives:

- To give an in-depth literature review on the nature of natural sciences with particular reference to demonstrations in a classroom.
- To investigate how teachers use demonstrations as a learning tool.
- To determine the teachers' knowledge of and insight into demonstrations.

- To determine the challenges that teachers face in the classroom in the use of demonstrations.
- To give the teachers understanding of the concept "demonstrations".

1.3 Hypothesis

Demonstrations in natural sciences are effective for promoting teaching in the classroom.

1.4 Description of terms

1.4.1 Demonstrations

The concept demonstration is discussed and explained in detail in section 4. It is however important to give a brief description of the term "demonstrations".

"Demonstration is a planned manipulation of equipment and material to the end that learners observe all or some of the manifestations of one or more scientific principles" (Pfeifer & Sutman, 1970:83)

According to Walters (in Vreken, 1980:151) this kind of a definition creates the assumption that demonstrations are exclusively reserved for illustrations of a phenomena or a technique to learners whose contribution is limited to listening and observing. However, according to Nieuwoudt (1998:6), the principle of learning is not only based on the premise of using senses but most importantly, it includes active inner experiences. From an ontological-contextual point of view, teaching is seen as an interactive process, where a learner must be guided through interaction to attain a preset goal of acquiring certain knowledge, skills, attitudes and even values. In this context, a learner will be assisted in totality. Van Dyk *et al.*,(2001:156) defines this kind of teaching from a positionistic point of view, as "a multidimensional formative activity, consisting of the three functions of guiding, unfolding and enabling

1.4.2 Learning

Learning as a concept, has dominated research of many educationists and psychologists. Depending on an individual's perspective on learning, the term acquired several definitions. As a result of constructionistic research, (Prawat, 1992; Cobb, 1994), the learner's role has changed from passive learner to that of an active co-responsible participant and contributor to the teaching situation. To this end, the following definitions will be advanced:

"Learning is an act of goal oriented, active, constructive and cumulative processing of information into meaningful and useful knowledge, which can best be characterized as problem solving."

Vreken (1980:132) supports this definition, by arguing that good conventional teaching must take account of the learner. Given the personal nature of learning, it is important for learners to interact with the learning content and be guided to construct their own meaning of the concept. This implies that learning cannot be separated from learning activities.

1.4.3 Teaching

The origin of teaching was mainly focused in the behaviouristic paradigm. Specific instructional behaviours were correlated with resulting learning products. Numerous theories were provided to define teaching. Firstly from an algorithmic perspective teaching was viewed as a "process believed to cause the desired learning products in a consistent way if done correctly" (Esler & Sciortino, 1988:3)

This model became known as traditional teaching and eventually developed into sophisticated models such as direct instructions. Like paradigms, teaching models can be subjected to change as a result of new information and knowledge. Many researchers continued to improve on the perspective of learning in an attempt to improve the way through which mankind acquires knowledge.

A teaching perspective that is central to this study is provided by Nieuwoudt (1998:6):

"a purposeful and complex educational human act of one person intentionally, and within a specific context, engaging into a live and guided interaction with another person, in order to enable the latter to attain a preset goal of acquiring certain knowledge, skills, attitudes or values.

This kind of definition indicates that all teaching and learning activities should converge towards specific yet expected outcomes (Cohen, 1993:392). By definition, teaching can only be effective if it enables the learner to learn what has to be learnt, as well as how to achieve specific outcomes.

1.5 Method of research/ Investigation

1.5.1 Literature

A DIALOG search was performed to obtain information using the following keywords: Demonstration, methods of teaching and learning, learning strategy in natural science. A second electronic search was conducted from EBSCO host to get information from thesis, journals and any other primary and secondary sources of information to gain an in-depth understanding on the role of demonstration in a teaching-learning situation.

A questionnaire was designed to investigate teacher's conceptions of and insight into demonstrations. The results obtained through the questionnaire served as an instrument for assessing the level of teachers' training and their conceptions of demonstrations.

1.5.2 Statistical Analysis

The Statistical Support Services of the North-West University (Potchefstroom campus) were consulted to assist in the statistical analysis of data.

1.5.3 Population

The study was limited to a group of teachers (n=79) who are teaching natural science in the General Education and Training band. These teachers are residing in and around Mabopane District in the Eastern Region of North West Province.

1.5.4 Questionnaire

For purposes of situational analysis a questionnaire was developed in cooperation with Professor Vreken and his associates based at the North-West University (Potchefstroom campus). The questionaire was split into two sections namely those that were based on a Likert type scale and those that are open ended. The questionnaire was administered on science teachers who were part of the study group. This was done to determine how teachers use demonstrations in a classroom situation and what they understand about demonstrations as a teaching-learning technique.

1.6 Conclusion.

This chapter was orientative in nature and provides the basis for undertaking this research. It gave a brief outline on the problem statement the key objectives and the method for carrying out this project. Having formed a background, the next chapter will then pronounce broadly on the nature of natural sciences.

CHAPTER 2

THE NATURE OF NATURAL SCIENCE

2.1 Introduction

One of the major characteristics of science is that a high premium is placed on the validity and credibility of its findings. The most important rationale for methodological research and analysis is therefore to be found in the emphasis, which is placed on the scientific nature of science (Mouton & Joubert, 1990:156). The nature of science contributes to our understanding of the universe and therefore when we study concepts in natural science, whose methods contributes mainly to how science is conceptualised, one ought to consider its nature and contribution to the society (Cilliers & Reynhard, 1998:178). The best way of making teaching of natural science effective is to focus on its nature and changes that it has undergone. Various aspects operating within the learning environment such as the teacher, the learner and the content in particular, can also influence the teaching or even the learning of a discipline like natural science. It is argued in education circles, that one of the best methods to teach science is through demonstration (Woodburn & Obourn, 1965:322).

The concept of demonstrations has enjoyed research by reputable academics (Watson, 2000: 59; Du Toit & Lachmann, 1997: 51). It is their conclusion that when effectively used, demonstrations can influence learning positively. It is thus the rationale of this research, to advance study of the nature of science with special reference to its teaching to provide a basis for an in-depth study on demonstrations as a method of enhancing concept formation.

2.2 Nature of natural science

There are many ways to approach an investigation of the nature of science. Historical literature exposes only two points of view as acceptable. Science can be viewed either as a method of acquiring knowledge or as a systematic body of knowledge (Giere, 1992). Once science is viewed as a method then there must exist a platform for science to prove its existence. It is in science's nature to find characters of representing their present world,and how to define that world. For example, science has characters such as observation, theory, models and laws to give meaning to their present understanding of knowledge (Motz & Weaver, 1989:1; Moloney, 2000:1).

Science has a history, which for so long has been neglected (Fraser & Tobin, 1998:1020). This has deprived a novice of science of exactly how science has evolved and why are we doing science in its present form. For example, in Giere (1992) the new naturalism in science studies recognises that people learn by active intervention in a world of objects and other people. People argue that the philosophy of science lacks resources to deal with new notions of reasoning and empirical access implied by the new image of scientific practice. To a novice these statements may have no relevance unless a person carries a particular knowledge of how science has evolved (Moloney, 2000:6).

To support the assertion that the practical nature of natural science contributes to our understanding of the universe, Cilliers and Reynhart (1998:178) states that physics, as a natural science is essentially investigative by nature, which makes experimentation an essential part of gathering information. Science is therefore a method of exposing human kind to new experiences as one comes into contact with matter. Lindsay (1971:3) holds that science as a method exposes human experience to everything that happens to an individual as he relates with matter. This contact is established as a pattern to describe matter in a more sequential and acceptable way. Such experience is built by performing experiments through arrangement of physical objects and performance of operations on them to make regular observations.

When such operations are carried out, discoveries have to be reported in ways and methods acceptable to science (Smith, 1964:134). These methods are mostly investigative to our own curiosity and knowledge of the environment. As scientists, people study questions of their choosing or those posed with a hope of finding an answer or even discovering some useful information. However science remains focused to stating a problem that is worth studying and is also narrow enough in scope that a useful conclusion can be reached (Kotz & Treichel, 1999:5).

2.2.1 Definitions

2.2.1.1 Physical science

Young learners, who take on natural sciences and physics in particular, know they are doing the science that deals with natural phenomena, material world and have a chance to a brighter future. No concrete meaning of exactly what science is becomes conceptualised. Motz and Weaver (1989:8) support this assumption as held by many students. To bring clarity they state: "A science is more than a body of knowledge expounded in original papers and collected in books; it is the pursuit of this knowledge by a group of people (scientists) who are devoted to this great adventure by an inner drive they cannot deny." Reasons for pursuing physics will in most cases differ from one person to another; some are driven by accomplishment (Levy, 1934:45) others can be in search for the fundamental laws of nature (Motz & Weaver, 1989:5). But what is the acceptable definition of physics? As such the following definitions are provided; physics is:

"A branch of science as a method for describing, creating and understanding human experience" (Lindsay, 1971:3).

"A story of the continuity of ideas, observations, speculations, and syntheses that constitutes the body of knowledge" (Motz & Weaver, 1989:1).

Natural science exposes a keen researcher to know more of how things came to being rather than why they happen (Motz & Weaver, 1989). The significance of studying physics as a natural science, has been more influenced by prediction rather than a focus on what makes things happen (Wesi, 2003:20).

Science and man have always had an influence on each other. Man's curiosity in science is mainly driven by observation of natural phenomena and trying to give meaning to how things happen. To agree with Levy (1934:45) as he asserts that science is driven by achievement, nature must provide a scene that is worth studying and whose findings once manipulated, must add value to the existing body of knowledge. In full view of this definition, human kind becomes linked to the scientific process in two ways. First, is the systematic isolation of the experiment material from confused mass of puzzles that faces a scientist, and secondly in the arrangement of this data in a logically cogent form which should be guided by thought and action in a tentative approach (Carnap, 1995; White, 1989).

Given how physics has transformed from the philosophy of science, which will be discussed in detail in the succeeding paragraphs, modern science distinguishes itself from ancient science by its emphasis on experimental methods. Experiment has since its origin been based on observations. With time, scientists wanted to participate in experiments and set up arbitrary arrangement of objects and performing operations to see what kind of results can be achieved if the systems are manipulated (Carnap, 1995:40).

2.2.2 History of science

The study of science proceeds to an objective study of natural processes in so far as they can be separated out of human interaction. To guard itself from human manipulation, science belies its name if it ceases at mere compilation of data. It expects researchers to go beyond data compilation into a systematic and logical reasoning. Natural science has its own roots in Greek philosophy. What is recorded in literature is mainly as a result of scientific methods (Motz & Weaver, 1989:2).

Science originated from speculations and mathematical creations. Any principles or laws that would enable one to predict the future events based on such observations, did not govern Science as a philosophy. Science was governed much by human reasoning of particular paradigms and driven by generalisations (Capra, 1985:257; Motz & Weaver, 1989:2).

The roots of natural science as well as western science are traced to the Greek philosophy in a culture where science, philosophy and religion were not separated. Philosophy of that age was not concerned with creating a divide of the three, but their aim was to discover the essential nature of things called "physics." For many centuries Greek used "Physis" to define an endeavour of seeing the essential nature of all things, and later replaced the term "physis" with the word physics as it is known today (Capra, 1985:20). It is on the basis of this definition that Milesian school had a strong mystical flavour; they perceived matter as alive and could not separate spirit and matter.

This view of matter dominated western science for quite a number years after culmination of Greek science and culture, until Aristotle came to organise and systematise the scientific knowledge. Aristotle himself accepted this assertion and focused on the contemplation of God's perfection as more significant than to investigate the material world. Based on his reference to God, Aristotle's doctrines enjoyed support from many Christian circles and went unchallenged even if it lacked virtue of the material world (Chunqi, 1998:3; Capra, 1985:21). It was only later in the eighteen century, when scientists started to treat matter as abiotic and separate from man.

Greeks with their philosophy of science contributed a great amount of knowledge to physics with their mathematical knowledge, their observational astronomy and their range of speculations. Their geometry remains an important part of physics because some laws can only be best expressed in geometrical content (Motz & Weaver, 1989:2). Since the Greeks' science is essential for high-grade thinking based on unaided observation, it is suitable for classroom teaching. The implication for the science classroom is that laws generated from Greek science can be discussed in interesting and motivating settings. For example, since Archimedes does not tell us what experiments he performed with the centre of gravity or with levers in order to test his ideas, we can speculate, invent and test the plausibility of our own ideas (Fraser & Tobin, 1998:1033).

2.2.2.1 <u>Archimedes (287 - 212 BC) contribution to science</u>

Archimedes (287-212 BC) remains the most notable and closest Greek philosopher to have come close to what we define as a scientist. He combined theory and experiment in the same principle as how we do our modern science. His focus was mainly from Euclid's geometry, to show that scientific knowledge can be deducted as theorems from a set of self-evident propositions. Since his work lacked a well-equipped laboratory to carry his experiment, he could not attach any theorem as a product of his work but he laid down principles necessary for the basis of research (Motz & Weaver, 1989). Archimedes' challenges are noted by Motz and Weaver (1989:4) that irrespective of what they (Greeks) knew about motions of planets through observation such information alone could not enable them to predict or understand the periodicity of tides and behaviour of free falling bodies. Archimedes, albeit being a great experimentalist, an investor and a keen student of nature, did not actualise his experiments. Hence his work did not qualify him into the class of Einsteins (Carnap, 1995; Motz & Weaver, 1989:4).

2.2.2.2 Aristotle (384-322 BC)

Aristotle was a student of Plato and his way of doing science has had an impact on the nature of science because for almost two millenia his philosophy governed human thinking (Chunqi, 1998:3; Motz & Weaver, 1989:5). His science was based on the assumption that observation was essential to the study of science. Aristotle was among the first to organise and create a systematic pattern of scientific knowledge. He combined mathematics to physics to show that mathematics is a model for organising science. He tried to develop a theory of motion that would explain kinematical behaviour of observable objects in the universe, but could not, because his conviction was that bodies could only move if and only if acted upon. Aristotle's views that questions concerning the human soul and the contemplation of God's perfection were more significant than material world deprived him of conducting necessary experiments to achieve even better results (Capra, 1985:21). Given today's perspective, a novice may ask why Aristotle's unscientific physics has remained at the centre of mankind's thinking for over two millenia? Chunqi (1998:2) holds that unless there is a need for clearer definition and explanations, paradigms remain unchallenged. Perhaps this could be true during times of Aristotle because based on his reference to God, his doctrines enjoyed support from many God fearing leaders and science society. In summary to Aristotle's work, Greeks indeed influenced science but their science was too much of a theoretical foundation supported by powerful mathematics (Moloney, 2000:2). His theory was mainly a search for truth.

2.2.2.3 Galileo Galilei (1564-1642)

Among the great philosophers, he was the first to combine empirical knowledge with mathematics, and is therefore seen as the father of modern science. As science developed during the Renaissance, men started to indulge in nature and freed themselves from the influence of Aristotle and the church. It was only during the late fifteenth century that nature was studied in a truly scientific method as experiments were undertaken to test speculative ideas. As this development matured, it led to the formulation of proper scientific theories based on experiments and expressed in mathematical language (Motz & Weaver, 1989:34).

2.2.2.3.1 What is science?

Science is a human activity and its course of development is greatly affected by human needs and desires. According to Levy (1934:45) achievement is a motivating factor for scientists to carry out experiments. Science is a communal activity where ideas and standards are shared and compared among people. This can be done if science has a system of articulating ideas. In this way scientific process is exposed as a magnified image of our every day processes of thinking and knowing. Scientists mainly focus on things that appeal to them (Giere, 1992).

Among other things science can be influenced by language, philosophy and mathematics (Chunqi, 1998:1). In its nature science has for so many years refined the original paradigm but inhibited innovation. This is evident by the impact of Aristotle's theory which dominated science circles and provided a framework in which all known physical phenomena fitted and had an influence on science (Motz & Weaver, 1989; 8). In terms of scholastic methods of inquiry most students went into Aristotle's school of thought and never challenged his ideas because of a need to belong (Moloney, 2000:2). Most philosophers believed that science operates in two stages. First it is empirical research then logical analysis of results. Empirical science was used as a means to gather data while philosophers analysed the data and clarified theories used to explain it. Any statement that could not be verified by their science was considered meaningless, Kuhn (in Moloney 2000:2). This is further supported by Fuller (2000:567) and Moloney (2000:3) in their conclusion that for astronomers to believe Corpenicus on his geocentric theory, they were not guided by the textbooks but their acceptance of his theory was based on their peculiar religions' theories about astrology and numerology. In this context, the study of physics is confined to a limited group of physical phenomena referred to as a process in which the nature of participating substances does not change. Moloney (2000:2) holds a view that science is successful because scientists can deliberately restrict their vision and their imagination in order to see some particular thing or aspect of study in a more focussed way. Science proceeds through the agency of individuals and not unexpectedly individual scientists express their values and culture when they engage in scientific activities (Fraser & Tobin, 1998:1055)

Kuhn (as quoted by Moloney, 2000:2) concludes that in following these trends science bound itself to a set of assumptions of a long-held theory without even recognising it. Kuhn (1973) realised that because science textbooks were useful if they just taught the conclusion and methods of science without all the false starts and theories discarded all the way, the story science told about itself ignored the ambiguity of its actual practice. Scientists believe in scientific reasoning, as reasoning at its best and may not subject the same to uncertainties (Chunqi, 1998:4).

2.2.2.3.2 How has science transformed?

A need for change arises when the original paradigm is unable to explain or causes confusion where there are new developments. Science responds to such need through "scientific revolutions" which means establishment of a new faith or research foundation, which alters the ways of thinking (Chunqi, 1998:1). When a new paradigm arises, philosophers have a responsibility to devote themselves to the development of the paradigm to a stage where empirical evidence is available. This is done to assert the acceptance of a new paradigm. On this basis, a single revolutionary reorganisation of past traditions is undertaken which is gradually spread amongst its supporting group until such time as empirical evidence is available. The process accounts for what known as paradigm shift (Moloney, 2000:2; Chunqi, 1998:4).

2.2.2.3.3 Definitions

Human kind is linked up with the scientific process in two ways. First by the systematic isolation of the facts from the confused mass of puzzles that faces a scientist, and secondly in the arrangement of his data in a logically cogent form. There must be thought and action and all steps are tentative until confirmed as valid (Mouton & Joubert, 1990; Cutnell & Johnson, 1998). Physics is a science that seeks to describe and create an understanding of human experience (Lindsay, 1971:3). This definition is vital in the sense it separates physics from other disciplines because of its exactness on objects and their methodological pursuit. Bybee as quoted by Wesi (2003:18) states that the methodologies of physics involve the use of empirical standards, logical arguments and scepticism. This is in support of Rogers (1962:211) who states that physics is a specialised view of how man experiences the world, which is an art of understanding nature as a science.

Natural phenomena then called the philosophy of science started in the era of Thales (640-546 BC). His work on the philosophy of nature was further advanced by Plato (428-348 BC) and written as a complete theory by Aristotle (384-322 BC). Aristotle's theory gave a unified picture of the world. It offered a framework into which all known physical quantities fitted and had an influenced on science (Motz & Weaver, 1989:8). However this view changed because of the emerging body of knowledge as science evolved. It however remains an important part of literature as the history of science. But what is science? Science is defined as an objective examination of material processes and a human activity, which therefore has a simultaneous subjective aspect to its operations (Levy, 1934:8).

Science is more than a body of knowledge expounded in papers and collected in books. It is the active pursuit of this knowledge by a dedicated group of people (scientists) who are devoted to this great adventure by an inner drive they cannot deny (Motz & Weaver, 1989:vii).

Proceeding from Motz and Weaver's (1989) definition we will observe that each of us even those untutored in science learns a great deal about laws of nature without being conscious of it. For example the law of gravity, everybody seems to know that once you jump from a building you are bound to fall down. Even if they may not be aware of Newton's laws they are conscious if its applications. Science is built on methods and history such that any given method belongs not only to scientific knowledge already possessed but also to the acquisition of that science.
Science can be defined as:

"Not necessarily a random gathering of data it also involves the drive to discover the casual relationship among the individual bits of data that we are aware of as observed in the universe around us (Motz & Weaver, 1989:51)."

"A communal activity where ideas and standards are shared and compared among people (Kattsoff, 1957:178)."

2.2.2.4 Classical physics

2.2.2.4.1 Newton's influence on the development of physics

Physics has had a profound influence on almost all aspects of human life as a basis of natural science. This influence is attributed to a concept that human participation in a scientific process is of greater value to science than observation. Modern physics as a version of science came into being as a result of human interaction with the universe that led to new discoveries. As it becomes modernised science clings and leads to a perception of a world, which is very similar to those views held in religious circles and traditions. As new approaches came into being, scientists started to view matter as abiotic and separate from man. This view of separating man and matter assisted Newton in the eighteenth century to form a mechanistic view of the world (Torretti, 1999:14; Capra, 1985:50).

Modern physics sets nature up to exhibits itself as a coherence of forces calculable in advance, to order its experiments precisely for the purpose of asking whether and how nature reports itself when set up in this way. The purpose here would be to show that modern physics needs experimental testing because; first modern theory moves beyond everyday common sense and experience and thereby loses its intuitive and Aristotelian character.

Using Newton's principle of relativity, new physics divides nature into the simplest dynamic forces and elements in such a way that they can be related and combined or represented by analytical functions and equations.

In his theory Isaac Newton (1642-1727) constructed mechanics on the basis of a world defined as a multitude of different objects assembled into a huge "machine." Newton's model of the universe, as a machine in which all physical phenomena took place was the three dimensional space of classical Euclidian geometry. In Newton's viewpoint the world was an absolute space, which is immovable such that all changes in the physical world could only be described in terms of a separate dimension called time, which was again absolute having no connection with the material world. This view could easily be read to a young scientist to mean that element of the Newtonian world which moved in this absolute space and absolute time, were material particles. In mathematical equations they are treated as mass points and Newton saw them as small, solid and indestructible objects out of which matter was made. This view had the correct basis of establishing a platform for further discovery (Motz & Weaver, 1989:57; Capra, 1985:22).

Newton's work proceeded where Galileo left. Newton developed three important laws that deal with force and mass. Collectively known as Newton's laws of motion, these laws provide a clear understanding for the effect of forces on an object (Cutnell & Johnson, 1998:86).

In Newton's perspective, the whole task of the philosophy is based upon the phenomena of motion to investigate the force of nature and then from these forces to demonstrate the other phenomena. It is Newton's assertion that time as understood in his laws of motion is absolute, true and mathematical, which from its own nature flows equally without relation to anything external. Still "true time" cannot play a role in our physics unless it is exhibited in a definite way by the phenomena of motion (Torretti, 1999:261).

Discoveries like the atomic physics startled great scientist into acknowledging that physics could change its theories and methodologies. Einstein experienced the same shock when he came into contact with the new reality of atomic physics and such a discovery had a profound impact on how concepts like time and space were conceived (Carnap, 1985:53). For example Newton's classical mechanics was considered the best and almost conclusive by many scientists. However his mechanics never took into account the effects of air resistance purely because for him it could be ignored. Though considered the best theory for the description of all natural phenomena, it had omissions. This statement was proved to be holding by the discovery of electric and magnetic phenomena which Newton never considered yet showed that his model was only applicable to solid bodies. Unfortunately this approximation of defining theories remains subtle because of limitations imposed by the explosion of information around us (Capra, 1985:36).

2.2.2.4.2 Albert Einstein (1879-1955)

Inarguably Einstein remains one of the greatest physicists of the twentieth century. His theory challenged the views held by many scientists. For example, Newton and his theory of mechanics and Aristotle on his theories of the universe (Motz & Weaver, 1989:248). He moved from a view of space as a backdrop against which the events of the universe unfold, but that space itself has a fundamental structure that is affected by energy and masses of bodies in contact. He introduced a theory of relativity. Einstein records in his theory that any event in nature is a physical happening that occurs at a certain place and time. To clearly observe any physical happening, each observer requires a reference point that consists of a set of a three-dimensional system and time. In his theory the three-dimensional system establishes a place (space) where an event occurs, an observer and a clock (time) specify such happenings. A participating observer remains at rest relative to his own reference frames. Cutnell and Johnson (1998:866) records that Einstein built his theory of relativity on two fundamental postulates about how nature behaves, which are:

- The relativity postulate in which laws of physics are the same in every inertial reference frame.
- The speed of light postulate in which the speed of light in a vacuum, measured in any inertial reference frame, always has the same value irrespective of how fast the source of light and the observer are moving relative to each other.

2.3 Role of mathematics in natural science

Any person who dislikes mathematics is apt to ask if ever there is essence of using mathematics to understand natural science. To respond to this concern Lindsay (1971:9) holds that to seek a deeper understanding of natural science, mathematics becomes an instrumental language. Mathematics cannot be entirely divorced from natural science. In as much as physics, which we understand and practice today, was unknown to the ancient Greeks, we still owe much to them for the mathematics. Mathematics is important to physics because for example, the laws of motion of bodies can best be expressed in a geometrical context. By using shorthand symbolism of mathematics instead of language of ordinary speech, the statement of physical hypothesis can be clearly expressed and manipulated (Motz & Weaver, 1989; Lindsay, 1971). As a consequence of this explanation mathematics has as a matter of fact become the preferred language of all science (Lindsay, 1971:9). This calls for the great importance of steadily creating new mathematics to match up with the creations of new physical experiments. Such a need was emphasised by refining mathematics by pure mathematics during the close of the nineteenth century and the beginning of the twentieth century. In more recent times it has become customary for physicists to find in the writing of pure mathematics some of the material needed for their theoretical developments (Torretti, 1999; Lindsay, 1971).

Mathematics is not physics but its use therein is essential for the proper study of physics. This is also true of such phenomena as the spatial interrelationships of bodies and the empirical description on the motion of a body (Motz & Weaver, 1989:2). This statement enjoys support Lindsay (1971:118) holds that physicists use mathematics in their attempt to describe and understand the natural experience. The impact of mathematics in physics is so phenomenal that it has become a pure language of expressing ideas in physics. The due purpose of physics is quantitative in the sense that it is concerned with the "how much" more than "how" things are done. However to express quantities requires numbers, so physicists use mathematics to deal with the numbers and the operations that may be performed on them (Lindsay, 1971:4; Motz & Weaver, 1989:2; Torretti, 1999:2). The science community agreed with this statement in that in 1921, Einstein was awarded the Nobel Prize in Physics for his contributions to mathematical physics and especially for his discovery of the law of photoelectric effect.

For example, let us consider Newton's law of universal gravitation:

$F= G\ m1m2/r^2$

This equation is the shorthand representation of the use of mathematics in physics. If one wanted to express this law in full, it could read:

" For any two particles, which have masses m1 and m2, which are separated by distance r, the force (F) that each exerts on the other is directed along the line joining the particles, such that the force is inversely proportional to the square of the distance between them and directly proportional to the product of their masses" (Cutnell & Johnson, 1998:96).

The relationship between mathematics and physics has context. Greek philosophy had its own limitations and was to be replaced by modern physics, which contributed to our knowledge of atomic theory, which has its roots from a hypothesis of a Greek theory. They claimed that matter consists of indivisible particles (atom), which differ in size or mass but had no idea of mathematical calculations. Their theory could not be extended until the emergence of modern atomic theory based on electromagnetic interactions. This principle enabled scientists to calculate atomic and molecular phenomena with incredible accuracy (Giere, 1992). With everything said, the extend of the difference between old and modern physics, is mostly due to the questions asked, the kind of explanations sought and the criteria for accepting one explanation against the other.

2.4 Features of science

2.4.1 Empirical nature of science

In physics the process of scientific research is always employed to acquire knowledge and this can be achieved in three stages. First a researcher must gather experimental evidence about the phenomena to be explained. Secondly correlate experimental facts with mathematical symbols and thereafter work out a mathematical scheme to interconnect symbols in a precise and consistent manner by application of theory to predict results. This process is defined as empirical work. Watson (2000:59) holds that empirical work is one of the defining features of science. To this end many countries devote considerable amount of resources to give students of science the opportunity of doing practical work in their science lessons. But does it work or is it worth the investment?

Watson (2000:58) states that many educators argue that a science education without practical work fails to reflect the true nature of scientific activity. The purpose of practicals has been about thinking that is about trying to understand relationship between evidence and theory and to stimulate and challenge pupils. In a way of science, the process of discovery and justification are slowed down and made systematic. This is done to avoid making snap decisions. The process is intended for justifying a theory based on scientific standard or methods (Kattsoff, 1957:178). To report or even conduct an experiment scientists record each and every step for visualisation of vital functioning parts. In this regard Kattsoff (1957:178) defines science as a very communal activity where ideas and standards are shared and compared among people. He further maintains that doing science forces an individual to be articulative and that science is like a magnified image of our every day process of thinking and knowing. Kosso (1992) concludes that scientific processes should be more open and accountable than our private thoughts. On record many scientists and science educators are convinced that practical work can play an important role in the learning of science. Empirical work defines the features of science and espouses the following aims doing science:

- To encourage accurate observation and description
- To make phenomena more real
- To arouse and maintain interest and
- Finally to promote a logical reasoning method of thought (Watson, 2000:58).

These points are informed by a belief among scientists that practical experience of a phenomenon is basic to the understanding of scientific concepts. Some mental images are necessary for creating episodes, which cannot be achieved by just talking about them (White, 1989). A teacher's role in practicals is to help learners to understand and apply scientific explanations. To do this a teacher must focus on key aspects of demonstrations by selecting and emphasising particular aspects of pupils' responses. To this end a demonstration can be defined as activities that allow learners to learn manual and/or behavioural skills. When doing demonstrations the teacher must ensure that a correct theoretical perspective is established to guide interpretation in relation to the teacher's expectations (Watson, 2000:59).

Good practicals engage students in dynamic problem solving and inquiry. Laboratory practical activities have the distinct advantage of enabling learners to work with real material and to experience their immediate world. Such experiences are an essential element in cognitive development (White, 1989).

The existing feature of physics is its capacity for predicting how nature will behave in one situation on the basis of experimental data obtained in another situation. Predictions such as these, place physics at the center of modern technology. Unlike the early philosophers (e.g. Aristotle) a world of physics cannot be defined purely on merits of observation. It should arise from the combination of both observed facts and the reasoning provoked by their perceptions. Cutnell and Johnson (1998:2) support this assertion that methods used in physics contribute to a character of what physics is today.

2.5 Language as a feature of science

Another approach to investigate the nature of science is to view it as a method of acquiring knowledge. Irrespective of the method used to gather that knowledge one had no science until the information gathered could be expressed in a systematic form. Science if viewed as a language of at least this sort and function, is therefore a representation of its subject matter. A purpose of a language is to provide the means for the correct description of a subject matter (Capra, 1985:30).

The concept that natural science is a language is not so novel if anyone begins to learn a new subject. A great deal of time is taken up by learning definitions of terms, how to apply them and write them as expressions. In a definite sense introductory work in natural science consists of studying the syntax of the field and to some extend the semantics also. When approached as a language, science is apt to answer and unify most questions raised in the philosophy of science (Kaffsoff, 1957:8)

On a practical scale science adopted mathematics as its language. For example consider Newton's "Principia." Here basic definitions are provided, fundamental statements are expressed and consequences drawn, yet Newton himself was not aware of the linguistic structure of science (Torretti, 1999: 74).

Physics uses mathematical shorthand representation like formulae and laws because language can be complex, and has an unfortunate part of ambiguity, which is a recipe for confusion. Language provides clarity on statements, which are generally considered as facts, or universal statements that are acceptable to a group of scientists (Capra, 1985:43).

In modern science, scientific literacy has been cited as key achievement on the vocabulary of many scholars of Outcomes Based Education (OBE). From such inferences science has been viewed either as a method of acquiring knowledge or as a systematic body of knowledge (Lindsay, 1971:3). To achieve this scientific literacy we require a medium of establishing such objectives like language. Torretti (1999:413) supports this assertion in that he writes that one cannot understand science until you know the structure of what it talks about. Since physics has used mathematics as its language, we must learn the significance of the formulae in order to comprehend what it communicates. When we study a language, we learn a set of symbols that are used to express thoughts, ideas, emotions or facts. Language is used to facilitate communication. Language is therefore defined as a set of symbols, which prescribe the way to use symbols in order to communicate (Kaffsoff, 1957: 10). Therefore, language makes it possible for scientists to communicate more adequately about its subject matter, with as little ambiguity as possible and verifiable.

2.5.1 Objectivity as a feature of science

Most scientific arguments and theories are based on consistent observations of natural phenomena. However observational evidence alone is never sufficiently informative to settle questions of the best explanations, confirmation or refutation (Kosso, 1992). Theories can only confront the evidence if under influence of other theories. Even if observational claims were pure and themselves beyond the influence of theory, they could not be explained or used as confirmation in the context of a network of a theoretical systems (Motz & Weaver, 1989:8).

In science objectivity is served by insisting that the theoretical influence on observation be by theories whose aims will not be served by the outcome of the particular observation. In addition to this standard of availability of information, science functions under a standard of objectivity as openness. This process is descriptive on how things are done rather than on the results of the process (Kaffsoff, 1957:169).

Another feature built in objectivity is independence. This refers to the quality of evidence used in justification. It is not just seeking and using any old evidence that counts as objectivity in science. It is better to seek independent evidence whose accounting is uninfluenced by the theory it is being used to test. This aspect of objectivity enhances the credibility of the case (Kaffsoff, 1957:180).

2.6 Methods of science

Science has been shaped by the search to understand the natural world through observation, codifying and testing ideas and has since evolved to become part of the cultural heritage of all nations. It is usually characterised by the possibility of making precise statements, which are susceptible to some sort of proof. To be acceptable as science, a discipline must meet and satisfy certain methods of enquiry, which are reproducible, objective and systematic (Cutnell & Johnson, 1998: 2).

Physics as a natural science gained its practical momentum by gaining recognition through the value of its methods. Physics subsequently became classified by its methods rather than its aims and purposes. For so long physics dominated life of man and his inquisitive mind through its methods. Every observation that took a regular status in the universe was subjected to the methods of science to verify if such observations were consistent with available facts or theories. Through the use of these methods scientists could easily try to find meaning to their daily experiences in a valid set of patterns. However further research accounts that the methods of physics are the best but are limited to the world of the physicist because they do not result in the general ability to solve problems in other disciplines (Smith, 1964:134).

Once a problem statement is made, its solution must be found in that particularly subject. This has been holding for ages. Aristotle (in Smith, 1964:137) insists that an argument drawn from another area cannot be properly demonstrative. In other words it should be in the nature of physics that any problem in natural science should be found in the realm of natural science and not metaphysics or mathematics. This is to support Smith's (1964:134) assertion that each science has its own modalities. Methods used in a particular science should not only reflect scientific knowledge already possessed but also the acquisition of that science.

Wojciski (1979) supports the submission that the cornerstone of research argument in a scientific method is the search for a definition that can serve as a middle term in a scientific demonstration. However he maintains that the ultimate aim or explanation should lie in the nature of that subject. Most importantly the proper and adequate demonstration of a solution can be found only within proper subject matter of a given science. Science maintains that asking the correct questions is the best way to arrive at the right answers. However these answers cannot be found in memory nor additions but by investigation of the matter in question provided that the questions are scientific in nature (Cutnell & Johnson, 1998:2; Capra, 1985:31).

The strength of physics derives from the fact that its laws are based on experiments. This statement does not disqualify educated guesses, but avoids making flashes of insight to become laws and provide for its implications to be verified by experiment. This insistence on experimental verification has enabled physicists to build a rational and coherent understanding of nature (Cutnell & Johnson, 1998:2).

Since science has its own methods, any method that is subjected to investigation must be appropriate to two things, to the researcher and to his set-up instruments. For unless it is appropriate to things studied, these would not be grasped and unless it is appropriate to the researcher, he cannot comprehend. The appropriate method of a particular science is therefore defined by the subjective requirements for comprehension and by the objective nature of the field to be investigated.

Philosophical beliefs from time to time guide physicists to a particular model which may cause them to belief in even when the contrary experimental evidence arises. In such instances, a model may have to be modified to account for the new findings. This model of science where all theories are firmly based on experiment is known as scientific methods (Capra, 1985:35).

2.6.1 Observation

Greek philosophy was driven mainly by observation of the universe and trying to find answers or the truth about such observation. Capra (1985:114) asserts that observation remains one key aspect that separates Greek philosophy from modern physics, in that in modern physics scientists participate in causing the process whereas Greek philosophy was purely dependent on observable events. In most cases observation was guided by personal theories and that had a danger of limiting science (Watson, 2000:57). The base of science initially was dependent on observations of what is happening on the manifest of the world to suggest the content of theories about what is happening beneath the surface of the universe. Observations are the source of our claims from which to draw inductive generalisations because they present confirmations, which contribute to formation of theories. Based on this information it is clear that theories are dependent on observations.

Observation guides our curiosity, because they reveal particular natural patterns or regularities in the world. Earlier studies of science were guided by how man particularly Greek philosophers observed the universe (Rogers, 1977; Carnap, 1995). Theories are thus employed to express our observations in a more precise manner. Carnap (1995) explains laws as nothing more than statements expressing the observed regularities as precisely as possible. For this expression to be acceptable in science as part of a method it should be valid, regular at all times and all places without exception. For example from daily experience water will boil upon heating. If this statement holds to be true always and is repetitive every time everywhere, then it can be accepted as a universal statement.

Popper as contained in Mouton and Marais (1996:134), exposes a challenge facing scientists in that observation is always selective. It needs a chosen object, a definite task, an interest and is provided by man's needs, the task of the moment, and its expectations for the scientist by his theoretical interest and the theories that he accepts as a kind of background, his frame of reference and his expectations. In practice problems are circumvented by describing the observing system in operational terms of instructions to permit a scientist to set up and carry out an experiment. In this way, measuring devices and scientists are effectively joined into one complex system, which has no distinct, well-defined parts, and the experimental apparatus does not have to be described as an isolated physical entity. For preciseness of observation, an item must be isolated or even created in a system to measure its properties (Capra, 1985:34).

2.6.2 Theories

Physics is based on the observation of natural phenomena in scientific experiments. In physics the interpretation of experiments are called models or theories and the realisation that all models and theories are approximate is basic to modern scientific research. Torretti (1999:209) defines theory as a scaffolding or schema of concepts together with their necessary mutual relations and their basic elements. Theory requires a construction of the mind, pictures of the world, as it might be which would lead the researcher to observed experience. Once a theory is made it provides space for creating hypothesis about relations connecting the constructs, with a hope that conclusions will be consistent with physical laws (Lindsay, 1971:17).

Another definition by Kerlinger (1973:9) is that a theory is a set of interrelated constructs (concepts), definitions and propositions that present a systematic view of a phenomena by specifying relations between variables with the purpose of explaining and predicting the phenomena. It is therefore the purpose of a theory to show that things are made up of elements and how this manipulative aspect is inherent in the theoretic constitution of modern science.

Success of a theory is based on its consistency. Once a theory is perceived to be consistent then experiments are carried out to validate it, so that the prediction value of a theory is enormously increased. On the strength of this statement the value of a theory becomes more of an invention than a discovery (Lindsay, 1971:4).

Theories can change or be modified as new experiences are continually created. This happen when older methods cannot account for changes or new discoveries and therefore new theories are sought for consideration. A theory remains tentative because of eruption of new volumes of knowledge that from time to time increases the options of a scientist. Unfortunately theories remains approximate which is subtle because we never know beforehand where the limitation of a theory is. (Capra, 1985:41).

2.6.2.1 Use of visuals to support a theory

Visuals or experiments and demonstrations are used in physics to create new experiences, which seeks to enlarge our understanding of what we have already learnt. To create an experience to a physicist there must be a use of the physical theory. In this regard a theory is an imaginative construction of the mind that employs ideas suggested by experience and also by arbitrary notions whose origin is difficult to trace. Together these ideas form a mental picture of things as they might be. Lindsay (1971:21) holds that valuable theories are those that assist scientists to draw from it consequences that can be identified with actual experiences. Theories are therefore used to predict results that have not been experienced and use scientific methods of experimentation to substantiate its prediction (Lindsay, 1971; Carnap, 1995).

For its acceptance a theory must provide adequate understanding of observed human experience in a given domain. However theories cannot only be accepted on a base of their predictive ability. Among other criterion of interest should be the choice of concept, mathematical correctness as language of physics and the limitations in the number of independent constructs employed through judgement (Lindsay, 1971:23).

2.6.2.2 Nature of a theory

Once a theory is used it should make it possible for the new empirical laws to be derived and be subjected to confirmation by new tests. However confirmation of a theory remains partial and never complete or absolute. For example, Einstein's theory of relativity which contributes to modern physics, provided room for further development into a revolutionary effect of new empirical laws which today provides for explanation of concepts like bending of light in the neighbourhood of the sun (Carnap, 1995:231). This proves that the value of a theory lies in its power to suggest new laws that can be confirmed by empirical means.

Scientific method starts with direct observations of the universe as solitary facts. Focus is then based on observable and identified objects where everything else is excluded and isolated. After repetition of the experiment regularities are likely to be discovered. Once a pattern is observed such regularities are expressed by statements called laws. These laws once tested and accepted through science methods serve a function of explaining facts already known or to predict facts not yet known (Capra, 1985:59). Prediction guides and shapes our further observation. Our knowledge of facts or observed regularities can be used to provide a basis for the predictions of unknown facts.

2.7 Laws in natural science

Laws in physics are based on the results of physical experiments. A physical law is a symbolic relation whose application to concrete reality requires that one knows and accepts a whole collection of theories (Torretti, 1999:246). Such a law is always provisional because it represents the facts to which it is applicable with an approximation that is considered by physicists as satisfactory yet perceived insufficient to explain future development. It sometimes happens that an unsuspected physical law is derived from a theory and subsequently corroborated by experiment. This process is defined as serendipity (Kotz & Treichel, 1999:8). On the basis of this information we must define a law. Kotz and Treichel (1999:6) hold the following definition:

> "A law is a concise verbal or mathematical statement of a relation that seems always to be the same under the same conditions."

This definition bases itself on the fact that, what is true for a reasonable number of observations made in the past is also true for all similar observations if carried out under the same conditions. For example consider this equation:

Stress =Y ΔL/ΔLO

Where Y is young's modulus and Δ L is the length and Δ LO is the initial length of expansion of a rod. This equation gives a law in a simple statement that can be understood through its mathematical shorthand representation. Usually laws describe the quantitative relationships between measurable quantities involved. This property of physical laws improves our ability to quantify and make predictions (Torretti, 1999:102; Kotz & Treichel, 1999:6).

Carnap (1995:105) states that other laws like Kepler's laws were formulated as a result of observations and not on a preconceived theory as to why planets behave as they do. Such laws are referred to as empirical laws because they come from properties that can generally be directly observed. These kinds of laws are derived as a generalisation based on many direct observations. The function of empirical laws is to explain facts or a particular observation in the actual world, because not only do they possess the certainty of logical and mathematical laws but they also describe the structure of the world. In their context empirical laws helps scientists to answer the question "how" rather than "why". Scientists in this regard exclude the question "why" because it is perceived as an unknown metaphysical agent (Capra, 1985:56).

Another example of a law is a hypothetical or theoretical law. These kinds of laws are not necessarily established because they refer to non-observables. They are about molecules, atoms, electrons and others that cannot be measured in a direct way. For example their magnitude changes within extremely small intervals of space and time that is almost not directly measurable. These events are called micro-events for example oscillation of an electromagnetic wave of visible light is a micro process. No instrument can directly measure how its intensity varies (Carnap, 1995:227). Functions of laws can be described as follows:

- Laws guide us to express our observations in a more precise manner (Carnap, 1995:40). Laws are written as statements expressing any regularity observed. However, for this expression to be accepted, it should be valid, regular at all times and all places without expression. For example from daily experiences, water will boil upon heating. This assertion if it is reproducible at all times can be accepted as universal statement (Lindsay, 1971:17; Carnap, 1995:105).
- A second function of laws is to give meaning between constants. For example, Newton's second law of motion gives a quantitative relationship between the force applied to a body and the acceleration it imparts. Algebraically expressed as F= m a, (Newton's law) further speaks to the proportionality of acceleration and forced. He expressed this idea by stating that if an unbalanced force is applied to a body, the body is accelerated in the direction of the force and the magnitude of the force divided by acceleration is constant regardless of the magnitude of force (Motz & Weaver, 1989:7).

Laws can further serve a function of explaining how the world operates including providing implications about how the universe evolved (Wesi, 2003:29). From respectable observations of ancient science, modern science managed to put credit to laws by experimentation. On the strength of this argument Davies (in Wesi, 2003:29) asserts that given the laws of physics the universe can bring itself into existence- much to the credit of currently known laws.

2.7.1 A hypothesis

Theoretical laws help scientists to explain laws already formulated and to permit the derivation of new empirical laws, therefore they cannot be justified by making observations of single facts. Once it cannot be stated as a generalisation of facts, such a law should be stated as a hypothesis. Based on one's hypothesis a number of empirical laws can be arrived at which guides confirmation or rejection of a hypothesis (Carnap, 1995:230). In this way a hypothesis is not based on any empirical law but create a theory of non-observables from which a law can be derived. To define a hypothesis Torretti (1999:61) holds that: "It is an assumption invoked as premises in the proof of the subsequent theorem." The explanation is confirmed by Kotz and Treichel (1999:5) who holds that a hypothesis is a tentative explanation or prediction of experimental observations. Another critical definition of hypothesis is provided by Leedy and Omrod (2001:6) as a logical supposition, a reasonableness or as educated conjective.

A hypothesis provides a way for a scientist to perform experiments that are designed to give results that may confirm some hypotheses and invalidate others (Kotz & Treichel, 1999:5). Hypotheses in scientific research are formulated in such a manner that they may be submitted to strict testing and more especially, that they may be rejected on the basis of research findings. Hypothesis can be adopted as a model to guide research on a particular horizon of expectations. The phrase "horizon of expectations" is intended to be consistent with theories, interests and general notions.

2.7.2 Paradigms in science

As science becomes modernised it moved from problem solving into researching fundamentals that question the principles of a particular mental framework. This thinking led to a paradigm shift. A paradigm can be defined as:

> "Super theory that acts as an umbrella under which at a given time, scientific theories are developed and experiments are developed and conducted within a given field of endeavour, (Goswami, 2001:8).
>
> "The clear manifestation of the social nature of science" (Mouton & Marais, 1996: 144)
> "The shared faith, value and technique for the members of a single social group" (Chunqi, 1998:2)

Following this definition, a paradigm cannot be completely fixed as it could change as a result of development in new information. Paradigms change as a result of dissatisfaction with context of defining a particular theory.

Paradigms are a way of comprehending the way scientists have built theoretical systems through the ages. When paradigms cannot explain new findings new ones can replace them. This process is called scientific revolutions. It is called scientific revolutions because it alters the faith, values and methods that were widely held by members of a particular social group who existed in that particular mental framework (Chunqi, 1998:4).
Paradigm shift are also called scientific revolutions because when accepted it calls for rearrangement of theories that scientists had committed themselves to. Theories forms cores of a paradigm and rearrangement of such theories can

take time so it involves creating and sustaining a culture of inquiry (Moloney, 2000:2). This statement is informed by the fact that scientists espouse a given methodology that is dictated by a paradigm. Paradigms function to establish appropriate facts (formation of theories) and to articulate a theory by experimentation.

The philosophy of science shows that Aristotle's physics remained at the center of mankind's thinking for almost two millenia to illustrate the concept "paradigm" as the manifestation of the social nature of science. It showed that one widely accepted scientific theory could remain a fundamental framework to command how science is conceptualised. Paradigms are tentative to the fact that human intelligence is limited and restrictions can be imposed by the methods of a given time (Chunqi, 1998:3). For example in the emergence of classical physics, Newton's mechanics regarded both time and space as absolute entities, this theory dominated scientific thinking during the eighteenth century and was considered completed. It is an example of a paradigm. Einstein's theory of relativity however proved that time and space were separate reference points. In his theory, the three dimensional system establishes a place (space) where the event occurs separate from the clock (time) which specify such happening when the observer records it (Torretti, 1999:276).

2.7.3 Models

2.7.3.1 Definitions of models

A model is a simplified version of the system that focuses on essentials of the problem, that is, a model seeks to identify the heart of the problem and ignores possible complications that are considered to be of only secondary importance.

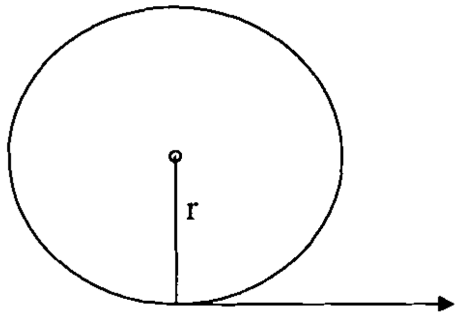
A model in physics is a representation or an illustration of invisible facts or concepts. Our conception of the word model, guides us to remember particular mental images which associates with the term (Wesi, 2003:47). Scientists have mental images of objects like field lines and electric circuit. The fundamental forces of nature are invisible, for example forces between magnets or atoms. Learners come into a classroom with alternative conceptions, which comes about as a result of engaging in particular visual activities. Taken from a constructivist point of view, a scientific process must be undertaken to uproot wrong images and create new ones or even to enhance understanding. To achieve this objective, scientists construct models to provide visualisation (of what could not otherwise be seen) through an analogy in the world in which we live. Examples of models are those of atoms, molecules, gasses and our planetary system. Models are used to build mental images, which can confront alternative conceptions (Lindsay, 1971; Carnap, 1995)

2.7.3.2 Subjective models

Subjective models are those illustrations that are conceived, created and chosen by man. The main purpose of these conceptions may be for the manufacture or designs and for increasing our body of knowledge (Wesi, 2003:37). Models guide engineers to maintain costs by using small scale apparatus to test their creation and when well mastered an ideas can be expanded to make real devices. Wesi (2003:47) concludes that each model has an identifying name or label and in doing so when we speak of a particular name, a particular mental picture is transferred from long term to short term memory where it is processed.

In this process models are presented visually to bring home the understanding of the unknown. For example, let us consider Bohr's model of the hydrogen atom, which bred particular theories about electrons. In his model of the hydrogen atom, the electron (e^-) is in orbit about the nuclear proton at a radius of $r = 5.29 \times 10^{-11}$m.

FIGURE 2.1 The model of the velocity of hydrogen atom



e- v

(Cutnell & Johnson, 1998: 529).

Models are like theories, tentative in nature (Carnap, 1995). They are easily replaced when assessed or measured against new knowledge. Once the model cannot continue to fit in the new information, experiments are adjusted but if the results continue to reject the model, it will have to be abandoned. Models are nothing more than a representation of real entities. They are used to structure and order existing knowledge (Torretti, 1999).

The function of models is directed from reality to man. Much of what young scientist find in the textbooks are ways that man has adapted to bring reality closer through the use of model. In this way scientific models becomes a creation of the human kind to aid us to obtain knowledge (Wesi, 2003:38). So it is clear that models as the basis of analogies do play an important role in scientific research, which eventually leads to creation of new theories. Something noteworthy about models is that they do not purport to be more than a partial representation of given phenomena. Mouton and Marais (1996:140) quotes Kaplan (1964) to indicate that the model is a particular mode of representation, so that not all its features correspond to some characteristic of its subject matter. In this case a model only outlines some features of what the reality can be, to identify central problems concerning a phenomenon of what ought to be studied.

2.7.4 <u>Use of concepts in natural science</u>

Concepts are defined as the most basic linguistic constructions by means of which people can order and categorise reality. Since the mind is not necessarily an inactive storehouse in which we place our unsystematised content of our daily experience. Concepts are thus regarded as the primary instruments which we employ in trying to make sense of our experiences. Concepts are symbols of meaning (Mouton & Marais, 1996:58).

A concept exposes a thought of a scientist as regard to his sense and reference of his experience. Concepts can be viewed as sets of common properties and critical attributes that are given to identify objects, events or even situation. A concept is as a collection of all memory elements that a person associates with a label and the pattern of their links (White, 1989). The definition also shows that concept formation is mainly driven by our subset of knowledge. The denotative dimension of a concept would refer to a specific and clearly defined set of entities or phenomena in reality. Lemmer (2003:13) quotes Einstein saying that the term concept is a free creation of the human mind that it is possible that to build many concepts around a singular concept based on how the concept was experienced by an observer. Words that scientists use to build concepts are mediums for defining objects. Particular images are attached to an object or an event as signs or symbols to define a particular happening (Wesi, 2003:38).

Concepts are however structured in certain types of statements, definitions or hypotheses, according to syntatic rules. When statements are structured in concept formation, they follow a particular pattern to align with a certain theory or model (Mouton & Marais, 1996:136). The nature of the conceptual framework is determined by the regulative function that the framework has to fulfil.

2.8Conclusion

The nature of physics(science) puts it up as an organised and structured way of expressing arguments. The way in which physics has evolved has managed to provide a novice with a clearer view of why are physicists of today doing things in the present form. Carrying out experiments and applying the information that we have gained to improve our technological instruments shows how physics can be applied to widen our experiences. Since the turn of the seventeenth century, experimentation is expected to lay the foundation of scientific argument. Rogers (1962:223) supports the importance of experimentation by indicating that whatever cannot be observed, measured or deduced from observation cannot be classified as a science. This fact ensures that science in its modern nature is separated from the Greek philosophy that had its arguments based on intellectual reasoning and speculations (Carnap,1995:40)

The relevance of the information gained in western science must continue to apply in our education system. Many teachers have embraced practical work as a defining feature of science and many countries have invested lot of money into school laboratories to get learners more hooked into studying physics. To this end, a comparative study into the system of education that is expected to improve learners' knowledge of science is imperative. A study must reflect how knowledge is acquired with special emphasis on the methods available for acquisition of that knowledge. The present curriculum is hailed by many as having an intention of placing emphasis on the teaching of natural science and the scientific methods (Wesi, 2003:266). The structure of natural science will thus have to be studied in the context of OBE to see how it merges the purposes and the concepts of science, through allocation and outcomes formulation. This is done against the backdrop that teaching of science cannot be understood if learners do not form appropriate conceptual understanding.

The nature of science has always been a subject of concern to both teachers and curriculum developers. Much expectation has been that science teaching would have a beneficial impact on the quality of culture and personal life by virtue of learners not only knowing science but also appreciating the nature of scientific inquiry. To achieve even better results of the curriculum, its goals must depend on what teachers know and the methodologies that they use to help with the acquisition of knowledge (Fraser & Tobin, 1998:985). The next chapter is devoted to the study of natural science within Outcomes Based model of education to see what are the general circumstances in which it is practised. This information is vital because the history of science has strongly contributed to a new image. The history of science gives us a new kind of synthesis that can be useful also in science education. On the other hand the history of science provides an analysis of the scientific debates and the alternative views of scientists that built our version of doing today 's science.

CHAPTER 3

THE TEACHING OF NATURAL SCIENCE IN CURRICULUM 2005

3.1 Introduction

One of the cardinal challenges facing the new democratic society in South Africa as regards education is to redistribute resources equally and somehow to rationalise the historical "model C" schools which tend to be well resourced and use these resources to provide for a defined, non-racial system of education. As a point of departure the new government identified three issues to contend with. The first outline of the solution was to provide clear objectives for the curricula (Howie, 2001:39). Secondly, that the inherited system of education was unresponsive to the needs of learners and the country (Nieuwoudt, 1998:1) and thirdly the existing plethora of incoherent subjects had to be reorganised (Department of Education, 2002:3). According to Cohen (1993:793) a system of education, which does not provide solutions to how the human mind actually functions, fails to provide solutions to the immediate needs of a human being in his total nature of development.

As a result of the paradigm audit, the new government wanted to transform the education system in a way that would allow it to achieve the intended outcomes through the review of the structure of the curriculum, which is a means of transmitting the outcomes (Prawat, 1992:369; Department of Education, 2002:4). To this end Curriculum 2005 was introduced as a means of driving the process of education transformation (Fritz, 1994). To provide for democracy into the education system, it is perceived that all stakeholders (i.e. parents, teachers, learners and society at large) must participate in school activities. This idea is embraced in the system through the South African Schools Act of 1996. With this in mind, the outcomes-driven system of education is believed to be the best solution to the education and training needs of the South African society at large (NDE, 1997).

3.2 Reorganising the curriculum

Curriculum 2005, which drives the process of transformation in education, is fundamentally different from the traditional education programmes, which were fragmented, largely content-based and teacher driven. One of the perfect features of Curriculum 2005 is that it is outcome-based, places a major emphasis on integration and is focussed towards the needs of learners (Department of Education, 2000:17; Nyamane, 2002:28).

Beyond its educational reformation, Curriculum 2005 brought about structural and organisational changes. Part of this change was to introduce the National Qualification Framework (NQF) as a mechanism for integrating education and training. Another embedded feature of the NQF is that it paved a way for accepting the fact that learning can take place in both formal and informal sectors like workplaces through learnerships (Kramer, 1999:124).

The second feature of NQF was to re-organise schools into bands, namely FET and GET which can further be divided into foundation, intermediate and senior phase (Department of Education, 2000). The focus of this project will however be limited to the GET band so as to check if demonstration as a technique of teaching and learning is ever applied in the teaching of natural sciences.

It is agreed by almost everybody that OBE considers a learner from all angles including from a Christian perspective. This statement can only hold when learning takes place to provide learners with skills, attitudes and knowledge of concepts or processes that they did not have previously (Kramer, 1999:4). The entire process is driven by a desire to achieve outcomes. Outcomes are regarded as key indicators of how and what learners must achieve and learning is organised towards developing these outcomes. Such an education system where learners are assessed to see how they demonstrate outcomes of their learning is called Outcomes Based Education (OBE) (Department of Education, 2000; Kramer, 1999:2).

The introduction of OBE was equally met with criticism. However criticism is normal whenever changes are made. This is a factor that ensures that weaknesses and mistakes are recognised and addressed (Kramer, 1999:4). Perhaps it was for this reason that in South Africa there has been continuous revision of the programmes to implement OBE as a reaction to problems that were encountered. Another element of the debate submitted by teachers on criticising OBE is that time and resources needed for such a great turnaround of paradigm are not sufficient (Nyamane, 2002:27; Kramer, 1999:5).

According to Kramer (1999) it is unfair of teachers not to support OBE and be 'spectator critics' is not fair because there is common cause for accepting OBE. The urgent need to train and support educators require of teachers to be physically, mentally and to have a positive attitude towards change. It could not therefore be a show of wisdom to shelf the introduction of Natural Science in OBE until all problems are resolved because some problems can only be identified through encounter.

Outcomes based education has two key objectives. First is to ensure that all learners are equipped with knowledge skills and values that they need to succeed in various that roles they will fill in their lives outside the classroom. The second objective is to provide a schooling environment to function to assist and encourage learners to achieve the set outcomes (Kramer, 1999:24). It is perhaps understandable that there is high anticipation that through OBE most learners can achieve high outcomes given effective teaching which is commensurate by sufficient resources and time (Department of Education, 2002:7).

3.3 Natural science

Natural sciences are defined as sciences that focus on the laws of nature that explain the properties and the interactions of matter and energy in the universe (Department of Education, 2002:9). The major emphasis is to investigate both the physical and chemical phenomena through scientific enquiry and through applying models, theories and the laws to explain and predict events in our world.

Natural science is included as another learning area among the eight designed for a GET school system. In its emphasis natural science includes life science, earth sciences and physical sciences. It emphasises natural and human made environments (models) in the material world. A current view in scientific circles is that science is a human activity involving investigation that is dependent on assumptions, which may change over time and within a different social setting (Department of Education, 2002:5). This activity will also have to be directed to a particular goal or outcomes (Trowbridge & Bybee, 1990:178). The teaching of natural sciences is expected to provide critical outcomes that will ensure that learners in the process are exposed to skills, knowledge and values that if correctly conceptualised will enable learners to contribute to their personal careers and make an impact in the society (Cohen, 1993:793). These critical outcomes should be such that once attained learners are able to demonstrate an understanding of the world as a set of related systems by recognising that daily problem solving context do not exist in isolation (Cohen, 1993:790).

3.4Assessment

Since the teaching of natural sciences was trusted with a responsibility of creating learning opportunities for learners to learn skills, knowledge and values, the outcomes of teaching had to be evaluated. The National Curriculum

Statement provides every learning area with learning outcomes and assessment based on unique knowledge, skills and values (Department of Education, 2002:3). In keeping with international standards the assessment approaches of OBE are comparable in quality, credibility and efficiency (Howie, 2001:8; Kramer, 1999:37; Annon, 2004:13).

Kramer (1999:35) defines assessment as the way to gather information to gauge or decide whether the outcomes have been achieved properly. This decision is vital because promotion of learning in OBE is informed by the ability of learners to demonstrate the achievement of outcomes. Teachers' role still requires of them to make assessment that is fair, accurate and acceptable based on their strategies of evaluation. To make this assessment teachers will require the necessary skills that are compliant to the teaching of Outcomes Based Education

The Department of Education (1998:4) defines assessment as the process of identifying, gathering and interpreting information about a learner's achievement as measured against the nationally agreed upon outcomes for a particular phase of learning. This process of assessment includes generating and collecting evidence of achievement. An Outcome Based Education, which is a learner centred and result oriented approach to education is based on a demonstration of achievement. In following this model of teaching, each learner's needs are accommodated through a multiple of teaching and learning strategies and assessment tools.

Assessment in OBE will therefore focus on the achievement of clearly defined outcomes to allow for crediting learners' achievement at every level. This process requires the use of tools that can appropriately assess learner achievement and encourage lifelong learning skills. The common word used in education cycles today is CASS which stands for continuous assessment as a tool for evaluating achievement throughout the teaching learning process. An all-important feature of assessment is its nature. It is expected of teachers to be developmental in nature (Pahad, 1997:39; Department of Education, 1998:4).

3.4.1 Formative assessment

In the principles of constructivism and formative assessment, there is an inherent change of roles for both the teacher and the learners (Fraser & Tobin, 1998:818). The change demands that the teachers should move beyond just correcting errors of learners. They should try to understand and deal with causes of such errors. To successfully execute this responsibility is a task that would tax the best of learning experts. To define formative assessment, Fraser and Tobin (1998:818) hold that it is a type of assessment where learners show the capacity to judge their own work. For the learners, the main resource of achieving self-adjustment is dependent on the model provided by the teacher. The teacher must further ensure that learners are provided with the frame of reference of the teacher in order to share the model of learning which gives meaning to the criteria that are reflected in the assessment (Trowbridge *et al.*, 2000:298).

The distinctive feature of formative assessment is that the information acquired in assessment can be used to modify the learning programme in order to make it more effective by adjusting the teaching method to help the learners. This arrangement is done to effectively use the results of the assessment to act upon the problems encountered. Formative assessment is actually designed to support the teaching and learning processes. It helps to inform the teachers about the learners' strength and weaknesses and to guide the teacher to introduce a new approach that is intended to remedy problems of learners (Pahad, 1997:45). In its nature, formative assessment is developmental in that it provides a learner with enough information and feedback, which can be done through self- assessment. If effectively used, such information can help the teacher to evaluate his own teaching strategies and the progress of a learning programme (Woolnough, 1994:18).

3.4.2 Summative assessment

Pahad (1997:45) defines this type of assessment which is usually a written examination taken at a particular moment in time or as a year-end examination or a series of tests leading to a final mark. Learner assessment in science remains a necessary and potentially beneficial aspect of science teaching. Summative assessment is vital in the sense that it provides feedback to teachers, parents and learners about the overall performance of a learner. In its form it helps to assess grade and achievement and gives direct feedback for selection purposes (Woolnough, 1994:18).

In the same breath this kind of evaluations can have unintended consequences in the sense that due to selection processes, learners can see themselves as hopeless failures of that instant. However this kind of assessment can be effective if its purposes are made explicit and done in other forms to augment written work. The most suitable definition, which is developmental in nature, is held by the Department of Education (1998:6) that summative evaluation is a type of assessment used for recording the overall achievement of a learner in a systematic way. For purposes of clarity, herewith the word systematic evaluation includes the periodic evaluation of all aspects of the schooling system and learning programmes. At any point in the cycle of learning, learners need to be exposed to a form of feedback that concerns their understanding of concepts and skills (Trowbridge *et al.*, 2000:299). When evaluation has occurred, the teacher must have information about the learners understanding and competencies in the process of gathering information for investigative purposes. William and Black (in Fraser & Tobin, 1998:814) argue that the difference between formative and summative assessment lies in the way in which evidence is interpreted and not in the nature of the collection of the information.

If education has to realise the full potential benefits of teacher assessment, then there must be investment in research and development that can extend and exploit the new ways of preparing learners for a working environment (Fraser & Tobin, 1998:819). This investment should provide for long-term programmes to change the roles of both the learners and the teacher with particular emphasis on developing the learner's self assessment. Nothing can replace a good assessment that is intended for raising the standards of learning especially if it is school based. However this opportunity presents a significant challenge for the teacher's practises within a classroom (Nyamane, 2002:28).

Another feature for changing science education assessment is the fundamental changes in the social values, that surround assessment and also in the types of inferences that are desired. The introduction of performance tasks and alternative assessment such as present portfolios introduces assessment complexities, which are mere reflections of the assumptions that science makes about its domains and beliefs (Fraser & Tobin 1998:806; Trowbridge *et al.*, 2000:298).

3.5 Goals of science teaching

Teaching of science was initially intended to provide scientific knowledge needed for safety and comfort in our technology driven age. Citizens depend on science for both security and commercial purpose (Rogers, 1962:6). This statement puts the role of schooling in a sense of purpose back in science (Cohen, 1993:794) and to provide for the scientific literacy to produce individuals who can make valid and considered decisions relating to science and technology (Trowbridge & Bybee, 1990:149). It is also expected that for commercial purpose, learners will then be able to enhance their career choices and deal with environmental awareness issues so that by interaction with natural resources, science proceeds to provide means of survival.

Aims and objectives of science teaching is to be studied because in our teaching we tend to focus too much attaining those goals which in turn controls what we teach and how we teach it. In our teaching we use textbooks to help students to develop conceptual understanding, which should be applicable and ready for use to solve daily problems. Given that learners bring into the classroom quite a number of alternative conceptions a teachers' first responsibility is to dispel an idea that physics is a mere collection of data (Rogers 1962:8).

Physicists must maintain the purpose of their discipline, which is to develop reasoning skill, which has its roots in conceptual understanding of physical principles (Cutnell & Johnson, 1998:2). Once this knowledge is gained, science then proceeds to prediction and control. The exercise of prediction and control is rooted in what we observe in the universe. Once a particular phenomenon is observed, scientists can use the acquired information to predict what may happen under a given set of circumstances when placed under control or subjected to manipulation. Beyond this stage the second objective for science is to explain and build some generalisations of a concept (Kotz & Treichel, 1999:2). However science never succeeded to achieve one aim, which is the transfer of skills. Somehow even after instruction learners were not transferring skills or using ideas from a science classroom into other studies or life in general (Rogers, 1962:5). Many attaches the reason, to be that science was taught in theory and no meaningful practicals were done to give virtue to the teaching. The teaching of science in our country is still below the norm and much needs to be done to upgrade the content and methodology to ensure that in all aspects, our teaching becomes effective (Wesi, 2003:1; Prawat, 1993:388).

3.6 Challenges facing the education system

For many years before the democratic dispensation came about, South Africa was isolated from the international society and its education system was not competitive by international standards (Department of Education, 2000:11). When South Africa was readmitted into international education conference, it had to write a report, which outlines the state of affairs in education, provide challenges and how the country intends moving on with solving such problems (Department of Education, 2000:2).

The South Africa Assessment report to Unesco (2000) was written to outline factors that may affect the provision of quality public education, which includes the physical environment of schools. The report reflects that about 48,6% of primary and middle schools use pit latrines, which are unclean and smelly thus, posing a health hazard. The majority of schools in the North West Province have no electricity and to be exact 56,2%, which still poses a threat in doing some practicals, required in science laboratories (Department of Education, 2000:38).

3.6.1 The provision of quality public education

The main challenge of the South African Assessment report to Unesco (2000:43) is that provision of public education is disturbed by lack of capacity in teachers and school managers. Poor achievement in natural science can be attributed to inappropriate teaching and learning methods (Department of Education, 2000: xv). These problems have been subject of research. Nyamane (2002:17) singles out natural science as one of the subjects that are mostly failed by learners. Short sight on the upgrading of serving educators was considered for research as a cause for underachievement (Mkhize & Gouden, 1990:2).

In addition to this shortcoming, teachers are still expected to provide effective teaching in organisational courses like laboratory work and examinations. It is expected of teachers to assist learners in laboratory work and help students enhance their skills in manipulation, observation and organisation as well as higher level of cognitive process (Lagowski, 1989:13).

As a result of these deficiencies in the system, South Africa is yet to provide students in the field of technology and other sciences related professions. Teachers are showing no signs of engaging in a more practical approach in science teaching particularly in changing their methods of teaching (Van der Linde *et al.*, 1994:50).

3.6.2 Teachers views on the new curriculum

When Outcomes Based Education was introduced, it was hailed by many as a "God-sent" to the South African education system (Nieuwoudt, 1998:1; Department of Education, 2000:4; Annon, 2001:12). However it had its unintended consequences in that it was not yielding results as expected. Everybody expected the OBE to produce results immediately but that was not so. It was met with mixed feelings (Nyamane, 2002:17). Many educators felt left out and were not ready for a change. The science educators' views as captured by Nyamane (2002:27) indicate that the majority of such educators are not yet conversant with methodological requirements of OBE. If teaching is reciprocated by learning, then problems encountered in teaching will surely induce the same in learning (Hasan, 1985:5).

It remains a further concern that if teaching and learning forms an integral part of effective teaching, that teachers cannot be best agents of OBE unless they fully understand and appreciate it. Demonstrations as a method of teaching are not immune to this concern. It is on everybody's report and lips that educators require constant in-service training to match up with the challenge of curriculum change and space needs to be provided for teachers to have time to undergo in-service -training (Mkhize & Gouden, 1990:2).

3.6.3 The deficiencies in the teaching system

If teachers are not confident to do practical work then learners may suffer on the skills of doing practical work because teachers are not carrying out demonstrations. This statement holds on the understanding that learners learn from their teachers since what teachers do in a class is normally a determinant of how learners will progress in any classroom of science (Nyamane, 2002:27; Hasan, 1985:5;).

The office of the President Thabo Mbeki (2002) has already identified the depth of the problem. He states that there is a serious shortage of suitable qualified primary and secondary school teachers particularly in the strategically important learning areas of mathematics and science. That given, much attention would need to be given to the compelling evidence that the country has a critical shortage of science teachers who can participate in technology oriented and global economy. This assertion is consistent with Watson's (2000:59) statement that practical work is seen as the hallmark of sciences. It is important to relate the teaching of science to doing demonstrations , so as to give learners coping skills. Rogers (1962:5) laid a foundation for understanding the goals of science teaching, first is to provide for the economy and security of the country. Every country that invests in science should soon be rewarded not by how much their citizens know but by the kind of decisions they take that are informed by their scientific knowledge.

3.7Traditional way of teaching

The traditional methods of teaching excluded learners from actively participating in their own learning purely because they were teacher driven.

Teaching was driven to achieve the prescripts of the syllabus (Prawat, 1992:364; Steyn, 1988:160) and was teacher centred because what we teach in what is learnt when we were ourselves still learners at school (Nieuwoudt, 1998:2). In this context teaching became a routine where everybody could seemingly do it because it took a pattern. For example, the direct instruction model, as presented in Gunter *et al.* (1995:66), reflects some of the simple steps that any person can follow to deliver a particular concept. Steyn (1988:161) holds Biddle and Anderson to agree with this statement in that they say teaching activities were seen as a set of rules or treatment to be applied in algorhythmic way with the sole aim of reaching desirable learning outcomes. Perhaps it is on such ground that people perceive teaching as an easy to master profession. However this kind of teaching cannot continue to contend with daily challenges facing education today.

3.7.1 Characteristics of teaching

Smith (in Steyn, 1988:161) holds that a fundamental characteristic of teaching is the aim towards which the teacher directs his/her actions. This intention of the teacher becomes an only qualifying principle of the teachers' action. The intention is further clarified to convey knowledge, skills and values. However this process does not happen in a vacuum, it has content or a curriculum, which provides for a platform of doing things.

Teaching cannot be separated from the environment within which it occurs. In fact, for teaching to be successful it needs to be arranged in line with the ever-changing environment. Nieuwoudt (1998:9) records that teaching always takes place in, and is essentially determined by, a specific context and environment. For natural science to continue with its pride in the method of reporting their findings it must have specific methods of carrying out investigations. Perhaps the invention of laboratories in schools is a simple demonstration of a need to create an environment suitable for doing science experiment.

Howie (2001:9) expresses concern that communities are still not receiving quality results in Natural Science. Most of the learners who go beyond matriculation find it hard to cope because of memorised concepts, which do not provide learners with problem solving skills. Bradley and Stanton (1998) in agreeing to this concern conducted research, which reveals that students who are not coping at university level are holding misconceptions, which are a result of their high school education.

3.7.2 Teaching as a means of skill development

Effective teaching should provide learners with the potential to actually remember more material for the future use (Woodburn & Obourn, 1965:320). Once the learners are exposed to knowledge of the nature of the natural science by demonstration, they are expected to sustain the interest in the scientific reading. To achieve this process skills and sufficient training must be facilitated to learners but Rogers (1962:6) claims that the learning of skills did not happen as easily as teachers and the general public hoped. He claims that there was no common ground between the field of training and the field to which we wish to transfer it. Simply understood this means that learners should apply what is gained in one class of chemistry to physics and such knowledge should translate into household application, which is required as an outcome of learning. Once learners can do this, learners shall have demonstrated an outcome of their learning. Therefore effective teaching requires a great deal of thought, preparation and design (Trowbridge & Bybee, 1990:149).

Kramer (1999:24) posits that the success of effective teaching is tied to continuous training, support and ongoing effort at improvement. This information indicts of teachers to spend time and energy on research to update their professional knowledge against the ever-exploding levels of information in the world. In this regard a science teacher becomes less of a scientist but a teacher who is keen to learn about methods of making him a better teacher yet with keen interest in science.

As a means of providing a solution, Steyn (1988) maintains that for teaching to be effective it should enable the learner to perform the task of learning. If this objective is realised then teaching cannot be judged by its achievement in learning but by its design. Teaching cannot be judged by its achievement because it is not process-product model. To put it simple: effective teaching can be defined as a situation where an aim of teaching, curriculum, teacher, learner and a live, guided interaction between the teacher and the learner appears simultaneously and interrelated (Steyn, 1988:159).

3.8 The teaching of Natural Science

Since 1994, it is assumed that teaching is taken seriously in that teachers are given more incentives, improved working conditions and rationalisation of schools was done to address equity (Howie, 2001:11). This was done to provide for effective utilisation of manpower and available resources (Annon, 2004:14). Teaching of natural science itself is mainly influenced by educational difficulties rooted in differences of educational, social and political ideologies (Rogers, 1977:5). Usually the drafting of curriculum statements is relegated to committees, which draws aims that are impractical and too ideological.

3.8.1 Effective teaching in natural science

For effective teaching, a teacher must perceive learners as able, friendly, motivated and willing to learn (Trowbridge *et al.*, 2000:26). Through this understanding a better teacher sees himself or herself assisting and facilitating rather than coercing and controlling. A good science teacher uses inquiry to introduce learners to the processes of obtaining new knowledge, such as observation, hypothesis and experimentation. To achieve this objective, effective teachers must have a variety of ways and means of presenting his subject matter. More than having the means and having the correct conceptual knowledge, the teacher has to be clear about his goals of instruction (Woolnough, 1994:24). An effective teacher informs the learners about these goals to keep them in mind when designing the teacher delivers an instruction.

The curriculum statement of natural science demands a teacher who is a lifelong researcher and committed to lifelong education. However the situation in the system dictates otherwise. The present teaching corps have their own problems. One of them being the lack clarity on what OBE entails in terms of their roles as teachers (Nyamane, 2002:27). Others are just unqualified in science (Howie 2001:38) and others fear the organisation of practical work and the lack of skills required for doing demonstrations (Van der Linde *et al.*, 1994:50).

3.8.2 Challenges facing the teaching of natural science

The preceding paragraph highlights a serious challenge facing the teaching of natural science. Seemingly there are no sufficient agents who can be trusted with the effective teaching of natural science. For the teaching of natural sciences to improve and be put back on track, there is a need for constant evaluation of the system. The implication of this argument is that the teachers lack the necessary skills to deal with many challenges they face in a science classroom. Without skills and the teachers' confidence brought about by knowledge, learners are apt to loose interest in natural science. Hasan (1985:4) holds that more enjoyment of a subject is found to be associated significantly with the students' perception of their science teacher as a well-organised and intelligent being. To provide for an improvement in the teaching of natural science Trowbridge and Bybee (1990:173) holds that the fun of teaching science can be measured against the skills of figuring out the most interesting strategies and techniques to enhance learning. The most outstanding feature of teaching is the ability to transfer skills and it therefore requires a skill to effectively teach natural science. It is not necessarily everybody's game. The skills need to be augmented by knowledge of how science operates and conceptual understanding.

3.8.3 Specific outcomes in the teaching of natural science

Guided by Steyn's (1988:159) definition of effective teaching, science is equally intended to achieve specific outcomes as a result of an interaction between teachers and learners. These specific outcomes for natural sciences includes skills, knowledge and values which should inform the demonstration is conceptualised to be consistent with ontological-contextual paradigm of teaching (Steyn, 1988; Prawat, 1993). This definition alone should extract the dependence on teaching on acquaintance with the main facts of science under the assumption that students soon forget such because it could not be carried beyond the classroom situation (Cohen, 1993:792). Attempts have been made to improve the teaching of science from a deplorable situation. For many years now the teaching of science has enjoyed recognition in that almost all schools have a laboratory or are using small scale or micro scale apparatus to conduct investigations in science.

3.8.4 Investing in the teaching of natural science

One of the investments made in science teaching includes a multimedia approach to laboratory reporting via computer presentation software (Jenkinson & Fraiman, 1999:293), and the other is Networked Instructional Chemistry (Smith & Stovall, 1996:911). Both approaches are intended towards improvement of learner achievement. The argument presented for computer-assisted learning is that it enhances image formation, which is believed to be critical to the learning of natural sciences (Smith & Jones, 1989:8).

According to Smith and Stovall (1996:911) the use of technology in the science classroom to replace some traditional laboratory work, provides learners with pre-laboratory training for beginners in the subject. Beyond this practice the teacher is able to demonstrate how the laboratory set-up will look like to provide learners with an idea of what the expected outcomes are. Through this approach the teacher uses the limited resources to teach a concept that could only be possible in the laboratory.

Before the use of computers, textbooks and laboratory work were the main sources of images of chemicals and chemical reactions. Teachers mainly relied on speech, models and demonstrations to help learners to visualise chemical reactions. In fact the competency, knowledge and skills of the teacher were put to the test. The challenge in this aspect was for teachers to possess skills that can enable the teaching to provide learners with opportunities of forming their mental images by self-construction. Once teachers master this skill, another method can be employed to enhance conception-formation, which is videotaped demonstrations and experiments, which are further considered to be valuable for creating mental pictures in learners. However this approach of teaching relies mostly on the teachers' knowledge and availability of resources. Beyond the mastery of this skill, teachers could then employ teaching strategies aimed at concept formation. This can be achieved through videotaped demonstrations and experiments. These are valuable instruments that are vital for creating mental pictures for learners.

3.8.5 The status of science teaching

The use of teaching aids is tied to a learner's level of knowledge and how such instruments influence learning. The huge investment made in equipping the laboratories can only be justified if teachers are making full use of such an opportunity. The limiting factor on the teacher's part is influenced by a severe lack of proper science background and necessary qualifications. Many educators who are teaching science feels ill prepared to teach the content of either mathematics or the science curriculum. On inspection of the qualifications and experience of science teachers it was found that there is a relatively few number of teachers with university level education. The crisis is deeper in the sense that those who have qualified through a three-year diploma from colleges did not go beyond repeating the science subjects that they did at school in grades 10-12, (Howie, 2001:38).

The Third International Mathematics and Science Survey (TIMSS) conducted in 1998 reveals that South African learners are the worst performers in Science out of forty-four countries (Howie, 2001). This situation is also apparent as the Department of Science and Technology (Anon 2004:12) attributes this performance to the morbid fear that learners have for science. This fear is coupled with the lack of effective guidance about the areas of application for Mathematics and Science available for science graduates. (Anon, 2004:13; Howie, 2001:22).

The more critical factor to this apathy is the lack of support from parents who themselves are not aware of the critical importance of Science, Engineering and Technology towards improving the quality of life of the people. As a result parents are apt to discourage their children from taking Mathematics and Natural Science. Consistent with this concern, schools are encouraging learners to enrol Mathematics and Natural Sciences on Standard Grade purely because they are manageable and such a step does not promote the objectives of the South African National Research standard (Annon, 2004:13).

The South African Assessment report to UNESCO (2000: xiv) indicates that nearly twenty-four percent (24%) of primary school teachers are not appropriately qualified (i.e. they are unqualified or under-qualified). The appointment of these teachers is dictated upon by a shortage of human resources particularly in the rural areas. The report emphasises that such a rate of unqualified teachers exists in Northwest, hence this research project will focus on rural areas of Northwest to see how the teaching of natural science progresses.

3. Perceptions of a science teacher

Given Hasan's (1985:5) perception of a science teacher and his impact on the learning of science, it is imperative of this research project to cover some aspects that makes teaching effective. Wisdom to outline such aspects will be much influenced by Steyn's (1988:160) definition of effective teaching because it provides conditions that guide in assisting learners to acquire skills and not through transfer of knowledge.

3.9 The teacher

The kind of a teacher that the learner meets in a science classroom determines the level of participation of learners in a classroom. Vreken and Vreken (1989) includes as a reason to this situation the fact that the kinds of teaching methods used can determine the level of participation of learners. Consistent with this idea, Wilkinson and Straus (1998) maintains that curriculum 2005 aims to transform teaching methods towards a learner-centred approach where learners can actively take part in the construction of their knowledge. Noting the challenge that faces an ordinary teacher, our teachers' needs to be re-directed and guided through in-service training to live up to the challenge imposed upon by curriculum change. This statement supports the concepts of in-service training as indicated by other researchers (Mkhize & Gouden, 1990:2).

3.9.1 The teacher and his methods

Teachers vary from science enthusiasts to those apathetic towards science and from teachers who are well trained in techniques of teaching to those not trained. These variations determine how teachers manipulate the types of learning environments which, in turn act to influence the learners attitudes towards science negatively or positively (Haladyna *et al.*, 1982:674). On the strength of this assertion it is thus very critical to ensure that when novices enter the profession nothing is left to fate of experience but the teacher training must be coupled with induction into new and practical methods of science teaching. A point is that novices are full of theoretical knowledge, which on its own cannot provide learners with skills necessary for understanding the nature of science.

3.9.2 Teacher training programmes

On applications for classroom teaching in South Africa, Nieuwoudt (1998:12) highlights a concern that the training programmes in our country are not necessarily effective preparing and equipping teachers to teach efficiently and one can only wonder if our teachers are good "role models" of what they teach particularly on matters of research and professional lifelong learning. A follow up on to this concern, is that good or effective teachers should continually figure out the most interesting strategies and techniques to enhance learning.

Trowbridge and Bybee (1990:173) hold that an effective teacher subjects himself to lifelong learning. Without in-service training teachers, particularly new teachers, still have to contend with challenges of new methods and mostly are likely to conclude that new methods are difficult and need not be practised at all particularly those that involve practical work.

Research carried out on learners in natural science reflects that learners' interest can be tied to instruction and the teacher as variables. This means that learners perception on the teacher, contributes largely to how learners achieve in natural sciences (Hasan, 1985: 4). If learners perceive the teacher as well organised, intellectual and stimulating, they tend to do well in his/her subject. Average and good learners want to emulate good role models and therefore a teacher's personality and relationship with his/her students remains a crucial variable in attitude formation.

3.9.3 The goals of natural science

Effective teachers should be clear about their purpose of going into a classroom. They must have a defined goal, which they intend to achieve and ensure that their learners are equally equipped with strategies that they can use for their own learning. Such a shift requires dedicated and committed teachers who can be thoughtful and reflective about their instruction to reach all learners or to employ another method of instruction. To close this submission on effective teachers, one can say that they are mostly process driven on how learners interact with their material or concepts of learning. They also provide innovative ways of their instruction purely to maintain interest of learners in any given subject (Trowbridge & Bybee, 1990:149; Nieuwoudt, 1998:9).

Another factor that seems to limit the full achievement of outcomes is the teacher's personality. Most teachers are tempted by their preferences, which eventually affect their effectiveness (Woolnough, 1994:24). No single method of instruction can be effective across the board so teachers are challenged to find out where their strength and weaknesses lie and develop their teaching methods accordingly. The quest for most effective teaching is found in knowing how children learn (Fraser & Tobin, 1998:1055).

3.9.4Teaching methods

Over the periods the curriculum of science has not been accompanied by equivalent reform of teaching style. Teachers still prefer the authoritarian style of teaching, the emphasis on the acquisition of factual knowledge and in preparing learners for examinations (Van der Linde *et al.*, 1994:50). The teaching of natural science was limited to the teaching of theory because almost a greater percentage of teachers have no necessary qualifications and the proper background to provide learners with the skills required for concept formation. The obvious implication is that many of the teachers are not conversant with the new methods of teaching that are outcomes based.

3.9.4 Purpose of teaching

The main expectation placed on any formal schooling is to create responsible citizens who can use the knowledge they accumulated in schools to identify significant purposes in the real world and to fulfil such purposes (Cohen, 1993:790). A purpose in this instance will embrace the ability to apply what is gained in the classroom to our day-to-day life. Once a learner can apply a skill and be able to show why a particular decision was arrived at, then the learner will be perceived as being able to demonstrate an outcome which process is consistent with outcomes based education.

In review of grade 12 results from 1998 to 2000, it shows by analysis that results in natural sciences are highly deplorable (Nyamane, 2002:18) but the situation is turning for a better as a result of intervention by the North-West University (Potchefstroom Campus) on improving the quality of teaching through in-service training of science teachers in the province. This downward trend in natural sciences was largely due to traditional methods of teaching, which mainly focused on the accumulated knowledge such that evaluation was based on how to answer questions posed by a different persons. This concept is believed to further compromises the standards of teaching in the sense that it takes away the sense of purpose from the education system.

3.9.5 Need for a overhaul in teaching methods

Prawat (1992:388) states that there is a good reason to believe that our current methods of instruction are inadequate and insufficient. He argues that a curriculum is like a set of new conceptual lenses, which not only challenges learners but also brings about new challenges on the teacher's role in a classroom. Such lenses insist that a clearer view can only be obtained when learners' efforts to understand are at the centre of the educational enterprise. In terms of Outcomes Based Education the traditional transmission model of teaching is replaced by a more dynamic complex and interactive model, which focuses on achieving outcomes of learning. This transition will require a conceptual change where teaching paradigms must change when they can no longer answer to the needs of the present demands in education. Even before exploring new methods of instruction all available methods must be applied and record must exist that they cannot help the situation (Chunqui, 1998:2).

Effectiveness of teaching depends on the aim of instruction, the individual learner and on the teacher. For example to develop practical skills the teacher must give learners practical exercises for them to demonstrate their knowledge. The teacher's effectiveness with the teaching methods can only be measured against his intention for using such methods. This approach is important because different learners prefer and respond differently to different teaching methods. Some may prefer freedom and responsibility to plan their own work while others prefer the security of a more structured approach. A suggestion in this approach is for a teacher to be well conversant with different teaching methods (Woolnough, 1994; 24).

3.9.7 Review of teaching methods / need for a change

It remains a matter of purpose to study what effective teaching is and then proceed to create methods of making the present teaching favourable to meeting the standards of science teaching. Demonstrations are still an element of research as a method that is relevant in the teaching of science simply because it targets outcomes (Department of Education, 2002).

One of the most influential factors that guide instruction is the kind of method employed to deliver the subject matter (Gunter *et al.*, 1999:66; Van der Linde *et al.*, 1994:50). A particular method may be suitable for some review but may not yield results in concept formation. In this regard teaching methods are considered as essential for improving the achievement of learners. However the present introduction of Outcomes Based Education was never paralleled by reform in teaching styles or at least in-service training of teachers (Howie, 2001:38).

The situation calls for a general review of our teaching methods to keep up with the escalating problem of the lack of in-service training to teachers. At this stage there is no research evidence to suggest that teachers are receiving adequate training in line with curriculum changes. At present the training programmes are not necessarily preparing the teachers to teach effectively. This statement indicts of those in power to reconsider the methods of teaching and streamline them with OBE requirements. This report will in trying to provide solutions, submit that demonstration can assist in improving the achievement of our learners (Nieuwoudt, 1998:12).

3.10 Curriculum

One of the daunting challenges that a country can ever face in education reform is to ensure that the curriculum does not only examine educational methods but moves beyond to embrace the ultimate goals of the education system. In addressing this challenge it is incumbent of the curriculum to express its goals in a clear and unambiguous way so that every person is aware of what the general purpose of the curriculum is. Any reform should therefore be streamlined to be in harmony with the way the human mind actually functions and be able to provide or raise environmental and societal awareness (Cohen, 1993:790; Department of Education, 2000).

3.10.1 Need for curriculum change

To achieve this objective any reform in education must be accompanied by in-service training of its implementing agents namely teachers. The modern science curriculum puts more emphasis on discovery learning and experimentation, which are in contrast to the status quo (Van der Linde *et al.*, 1994:50). Kahn and Levy (in Van der Linde *et al.*, 1994:50) claims that science syllabi in South Africa fail to embrace the interests of the community and those who leave school before at least grade ten. In this way the curriculum was not responsive to the needs of the society and had to change. It is for this reason that Curriculum 2005 for natural science was put to review.

3.10.2 The kind of learner envisaged by Curriculum 2005

In introducing the OBE system, the government wanted to answer a challenge that said, what kind of a learner is envisaged and what kind of a teacher can ensure that such a learner is borne out of the system of education? It is an embedded feature of Curriculum 2005 that both learners and teachers must be lifelong learners and researchers. However the present teaching corps has not necessarily managed to live up to this expectation because the facilitator of the programmes is not possessing skills that can aid them to achieve with confidence (Du Toit & Lachmann, 1997; Wesi, 1999).

The new OBE Curriculum gets credit for becoming the most single important instrument to driving educational change. In the South African context the old curriculum had its own ways, which promoted race, class, gender and ethnic divisions and prevented blacks from being over-qualified for positions not envisaged for them (Bantu Education Act of 1953; National Education Policy Act of 1967). Post 1994, when South Africans of all races voted for democracy it became imperative to restructure a curriculum to reflect on values and principles of the new democratic society (Department of Education, 2000).

A White Paper on Education and Training (DOE, 1995) was then introduced to form a baseline to restructure the education system in order to normalise and transform teaching and learning. The emphasis was then placed on the importance of shifting from the traditional aims and objective methods of teaching towards a more outcomes based system where learners are assessed on particular activities in which they can demonstrate particular aspects. Many reputable academics perceive Outcomes Based Education as the best system for a developing country like South Africa. The result of the review was spectacular in that it became a user friendly curriculum, where if teachers are adequately trained, it has every prospect of being the most progressive in the world (Niewoudt, 1998:2).

3.10.3 Design of the curriculum

The design of the curriculum should embrace the developmental stages of a child. To achieve its objective for natural science, education during middle school stage should provide for the extension of experiences gained at elementary schools. In order to successfully achieve this objective, the general goals for education and instruction for science should be conceptualised and be streamlined to meet the needs of the adolescents. This group of learners is active and therefore readily available to interact with the subject matter (Woolnough, 1994:102; Trowbrige *et al.*, 2000:107). The middle school phase of learning represents an important conceptual and physical change in the education system because herein learners are at developmental stages of their lives. To provide for a platform for the successful teaching of natural sciences the following characteristics are emphasised to define the status of the subject;

- That instruction must be varied,
- More emphasis needs to be made on decision-making and problem solving skills.
- To provide positive and active learning environments,
- Place emphasis on acquiring essential knowledge, skills and attitudes in a sequential and individual manner and have teaching staff that recognises learners' needs, motivations fears and goals (Trowbridge *et al.*, 2000:109; Woolnough, 1994:103).

Beyond the above stated factors, the curriculum is equally correct if it includes influences of science, society and learners themselves. The curriculum should move in par with the recent advances in science and technology, which are important for learners to use in their personal lives and as citizens. However knowledge explodes at a rapid rate and understandably, not all of it can be incorporated into the school curriculum. It is upon this understanding that science teachers needs to have the knowledge and skills required to sift through the learning material to decide what must and can go into the classroom (Trowbridge *et al.*, 2000:107).

3.10.4 Input by stakeholders in education

Fraser and Tobin (1998:950) maintain that there must be input from all role players into the curriculum so that goals of the system can be fitted into the final structure as a guide on how the department can be managed. In review processes of the curriculum, much emphasis needs to be placed on any topics, units or lessons learnt from the previous education system. Nyamane

(2002:27) agrees that the previous system of education had some good points that could be learnt. It is therefore vital not to discard any learning path without using any of its experiences.

Woolnough (1994:102) also holds that the curriculum needs to be planned and structured in such a way that coherence, continuity and progression can be established when moving between systems. A curriculum should be essentially used to dictate aspects that need to be revisited on educational grounds to improve on what could not be achieved previously. In this way previous experiences can be used to enable constructive reinforcement and efficient development of the topics. Many teachers in middle schools tend to disregard the science that learners have studied in their primary schools on the ground that there is no trace of pattern as to what has been previously taught (Wooolnough, 1994:102).

The curriculum should also be a representative of the major aspects of science, relevant to learner's lives and abilities and should be comprehensive enough to provide learners with appreciation of those areas, which have value in their everyday lives. Natural science should help learners to appreciate and enjoy the world in which they live and be empowered to respond to challenges confronting them daily. Woolnough (1994:103) adds that it is better to concentrate on quality rather than the quantity of learning and to ensure that learning is genuinely constructive to develop successful experiences. This is greatly important because the applications of science in our society and the uses of science will forever determine the kind of citizens we have in our country.

3.10.5 Aims for science teaching

In the same line of argument Trowbrigde *et al.* (2000:67) states that beyond what the curriculum defines as the aims for science teaching, teachers are still privileged to continue to discuss and develop a few of their own aims for their science department. Through science the society expects that teachers will further develop general educational aims such as interpersonal skills, self-confidence and to promote awareness of the significance of science to the society. Science as a discipline can assist to promote the value and processes of science itself if teachers are motivated to demonstrate the beauty of scientific theories and models.

In a schooling system the teaching of scientific concepts must be driven through a medium, in this case natural science is used to achieve particular critical outcomes. A syllabus however should serve as a guide for teaching objectives to remain in the learners' zone of proximal development (Prawat, 1993:379). Once a syllabus can be perceived as suggestive and that its findings only yield results in humanities then such a step can be fatal to the development of vital teaching of science.

3.11 Conclusion

Curriculum 2005 emphasises that all learners must achieve outcomes at the end of instruction. Howie (2001:39) reflects that even when Curriculum 2005 was introduced in South Africa learners still shows an apparent lack of basic science knowledge and the understanding of science concepts. This statement suggests that there is another missing link in the offering of science that takes away the acquisition of concepts and skills. The agents responsible for the teaching of natural science have to be considered for research as regards their ability to effectively teach natural sciences. As a point of departure demonstrations will be considered as an effective tool in the hands of the teacher for building good skills required for the achievement of outcomes in natural science.

The debate about the nature of the appropriate processes of science will remain a challenge facing the teaching of science. How scientists work, can be easier to analyse and thereby outlining some of the component skills. To be conclusive about any approach may itself undermine the nature of science and limit its growth. The whole reason for doing science, does not and cannot equal the sum of its parts, it differs and exceeds it. Processes that scientists use such as planning, hypothesising, observing, measuring, inferring and reporting are in fact general life skills and are context dependant. They can be classified as scientific processes only if they are set in the context of a scientific activity and the results will be interpreted with scientific understanding (Woolnough, 1994:18).

Similarly what the teachers know is critical to the teaching and understanding of scientific skills. The methods that they employ in teaching contribute to the development of learners. Science teaching in schools needs to be removed from being too prescribed and lacking a sense of creativity. The reason for this concern is that most teaching activities are unrelated to the world in which the learners are exposed. By involving learners in the scientific activities like demonstrations, the teacher may be providing justice to our education and to the scientific enterprise itself. In the next chapter we will therefore focus on demonstrations as a means of teaching scientific concepts.

CHAPTER 4

DEMONSTRATIONS IN NATURAL SCIENCE

4.1 Introduction

Classroom demonstrations are commonly believed to help learners to learn science and to stimulate their interest. Inarguably the well-performed demonstrations help to keep the interest of learners towards science positive, because children learn mostly by doing. Since we learn by doing, a good demonstration can assist in bringing the audience into active participation with the experimenter. Demonstrations play a major role in the teaching of natural science (Vreken, 1980:150). The role of demonstration in a classroom of science has changed over the years to coincide with the transition of research knowledge to the world of experience (Mumby & Russel, 1998:643). Many writers are tempted to overemphasize the decline in the use of demonstrations (Woolnough, 1994:87; Trowbridge *et al.*, 2000:217; Woodburn & Obourn, 1965:321) to name a few. However the impact and influence of good demonstration cannot be too highly emphasized. Apart from cognitive benefits, where the teacher explains principles of a demonstration, there still remain some affective benefits in which the learners' imagination and interests are developed.

4.2 Definition of a demonstration

Teaching natural science is about building new physics, new knowledge and understanding in young minds. To achieve this objective, our teaching must go far beyond giving information but start to expose the nature of physics to young minds. Learners must know what physics is, how it is done, how it grows in strength of knowledge and where it is going. Demonstrations have always been part of this art, but what is a demonstration?

> "Demonstration is a planned manipulation of materials and equipment to the end that learners are able to observe all or at least some of the manifestations of one or more scientific principles and operations within a phenomena." (Woodburn & Obourn, 1965:322).

> "Demonstration is a process where the teacher shows or illustrates a skill or a principle." (Kramer, 1999:91).

> "A demonstration is the repetition of a series of planned actions designed to illustrate certain phenomena" (Peterson in Vreken, 1980:151).

Knox (in Woodburn & Obourn, 1965:321) holds that demonstrations are better suited for the presentation of information for a relatively permanent retention. He argues that for the purpose of imparting scientific attitudes and training to a group of learners, demonstration method is equal if not superior to the laboratory method of instruction. A properly presented demonstration provides an opportunity for the teacher to observe his learners while performing many of the intellectual processes which are ordinarily held to be associated with the work of scientists.

Demonstrations help to keep the learners engaged both because they are themselves engaging and because they enhance the learners' sense that they are learning. A critical factor here is for learners to have a clear understanding of basic concepts to remain focused (Buncick, *et al.*, 2001:1251). Demonstrations are designed to enable learners to understand where they are going in relation to where they are, to position themselves in the overall landscape and to identify the landmarks where they will return should they loose their way.

Natural science mainly subjects itself to the study of laws of nature, which explains the properties, and the interactions of matter and energy in the universe (Department of Education, 2002:9). The major emphasis on science is to investigate both physical and chemical phenomena through scientific inquiry and by applying models, theories and laws to explain and predict events in our physical environment. It is the submission of this research project that by its definition demonstrations are adequate in exposing the true ideals of the demands of natural sciences.

4.3 Nature of science teaching

Observations play a major role in how science has changed over time. However random observation itself is not a good science unless it provides learners with useful scientific information. Despite various analysis of dangers of doing too much or inappropriate types of practical work which is in turn ineffective, there is much unfocused practical work in school. Such kind of practical work does very little to increase the cognitive understanding of learners (Woolnough, 1994:25). Teachers often criticize science teaching in schools for being too prescribed and lacking demonstration as a sense of creativity. Reason to the criticism has been fuelled by the fact that most practical work done at schools is costly and unrelated to the world in which the learners are exposed.

Science itself is complicated because it does not have simple clear-cut aims (Woolnough, 1994:11). Due to lack of focused aims for science teaching in particular there arises in the system conflict of interest. The society has its own expectations from the teaching of science like issues of security (Rogers, 1965:5), and in providing for a suitably skilled work force for developing industries and the economy (Woolnough, 1994:11). Teachers themselves in educational terms, aim to transfer knowledge, skills and attitudes that can assist learners to become broad, well-educated citizens. However all these beautiful aims indicate that aims for science teaching are not a "one size fits all" types. Each and every learner comes to a classroom with specific expectations, which may be totally different to those enclosed in a science curriculum. The challenge that comes with this understanding is to ensure that the most appropriate aims are met for all learners without isolating any learner.

4.3.1 Science as a knowledge generating process

4.3.1.1Introduction

Science is one of the things men do and is marked by initiativeness, boldness and energy (Woodburn & Obourn, 1965: 12). The pursuit of science refers not merely to data acquired by scientists but mostly the means of its acquisition. In their teaching, teachers direct their instruction in a classroom and the laboratory towards achieving several purposes. One of such purposes may be to develop within the minds of learners increased appreciation of the knowledge of science, its inventions and discoveries. The other objective of the instruction may be to nurture the modes of thought and abilities of the mind that seem to be exercised in the execution of inventions and discoveries. Learners remain new in the scientific situation and therefore the teacher must play a vital role of demonstrating all the new concepts and methods that learners need to know.

4.3.1.2Definitions of science

The rationale of natural science as stated in the South African policy document (1997:NS-5) seek to develop learners with scientific literacy which encompasses knowledge. As a result, the strategies involved in the teaching and learning of natural science should reflect the investigative nature of knowledge acquisition and hence conceptual development.

Science is that human endeavour that seeks to describe with ever increasing accuracy, the events and circumstances that occur or exist within our natural environment (Woodburn & Obourn, 1965:12).

Following Alfonso and Finn (in Vreken, 1980:13) physics is a science whose objectives are to study the components of matter and their mutual interactions. In terms of these interactions the scientist explains the properties of matter in bulk as well as the other natural phenomena we observe. After a scientist makes this observation and carried out an investigation it is characteristic of a scientific to set his findings down in a logic and readable form for the benefit of humanity in general. The treaties built in this way constitute a great monument to the inquiring mind of a scientist. Knowledge is not a gift bestowed upon mankind, but must be acquired through findings and observation (Woodburn & Obourn, 1965:12). To carry out these findings, above achievement and glory, learners need to be sustained by motivation, which is internal, that in turn assists the learners in findings ways of coping. This concept where learners continue to engage with the problem even when there are difficulties is called motivation.

4.4 Motivation

Pintrich and Schunk (1996:5) define motivation as a process whereby goal-directed activity is instigated and sustained. In other words motivation is something that gets us going, keeps us moving and helps us complete the task. No matter how hard teachers teach it remains expected from learners to be engaged in both physical and mental activities that help them to sustain their learning.

4.4.1 Intrinsic motivation

A good demonstration can be effective in maintaining learner motivation and interest in the way in which scientists deal with natural phenomena (Woodburn & Obourn, 1965:320). Learning occurs naturally through the pursuit of personally motivated goals. It is an internally mediated process of discovery and constructing meaning from information and experience (Trowbridge *et al.*, 2000:319). As students learn science they generate integrated mental representations and subsequent verbal explanations for the experience. Sometimes these explanations may demonstrate poorly understood or inadequately developed facts, concepts or theories of science. When identified by the teacher they provide for necessary interventions to enhance learning.

Individuals are naturally curious and enjoy learning but intense negative conditions and emotions can in turn destroy their enthusiasm. These factors include feeling insecure, worrying about failure and being self-conscious. Positive interpersonal support and instruction in self-control strategies can enhance learning by offsetting factors that interfere with optimal learning. Learning is facilitated by social interactions and communication with others in small groups that are diverse and adaptive. Teachers can assist this process by providing learners with an opportunity to interact with other learners of different cultural and family backgrounds, interest and social values. A classroom that allows for and respect diversity encourages flexibility thinking as well as social competence and moral development (Trowbridge *et al.*, 2000:321).

4.4.2 Teaching the scientific process

Consistent with this idea Woolnough (1994:19) holds that science should be a holistic and not a reductionist activity. It should be able to move beyond what learners can do to embrace what they are willing to do. It is important to develop learners' emotional involvement in the work, develop their motivation, creativity and enjoyment of science. Without this skills learners cannot learn effectively. It should be borne in mind that there is more than giving knowledge and developing skills. The area of the affective, personal acceptance and commitment to the scientific process is of central importance to doing science. If teachers can accept learners as developing individuals and expose them to scientific way of thought they encourage learners to have respect for the relationship of science and our way of doing things.

4.4.3 Demonstrations and attitudes

Meiner (1970:8) holds that the most important fruits of demonstrations are not only facts but also attitudes and motivation. This he argues can be achieved if an extra effort goes into highlighting a topic with an appropriate demonstration. Attitudes can be improved by a swing towards moving away from teaching theory and doing practical work. Enthusiasm for teachers increases through encounter with fellow teachers in the classroom to compare notes or to share new ways of presenting physics. This same argument is likely to hold for learning science because learners can easily adapt when the situation is more favourable to them. When learners are inserted into groups the fear factor is reduced and more responsibility for their learning is assumed. Demonstrations in such exercises are found to add more to the understanding of the problem under consideration.

4.4.4 Demonstration as a means towards attitude change

A good demonstration can be used to create a memorable impression of how a particular principle operates. Du Toit and Lachmann (1997) have studied the influence of a demonstration program on the attitude of high school learners towards chemistry. Their study reports that demonstration to a large audience is a powerful method to bring about a positive change in attitudes. This report supports the findings of Brophy (1986) that demonstrations in their nature influences learning positively or negatively. The teaching of science must continue to facilitate learners' knowledge about science, which they can use in their personal lives and as future citizens. This teaching should sustain learners' natural curiosity, develop their skills in inquiry and design and finally to help them develop an understanding in science (Trowbridge *et al.*, 2000:4).

4.4.5 Interpersonal relations as a factor in teaching

It is very vital for a teacher to realize the importance of interpersonal relations. One of the most important factors in regard to helping others is that objectivity has a negative correlation with effectiveness that is if learners are treated as objects, the teacher becomes less successful with his teaching (Prawat, 1992:357).

4.5 Teaching methods

A choice of a method that a teacher adopts for instruction plays a major role in learning. Since learning cannot be divorced from teaching the effectiveness of learning is largely influenced by the aim of the teaching first towards the learner and on the teacher. This effectiveness can be hindered by the teacher's personalities and preferences of teaching methods. Most constructivists hold that the quest for most effective teaching method is the question of how children learn. If the goal of science teaching is to provide learners with skills, values and positive attitudes towards science then a set of suitable methods needs to be discussed and how they contribute to the world of science.

Reflection on teaching methods is essential because problems associated with learning are greatly tied to the method used in teaching (Vreken, 1980:83). Therefore few of these methods that are tied to the variable of teaching will be discussed in brief.

4.5.1 Simulations

By definition Simulation means "an imitation of a real system..." (Lunetta & Hofstein,1991:125). This is not a new concept. Computing has been found to be useful in virtually all areas of the educational process where both the teacher and the learner have a legitimate interest. Vreken (1980:176) says about simulations " ...in hierdie geval word die rekenaar gebruik om werklike situasie te simuleer." In this way learners can be introduced to laboratory work in a more cost effective way. McKenzie (in Vreken, 1980:181) asserts that teaching aids are the designs that help the teacher because they can actually transmit reality or simulations of reality in a manner superior to those available to the solitary lecture instruction to a class.

4.5.2 Multimedia demonstrations

According to Jenkinson and Fraiman (1999:283), multimedia instruction refers to the combination of communication media like text, hypertext, graphics, still images, sound, interactive video and animations directed and co-ordinated by the computer and shown on computer screen.

4.5.2.1 Computer simulations

Lagowski (1989:13) holds that computer simulations can be used to anticipate a laboratory experience, making it more meaningful to the learner. Although interactive computing cannot be a substitute for practicals in the laboratory, a number of strategies can be learnt through the use of computer simulations. Doing computer simulations, learners can gain confidence and insight into the nature of qualitative analysis.

Simulation has been a part of science education for a long time. Since the eighteenth century, mechanical orreries were used to simulate the relative motion of planets in the solar system (Lunetta & Hofstein, 1991:125). Experiments that we carry out in school science are simulations of the scientific practice. Experiments are used in schools to provide learners with experiences that will give them chance to have a better understanding of the scientific enterprise.

4.5.2.2 Simulations as used for concept formation

Simulations can increase dynamic encounters with concepts and systems by providing an easy to manipulate process without the risk of cost and hazards. Simulations can be much more than a substitute for conventional laboratory practical activity if designed to provide meaningful experiences that are often not possible with real materials in introductory courses. Conceptual understanding can be enhanced through experiences with simulations of models, nuclear or chemical reactions as alternatives to expensive, dangerous and time-consuming materials (Lunetta & Hofstein, 1991:126; Lagowski, 1989:14).

4.5.2.3 The cost of simulations

To cap problems of cost, size of the class and gaining access to meaningful experiments, simulations can be explored. The main purpose of simulations is to increase the learners' abilities to apply concepts, analyse situations, solve problems and understand different points of view. Simulations provide the teacher with a means of presenting situations, concepts and issues in a condensed and simplified form (Trowbridge *et al.*, 2000:34).

4.5.2.4 Use of computer instruction

Computer assisted instructing as a means of enhancing student experiment can be used to augment the textbooks which for now have been the sole and primary sources of images and imagination (Smith & Jones, 1989:8). Textbooks had to be augmented because in their nature they are limited to words, diagrams and still photographs. This approach agrees to the integration programmed of outcomes based education (OBE) by using technology to help teachers to manage the learning environment. As learners anticipate the laboratory work, they are given a chance to observe and have a mental image of how the results should be when actual demonstrations are carried out.

Trowbridge *et al.* (2000:18) states that beyond the perception that laboratory management and use of practical are expensive; computers can be used to replace some of traditional laboratory work. New learners in a classroom of physics for example can be shown by teacher demonstrations how to collect experimental data on line and execute the experiment through the computer-aided instruction.

4.5.2.5 Anxiety as a challenge of using technology

Smith and Stoval (1996:911) asserts that in as much as there are few learners who are not computer literate, there are still learners who are anxious about handling the apparatus. To save this situation learners should learn the content and not necessarily how to handle apparatus. By implication a teacher must remain at the helm of operations through teacher demonstration, to guide on how to handle the technological instruments. Simulations are not necessarily intended to replace the teacher but are provided to enhance and support a teacher to be able to teach effectively.

4.5.2.6 Challenges facing the use of computer instruction

The use of computers in a classroom of science can bring about unintended results unless it is seen to be contributing to the relationship that already exists between the teacher and a learner. In this regard a computer becomes the third person in a learner – teacher relationship and this comes with its own challenges (Edwards, 1990:24). The computer remains a teaching aid in the hands of a teacher without necessarily replacing his role. It could be to detriment of effective teaching if the teacher withdraws completely from a leading role in the classroom, leaving only the learner – computer relationship to continue without facilitation. However a teacher is not necessarily supposed to intervene needless of a call to intervene. This is influenced by the fact that teaching by simulation is mainly guided by the degree of learner autonomy based on the nature of the software.

The knowledge of the teacher about the software determines the level of guidance and leadership that the learner can get from the teacher. Learner achievement is mostly related to the output of the teacher (Hasan, 1985:5) such that when learners are given some autonomy to investigate and test their own ideas and understanding using computer simulations. The benefit of this exercise is to improve the learning technique. Even with a simple simulation, a teacher is expected to plan and identify what the exact outcomes of the exercise are which can only be best achieved through the use of computer simulations. Before learners are required to work on computers a teacher is expected to introduce the lesson to all learners. Irrespective of the expertise that the learners have about computers, in this instance the teacher's knowledge is vital because it is about science itself and not computers.

4.5.3 Lecture demonstration

Woodburn and Obourn (1965:298) define lecture methods as an extended formal discourse for the presentation of knowledge. Following on this definition in the lecture method, the teacher imparts knowledge to the learner by word of mouth the knowledge that the former possesses and the latter lacks. This method is widely used by novice and amateur teachers, and yet inspired teachers often reach their greatest height by using this method to invoke active intellectual rather than physical participation on the part of the learner.
The teachers who enjoy complete control of the classroom situations prefer this method. Further to this objective, the lecture provides a way to present a closely knit and organized body of information in the least possible amount of time. Coupled with demonstrations, lecture method can startle or challenge pupils, provoke thought and discussion. A greater advantage of using teacher demonstrations is that of safety. Sometimes teacher demonstrations can be used when there is a shortage of apparatus. A demonstration in this regard can be useful for introducing the use of new or difficult apparatus and procedures. Teacher or lecture demonstrations are vital because they require practice and skill to ensure that all pupils are actively participating in the lesson.

Vreken (1980:142) holds the lecture method as most appropriate for providing a conceptual framework as a basis for independent study. It is easier for the teacher to guide his learners by lecture through concept mapping and to assist them to identify the key words for their learning.

According to Woolnough (1994:84) lecture demonstrations are most effective when presented with the sole aim of introducing learner to a quality of scientific demonstration in a more spectacular and more impressive way. This he argues that a spectacular demonstration never fails to stimulate intellect, imagination and involvement of learners.

4.5.3.1 Advantages of lecture demonstrations

The lecture method is effective as a bridging method when the curriculum moves towards more learner-centered approaches to learning as it saves on a huge investment in in-service training and material development (Qualter & Abu-Hola, 2000:228). Lecture demonstration approaches are easier to adapt from the teacher-centered methods in moving to those methods that involves learners. Qualter and Abu-Hola (2000) argue that this approach towards change can create less pressure on the system in terms of costs and would require a less radical change on the part of teachers. To support this input, Killermann (1996) found that the performance of learners taught through lecture demonstration increased with the increasing attitude towards science. However this situation is always true only if the format of a lecture-demonstration lesson was usually to start with a question or activity given by the teacher to initiate discussion and to ensure learners participation, this was followed by a demonstration involving learners. The learners are encouraged to write their observations and then the whole class must engage in general discussion.

Du Toit and Lachmann (1997:50) raised a concern from their study that the change in curriculum has not been accompanied by change in teaching methods. Lack of training militates against teachers exploring alternative teaching methods. Perhaps it is an obvious flow of argument that the lack of training in the use of different teaching methods and in the modification of teaching material to suit the new methods prohibits the variation of experiments on the side of the teacher (Qualter & Abu-Hola, 2000:236).

4.5.4 The laboratory method

The reason for practical work is to simplify science that involves highly complex and abstract subject matter. It would be very difficult for learners to comprehend such abstract concepts without the concrete props and the opportunity for manipulation afforded in the laboratory. Ausubel (in Tamir, 1989:64) asserts that the primary responsibility for transmitting appreciation of scientific methods should be delegated to the laboratory. On the same breadth the responsibility of transmitting the content of science must be delegated to the teacher and the textbooks. Following this assertion by Ausubel, the laboratory teaching must be tasked with the responsibility of providing learners with the methods of acquiring scientific skills of manipulation. Practical experiences are effective in inducing conceptual change. When learners are engaged in practical work in the laboratory they are apt to gain skills, which are necessary for manipulation of problems. Skills provide any learner with an opportunity to appreciate the spirit of science and can further promote problem solving. A laboratory exercise if well designed can provide a scene for learners to act like a real scientist and to develop in them a critical assessment of results and of the limitations of the laboratory.

A laboratory continues to offer unique opportunities that are conducive to the identification and remediation of learners' misconceptions (Tamir, 1989:64). Learners usually enjoy activities and practical work when they are offered a chance to experience meaningful and non- trivial encounters. The successful completion of any challenge in the laboratory breeds a sense of achievement that also motivates and creates interest in the learners towards science. The laboratory work provides learners with a scene of ideas and principles first hand. Understandably UNESCO has a taken a lead in declaring that if science is to be learned effectively, it must be experienced purely because it plays a major role in providing learners with experiences of what science is. Tamir (1989) holds that a laboratory is a unique fact of science education.

4.6 Planning a demonstration

Reif *et al.*, (in Vreken, 1980:147) holds planning of a demonstration to include a selection of basic relations pertinent for solving the problem and thereby providing an outline of how they are used. Planning for a demonstration should largely be influenced by a desired outcome for finding a solution. For a demonstration to be effective it requires of a teacher to be able to identify the concept and principles that needs to be taught and thereafter direct the design of his demonstration towards achieving that objective (Trowbridge *et al.*, 2000:216).

According to Meiner (1970:4) planning of a demonstration must sift out any feature that may dominate the central feature or otherwise steal away the focus of the experiment. To help the teacher to maintain control of his instruction it is very important to test if the experiment is "valid" by doing it at least twice before presenting it to the class. To further assist learners, teachers can break down the information around demonstrations into small chunks of information for easy digestion. Where learners are all exposed to the information, a teacher can continually evaluate progress of his learners through questioning to guide learners towards a central feature.

A good demonstration should be planned in such a way that it remains simple and clear, be constructed to a scale which will make it visible to every learner in the audience and requires a skill (Woodburn & Obourn, 1965:320; Trowbridge *et al.*, 2000:218). Further to this requirement, we must not

abandon an instructional technique that if in skilled hands, offers to a large group of learners, a first hand association with rich content of physics.
Planning a demonstration requires an extensive organization and consideration of the following critical points:

4.6.1 Identifying a principle

A teacher needs to ensure that even before he plans a demonstration, he has identified a principle that he wants to show to the class. A good demonstration can only be measured by what it intends to achieve. By so doing, a teacher is able to direct the design of the entire demonstration to the attainment of the particular principle (Trowbridge and Bybee, 1990:233)

4.6.2 Simplifying a complex principle

An effective teaching requires that both the teacher and the learner must share the purpose or goal of instruction. Prawat (1992) argues that the amount and quantity of teaching and learning that occur in a classroom never suffer without a certain degree of congruence between the teachers' and the learners' knowledge, skills and dispositions. If a teacher recognizes that the principle envisaged to show is complex, one should break it down into "chunks" accompanied by examples. If a given phenomena has a chance of demonstrating numerous principles, a teacher must focus learners towards what he intends to teach (O'Brien, 1991:934)

4.6.3 Designing the activities

Every demonstration must be selected on the merit of its design and the outcome that it can help to achieve (Olivier, 2001:96). Therefore, the activities before the actual demonstration should be designed to involve learners as much as possible with clear outcomes. A teacher is still expected to ensure that selected apparatus are gathered and assembled on time. Secondly, the teacher must ascertain that such apparatus are in good working conditions and tested before hand (Trowbridge and Bybee:1990:233).

4.7 Implementing a demonstration

Peiper and Sutman (1970:83) define demonstration as a planned manipulation of equipment and materials to the end that learners observe all or some of the manifestations of scientific principles. This definition reflects that demonstration if well implemented in the classroom of science can provide a teacher with as essential tool of illustration of a concept or a technique to learners (Vreken, 1980:151). A demonstration needs to be carried out in a manner that makes it visible to all learners in the classroom and where necessary the teacher can use an overhead projector to make apparatus even more visible and accessible. Now that another factor is added to the demonstration namely the apparatus, it is important for the teacher to keep to the purpose of what needs to be demonstrated by asking questions as a means of redirecting learners back to the central purpose of the activity. A teacher needs to be careful of the path that the demonstration will take towards achieving a solution.

4.8 Kinds of demonstrations

Demonstrations influence learning positively (Brophy,1986). Teachers should be keen to bridging gaps that exist in the learners' background which can impede active learning of scientific concepts. Learning of natural science is related to the teachers' conceptions of the science content and knowledge of his methods of instruction.

The teachers' confidence plays a major role in achieving the desired results in demonstrations, the teacher must be seen to be enjoying the presentation and himself be well organized, since many learners' attitude towards science is largely influenced by their perception of the teacher (Hasan, 1985:4).

4.8.1 Visual demonstrations

The best way to provide good demonstration in a sensitive and interactive way is by preparing learners on what they should see, either through their own preconceptions or by focused prepared questions (Woolnough, 1994:25). Good and carefully selected questions which link to the learners' prior knowledge are best suited to develop application and practice. This kind of demonstration requires a teacher to use direct discussion with the class and away from the laboratory equipment where learners are obliged to think rather than to do.

4.8.2 Teacher demonstration

Fairbrother (1999:10) states that the learners need to express what they think because they need a thinking vocabulary for communication purposes. During planning and problem-solving situations, teachers should think aloud so that learners can follow a demonstrated thinking process. When the teacher takes the lead in this way and encouraging discussion, she helps to develop a vocabulary that learners need for thinking and talking about their own thinking.

4.8.3 Nature of an effective demonstration

Clarifying and labelling the thinking processes like prediction, observation and reporting stages is vital for learners' recognition of thinking skills. It is often difficult for learners to directly express their understanding through talking. When teachers are leading and learners are allowed to give responses it helps to develop their vocabulary in order to express themselves with confidence. Talking to one another in small groups is a non-threatening situation which also breaks away from conventional lesson in which the teacher controls both the question and the answer.

Teacher demonstration can still play a role to promote thought and challenge learners. It also gives the teacher control of the lesson. Other important reason for using demonstrations is that of safety. In many other instances demonstrations can be used where there is shortage of apparatus and procedures. Demonstrations can be useful for introducing the use of new or difficult apparatus and procedures. This is done because demonstrations require practice and sense of theatre for the greatest effect, but it must not be overdone otherwise it can have the opposite effect to that intended, like clouding the concepts. To enliven demonstrations learners need to be involved and be guided on how to do their own demonstrations either with or without practice (Trowbridge *et al.*, 2000:216).

A teacher can use demonstrations to predict the solution through observation and thereafter be given a chance to explain. In this approach to the use of demonstrations, learners are shown a particular situation and asked to predict what they think will happen. Learners written predictions and reasons are recorded without rejecting any response as wrong or right. This approach further enhances commitment and participation from learners. When every learner has made a prediction, the demonstration is then performed and all learners' record observations. Finally reconciliation of any conflict between predictions and observation is undertaken. Gunstone (1991: 69) defines this approach as Predict- Observe- Explain (POE) method. This method still allows the teacher to facilitate the demonstration, by inviting learner to predict what would happen and expose what possible preconceptions is held learners, and allow for observation to clarify any conflict. When this approach is carried out, it illustrates the importance of personal theories. This approach does not deal with observation but also exposes the way in which learners accept them. Trowbridge *et al.* (2000:216) holds that demonstrations can be justified by its ability to direct learners to the thinking process. Since a teacher has a better indication of the learner thinking process he can do much to stimulate learners to be more analytical and synthetic in their reasoning.

4.8.4 Role of prior knowledge in demonstration

Learners' prior knowledge needs to be assessed because it always guides the teacher on the level of knowledge that they have. With this knowledge the teacher knows exactly which areas needs emphasis before he starts with a new concept. Most teachers feel that practical experience of a phenomenon is essential for understanding scientific concepts. White (in Watson, 2000:60) indicates that recall of incidents or episodes in the laboratory gives a dimension to scientific concepts that cannot be achieved simply by talking about them. Progression from observation to construction of scientific concepts is not a simple one; they call for clarity and assistance. The teacher's role here at may be to use demonstration to help learners understand using scientific explanations. Using what can be related to their prior knowledge the teacher uses demonstration to take learners from the known to the unknown. To do this the teacher focuses on the key aspects of the demonstration, selecting and emphasizing particular aspects of pupil's responses as he asks leading questions. Correct answers should be praised and given scientific language. This illustration defines the teacher's ability of talking about the phenomenon, relating selected observations to a scientific explanation. However it is important for the teacher to realize that learners must share in his theoretical perspective, which makes sense of the practical activities (Gunstone, 1991: 69).

4.8.5 Doing a demonstration to a large audience

As a teaching method, demonstrations can be used to teach concepts or skills directly, or to prepare students for work in the laboratory. In a situation where there are insufficient resources with large groups, demonstrations can be used to cover for cost and for safety reasons. In this instance demonstrations serve a purpose of providing the students with an opportunity to see a phenomenon or event that they otherwise would not see (Trowbridge *et al.*, 2000:30). The challenge of this approach is for the teacher to present demonstrations so that all students can see them and be tested beforehand (Woodburn & Obourn, 1965:320). Even if the demonstration can have a dramatic quality and provide sufficient puzzle to the learners, it must clearly maintain focus to the intended concept or skills. When the teacher shows this good teaching quality, then learner's attitude towards science can be influenced positively (Hasan, 1985:4).

4.8.6 Demonstrations when used to introduce prior knowledge

Demonstrations can be purposefully used to capture attention because in themselves they are quick, spectacular, and demands attention which is tied to enhancing presentation (Trowbridge *et al.*, 2000:468). In the hands of a teacher demonstrations continue to be effective to emphasise a principle, fix a fact or condition a class for further learning. Planned activities in a science classroom will provide learners with methods required for generating interest or motivating natural science learners to learn about its basics. A good teacher should be able to select the most effective demonstration to augment his teaching.

4.8.6.1 Demonstrations as a source of prediction

Demonstrations may not necessarily be the core aim of the encounter but can be used to offer learners the opportunity to observe experimental basis of a particular scientific phenomenon. If the question such as "what do you suppose would happen?" is asked, a sense of prediction is challenged for learners to focus and participate (Meiner, 1970:4).

4.8.6.2 Demonstrations as an analysis tool

Demonstrations if separated from any philosophy can be categorized into functions such as qualitative displays that show functions and relationships and quantitative displays in which measured values can be recorded and analysed. According to Buncick *et al.*, (2001:1138) demonstration is a staple of most physics course that do not necessarily perform a connective function unless they are carefully planned and placed to perform a particular role. Otherwise, they are just one more potentially disconnected illustration of a concept that may be only poorly understood. When effectively used demonstrations are an example of activities that can be used to demonstrate multiple concepts and tie together different sections of some basic concepts. To promote active engagement the teacher must continually ask the learners to predict the outcome of the demonstration and participate in discussion of the demonstration as it is being presented. A teacher remains critical for developing growth in conceptual understanding, which is enhanced by expertise in skill usage.

4.9 Purposes and uses of demonstration

4.9.1 Communication

According to Meiner (1970:4) demonstrations can serve as a means of communication. The main function of demonstration in this regard is to capture learners' attention and keep focus. This can be successfully achieved if a demonstration is carefully planned to be appealing or dramatic. For clarity purposes, demonstration as a teaching method forms an integral part of a complex education interaction between the teacher and his learner. In a case where an activity is carried out to clarify some physical phenomenon there should be sufficient planning to ensure that nothing else is communicated which may obscure the central feature. Perceived as a method of improving classroom communication, demonstrations require a teacher to possess good questioning skills to guide learner through the demonstration experiment.

4.9.2 How to state a rule

During evaluation stages the teacher can ask the learners to demonstrate the rule by using or applying it in a specific situation. According to Gagne (in Vreken, 1980:104) once learners have learnt the basics of the concept, they should be encouraged to state the rule at least verbally. This is necessary for improving communication between teachers and learners.

4.9.3 To teach scientific concepts

If a learner is considered from a cognitive point of development, his learning must be based on acquiring knowledge through the interaction with our environment physical, ideational and social. As individuals we interact with the objects, ideas and persons that are part of our psychological world, manipulating and experiment with them by discovering relationships and interrelationships among them (Vreken, 1980:102). In approaching learning from this perspective learners acquire relationships between the objects through manipulation of objects that are relevant to the question. In teaching skills, concepts form a vehicle by which skills are learnt. A teacher's role includes continually asking questions and guiding learners towards the concepts under the study (Buncick *et al.*, 2001:1239).

To teach scientific concepts, a teacher is expected to possess particular skills to state what kind of outcomes is expected at the end of learning. When the teacher teaches a law, he should do everything to guide learners to learn a rule without stating it, but by simply using performances that helps learners to see the relationships (Meiner, 1970:4).

4.9.4 To teach scientific reasoning

Since science is connected by experiment to the world wherein we live, demonstrations can be used to convey the essence of scientific experiments and reasoning (Meiner, 1970:43). For the teaching of science to be effective, teachers must be able to expose the inherent link between theory and experiment, whose performance can lead to the proper understanding of science itself. To teach for understanding we must prepare both the ground and conduct of our teaching with much greater care, because learners gain knowledge and understanding better by their own effort when they are engaged by arguing their own way through the problems. Learners need to be encouraged to participate in providing solutions to the problems that exist in science.

4.9.5 To test hypothesis

Thurber and Collete (1965:130) provide another advantage for using demonstration experiment instead of individual experiment by learners, which is to test hypothesis. The teacher may pose a question to learners and ask them to predict the solution. All learners are then afforded an opportunity to write down their answers through prediction. When all answers are recorded, the teacher then carries out a demonstration. After the experiment learners are allowed to confirm or reject their prediction based on their observations. Where results challenge learner's prediction, there is likely to be a conflict in their minds, which is necessary for diffusing their alternative conceptions. In this way demonstration becomes highly effective as a *stimulating and* illuminating factor in the teaching of natural science (Woolnough, 1994:69). Once learners' minds are stimulated, a teacher can allow a few minutes discussions for learners to discuss their observations against their initially predictions before providing any explanation. These discussions sessions will in turn improve the learners' communication skills and to integrate theory with practical work (Meiner, 1970:43). Beyond communication in groups where learners *try to find common* ground, the teacher can assist either by rejecting or confirming the alternative concepts which are in conflict with the learning of science.

4.9.6 To provide learners with first hand experience

Demonstrations can otherwise be used to provide learners with first hand experience of the beauty of physics. Direct teaching is not sufficient or a particularly effective way of transmitting information (Meiner, 1970:7). Teaching itself provides substance and not the form of making necessary concept formation that is vital. It is in "true" demonstrations that we find the nature of science speaking for itself. For example, in teaching qualitative concepts demonstrations can be used to show how scientists think about a topic or how they develop a viewpoint from first principles and primary phenomena through deductions and reasoning. Once this objective is achieved then science proceeds to add that extra interest without which teaching would be tedious (Woodburn & Obourn, 1965:320).

Qualitatively demonstrations can show that one aspect of nature can serve to initiate the analysis (Observation) which in turn suggests that another phenomena which is unrelated (generalization) have an influence on the same demonstration concept. For example, French Antony (in Meiner, 1970:8) states that with the help of optimal projection one can let the whole class to see a demonstration and few minutes later collect data, tabulate and plot a set of data to clarify a way of doing science. This type of demonstration can cause learners to actively observe by collecting experimental data and thereby contributing to their own learning. Demonstrations are used further to emphasise a point or to introduce any abstract phenomena.

4.9.7 <u>To teach scientific concepts</u>

Following McKenzie *et al.* (in Vreken, 1980:132) the teaching of science should be able to provide learners with information and means of explaining difficult concepts and problems and to develop critical thinking. Demonstrations as a teaching method can encourage originality in learners. For example if learners are required to demonstrate an outcome, they are apt to come up with different methods of explaining the same concept. Vreken (1980:151) holds that demonstrations can be used to teach laws, concepts and to encourage originality. Demonstrations provide learners with a picture worth of thousand words, which are essential for explaining scientific concepts.

Demonstrations represent the manual side of a physicist's thought activity which is naturally accompanied by much mental processes (Lindsay, 1971:18). Skillful teaching is of great value and the view that students forms are even more important. It is increasingly becoming more important to change from traditional elementary presentation of physics from a course of traditional rules, formulae, routine numerical problems which does not meet our aims of science teaching. Meiner (1970:44) asserts that one of the main functions of demonstrations, beyond showing the experimental basis of physics is to teach factual knowledge.

4.9.8 Challenges facing demonstrations as a teaching technique

Demonstrations remain influenced by many factors. The teachers' conceptions of teaching science remain the focus of concern. There is evidence to suggest that teachers express a preference for science teaching that focuses more on the science discipline itself more than on the social issues of science (De Jong *et al.*, 1998:745). The evidence shows that teachers still prefer to teach goals that deal with covering the topics specified in the curriculum against teaching the scientific methods. Very little is done to teach or to prepare learners for scientific careers and facilitating learners' personal growth.

Many teachers feel justified not to carry out demonstrations purely because they perceive demonstrations as basically costly in terms of money, time consuming for preparation and storage (Meiner, 1970:6). This perception relegates physics to become a mere mathematical and historical exercises and thereby eliminating the experimental nature of science. Learners still need to have a direct confrontation with the phenomena to be able to observe how natural science relates to objects and how these objects are related. Demonstrations can help learners in this regard with mental images required for understanding and recollection of data (Trowbridge *et al.*, 2000:218).

Vreken (1980:158) maintains that above its strength, demonstrations are not sufficient to provide learners with a holistic view of what science is all about. He maintains that a demonstration however well done, however dramatic, however well convincing has its virtues completely lost if its physics is not seriously and penetratingly explored. In this way demonstrations may be used as a method of preparing learners for a new lesson and to capture attention. It shows the demonstration as a teaching method, requires to be supplemented by other methods of teaching to give a deeper meaning to the learning of science.

Many teachers still want to hold on to classroom control by assuming that new activities will give learners more charge of the classroom activities than themselves. For example increased noise level and more movement around the classroom are some of the challenges facing the teacher. This kind of teaching is intended to transmit knowledge when teachers focus mainly on the discipline itself.

Perlberg and O'Bryant (in Vreken, 1980:132) hold that good conventional teaching has always sought to take account of the learner, but its structure and methods have greatly inhibited that goal. The methods of teaching have always been dictated upon by large number of learners where teaching was largely based upon a particular format accepted by academic discipline. This has shown that much emphasis was placed on teaching particular concepts and not how learners themselves construct meaning.

The use of demonstration is gradually losing its position in a classroom because of lack of clarity for its use. Two most important features that can restore the status of demonstrations are its design and the goal that is intended for its use. Naturally a good demonstration provides a context for learning concepts, strengthen course continuity and promote active engagement. In terms its design the demonstration must appeal to thought and invite the learners to hypothesise, speculate, interprete and apply what is being illustrated to the physical world in which they are familiar (Buncick *et al.*, 2001:1253).

4.10 Conclusion

The ever-changing nature of the curriculum through its development, expects that teachers must also improve on their teaching skills or methods. Teacher demonstration is what the teacher prepares as part of his own instruction and has the added advantage of better organization and more sophisticated presentation. However the teaching in today's context must be directed towards the interest of learners. Teacher demonstrations however well executed are seldom the best way because they do not provide enough learner involvement. From a constructivist's point of view, it is only when learners are actively involved that their learning is optimized (Trowbridge *et al.*, 2000:218).

The science laboratory has always been regarded as the place where learners should learn the process skills of doing science. Like many other methods, more recent studies also reflects an appalling lack effectiveness of the laboratory instruction and traces the processes back to lecture demonstrations. Many teachers claim that learners are apathetic about laboratory work and that practicals are difficult to stock, maintain and control. This is another feature that deprives science learners from experiencing much of the nature, methods and the spirit of science.

From all these submissions it is evident that even in today's teaching demonstrations have an important role to play. Beyond cost, and time management benefits, it is the design and the implementation of a demonstration that adds value in a classroom. Central to this function is the teacher and therefore a feasible study is essential to determine the objective of the study as outlined in Chapter 1 (see sections 1.6.3, 1.6.4, 1.6.5, 1.6.6).

CHAPTER 5

RESEARCH METHODOLOGY

5.1 Introduction

The key purpose of this study was to investigate teacher's knowledge of and insight into demonstration as a teaching and learning technique. The study was intended to embrace the constraints and the knowledge that the teachers uphold as regards demonstration. The literature survey as reflected mainly by chapter 4, outlines arguments for and against the use of demonstration as a method of teaching. Now a more empirical investigation needs to be carried to get a true reflection of what is actually happening in the science classroom. Much of this chapter is intended to answer questions posed in the first chapter, that is sections 1.6.1; section 1.6.2; section 1.6.3 and section 1.6.6.

5.2 Literature survey

Numerous researches have been done on the subject of demonstrations and benefits associated with its use (Vreken, 1980; Woodburn & Obourn, 1965; Trowbridge *et al.*, 2000; Van der Linde *et al.*, 1994). The literature survey is in part based on recommendations of these researches. The context of this study was focused on demonstrations within a schooling system since the subjects of the study was drawn solely from schools.

Review of related literature was obtained by means of an electronic search on publications on the subjects in both scientific and educational journals and from the Internet. The following key words were used in the search for literature: physics, demonstrations (science), teaching methods, science instruction, scientific concepts, science education, and teaching. The developmental background done previously by Vreken (1980) contributed largely to the foundation and compilation of this study. The materials cited in this study were obtained from the North-West University (Potchefstroom Campus).

The introductory part of the literature study gave an overview of the nature of natural science with specific emphasis on physics. The origin of the concept physics was discussed in detail to give an understanding of what components of physics constitute natural sciences. On this basis, the term physics was used in chapter two to reflect the evolution of natural sciences.

5.3 Empirical Research

5.3.1 Target population

A population for this study was drawn from schools from Mabopane Area Project Office, in the North-West Province. A teachers' sample was constituted of five representatives from each school. All teachers who participated in the study are teaching learners from previously disadvantaged communities from most areas of North-West Province in South Africa. A factor that needs to be noted is that almost all of these teachers are Tswana speaking while the medium of instruction is English. This factor can be a concept for study, but it is only for noting in this project, and therefore its effect on the results will be ignored. All teachers used in the study are currently teaching natural sciences in the GET band.

These teachers were earmarked for this research project because they are from a rural area that does not have electricity. Electricity is an important factor for consideration because it is essential for aiding the functionality of a laboratory. Without electricity is it difficult to do most practicals in the laboratory. Hence doing demonstrations is expected to form a major part of science teaching in this area.

The schools and teachers who participated in the study were randomly selected. According to Stoker (1989:103) randomness is at the heart of the process of obtaining a representative part of the population by means of probability sampling. The advantage of this process is such that there is an equal possibility for every member of the population to be selected. When such a random sample is selected, the researcher can assess that the characteristics of the sample approximate the characteristics of the total population (Leedy & Omrod, 2001:211; Stoker,1989:104).

5.3.2 Method used and its justification

The essential purpose of quantitative research is to document in detail the conducts of every events and to identify the meaning that those who participate in them attaches. Empirical investigation in this study was done by means of quantitative survey. This kind of survey was chosen because of its nature to recognize that the issues that are studied have many dimensions and layers, and can only be represented in a multifaceted way (Leedy & Omrod, 2001:147). This method of research supports the literature survey that provides sufficient literature for arguments for and against the use of demonstrations as a teaching technique without providing clear-cut solutions.

The research method embraces an interpretive paradigm, which assumes the existence of multiple realities. To explore these realities, the researcher has attempted to maintain independence from what is observed. This is informed by a view that all knowledge in the field of science educational research is relative and necessitates multiple realities that are belied by the common experiences that are prevalent in science world.

Questionnaires have their challenges and drawbacks as well. Typically the majority of people who receive the questionnaire do not return them and those who do are not a true representative of the original sample (Leedy & Omrod, 2001:197). To circumvent the situation, the researcher devoted his time to personally distribute and collect the questionnaire and to provide clarity when requested to do so by subjects who took part in the study.
Questionnaires are employed to obtain data about knowledge and understandings, views and perceptions as well as both demographic and personal information. The strength of a well-conducted survey lies in the fact that it is possible to design a probability sample for a well-defined target population with a high response rate (Keeves in Fraser & Tobin, 1998:1145).

Questions 33 – 38 required of teachers to respond to open – ended questions. The intention of the researcher was to do a indepth analysis of the teachers understanding of the concept demonstrations. This approach will form basis for the qualitative analysis of the results.

5.3.3 Reliability and validity of the instrument

The validity and reliability of any measurement instrument influences the extent to which the researcher can learn more about the phenomena that is studied and also the extent to which meaningful conclusions can be drawn from the present data (Leedy & Omrod, 2001:31).

Validity refers to an integrated evaluative judgement of the degree to which empirical evidence and theoretical rationale support the adequacy and appropriateness of inferences and actions based on the test scores and the other methods of assessment (Messick, 1989:13). For all instruments used in a research, a general concern was mainly about the validity and reliability of the instrument used. Wiersma (in Wesi, 2003:223) defines validity as the extent to which an instrument measures what is supposed to be measured. On the other hand, reliability is the consistency with which the measuring instrument yields a certain result when the entity being measured has not changed.

Validity embraces two concepts at once, which are called internal and external validity. Interval validity is the extent to which results can be interpreted accurately (Mouton & Marais, 1996:50) and external validity is the extent to which results can be generalized to populations, situations and conditions (Leedy & Omrod, 2001: 105). Internal validity allows a researcher to draw more accurate conclusions about the cause-and-effect and other relationships within the data. Having provided for relationships within concepts, internal validity provides space for the acceptance of the study results to apply beyond the study itself.

A distinction is drawn between content validity and face validity. Content validity refers to the systematic examinations of the test content to determine whether it covers a representative sample of the behaviour domain to be measured while face validity pertains to whether the test looks valid to the subjects who takes it, the administrative personnel who decides on its use, and other technically untrained observers (Leedy & Omrod, 2001:141).

A questionnaire as a method of research is acceptable if it satisfies the above stated requirements. Further to this an advice was sought from professionals like professor N.J. Vreken and his associates at the North-West University (Potchefstroom Campus).

According to Rosenthal and Rosnow (in Wesi, 2003:224) all instruments including measurement behaviour are subject to fluctuations, which in turn affect both the validity and reliability. In case of this survey, attempts were made to eliminate error by emphasizing mainly key words of the research purely from scientific points of view and how consistent those references are with available literature.

5.3.4 Data collection

In its nature numerical data is both rich in detail and can be lengthy. The data of this study was collected through interviews and questionnaires because this method allows the researcher to employ his integrative and interpretative skills (Gay & Airasain,2000:211).

5.3.5 Data analysis

The questionnaires were administered to teachers who are currently teaching natural science in the General Education and Training band. Out of one hundred teachers identified, seventy-nine (n=79) responded by returning the questionnaire. The questionnaire itself consisted of 38 items designed to probe the teachers' knowledge of and insight into demonstrations as a teaching technique. In order to assess the teachers' knowledge of and insight into demonstrations questions such as "What is demonstrations, what benefits do you associate with the use of demonstrations were included in the questionnaire (see Appendix 1).

Data was collected through the use of the questionnaire and the direct interviews with ten teachers. The participants were told that the objective of the study was to gather information about the teachers' knowledge of and insight into demonstrations as a teaching learning technique. Teachers were also made aware of the fact that their names or identity will not be required at all stages of the research (Leedy & Omrod, 2001:141).

Due to the type of data gathered through the questionnaires and the number of subjects involved, the discussion of the results needs to be subjected to critical and in-depth analysis. A quantitative research strategy is inductive in that the researcher attempts to understand a situation without imposing pre-existing expectations on the setting. As a point of departure the research begins with specific observations and builds towards general patterns. This is guided by method of analysis as captured by Cresswell (in Leedy & Omrod, 2001:150), which outlines five steps as follows:

- Organising details about the case to be studied,
- Categorising the data,
- Interpretation of the data,
- Identifying patterns of single instances within facts,
- Synthesis of information and making final generalisations.

Analysis of data was made on the basis of selected analytical key words namely knowledge of teaching techniques and demonstrations as defined. For a proper understanding of the data, the subjects' account on the questionnaire will be analysed against the background information as captured in chapter three and four as this was done through acceptable research methods. The literature survey provided for a context for the analysis of data. Although the focus of the study was on the teachers' perceptions of demonstrations it remained incumbent upon the researcher to approach the data from a scientific perspective.

Having provided a context for the study during the analysis of data definite patterns and dimensions emerged. This is accounted for by the purpose and the structure of the questionnaire as a method of collecting data.

5.4Ethical standards

The research was done with highest code of ethical standards with respect to the teachers participating in the study. Consideration was given to principles of fairness, honesty, openness of intent, disclosure of methods, a respect for confidence and an informed consent and willingness on part of the subjects who participated in the study.

5.5 Conclusion

This chapter was given to outline the step-by-step process followed in this research. Qualitative methodology was discussed, together with the significance of choosing this particular methodology for this study. This was followed by a discussion of the research process, and provided the instruments used, the participants and the actual process of the research itself. The chapter has also considered the issues of reliability and validity, together with the role of these concepts in qualitative research. The next chapter will reflect the results of the empirical study and to give a detailed discussion on the results of the study.

CHAPTER 6

EMPIRICAL SURVEY AND RESULTS

6.1. Introduction

The research sought to address the objectives as outlined in section 1.2.2. To achieve data for this dissertation, a questionnaire was administered to seventy-nine (n = 79) natural science teachers. The questionnaire was composed of 32 items on the 5-point Likert-type scale (Appendix 1) and 6 open ended questions. Questions were designed to assess teachers' knowledge of and insight into the use of demonstrations, with statements such as "are demonstrations an essential part of Natural Science teaching, "Preparing demonstrations takes a long time" and "I am well-trained to handle demonstrations". Questions ranging from item 22 to 32, allowed space for teachers to motivate for their choices. The purpose of this chapter therefore, is to present a discussion of the empirical results obtained by means of a questionnaire.

6.2. Statistical analysis of results

Descriptive statistics was used for analysis because of the type of information that was gathered through the questionnaire on a number of subjects used (n =79).

Ellis and Steyn (2003) provide the basis for evaluation of relationships in two way tables. For random samples as is for this study, the statistical significance of such relationships are determined with Chi-squared tests, but the actual consideration is to check if values are large enough to be significant. For cases of this study the effect size is given by $w = \sqrt{x^2/n}$ where x^2 is the usual Chi-square statistics for the contingency table and n is the sample size (Ellis &

Steyn, 2003:4). It is important to note that effect size remains independent of the sample size. For guidance purposes, the following values are important
(a) Small effect : w = 0,1 ; (b) Medium effect : w = 0,3 ; (c) Large effect : w = 0,5; where the relationship of w ≥ 5 is considered as practically significant.

6.3. Teachers' biographical Information

Table 6.1. Teachers demographic information (n = 79)

Males	Females	Teaching Experience						Academic Qualifications				Qualifications in Natural Science					Those involved in further studies in Natural Science	
33	46	<5	6	7	8	9	>10	M+3	M+4	M+5	M+6	Dip	HED	BSc	Hons B.Ed	M Ed	Y	N
		4	3	4	3	28	42	32	32	14	1	34	25	11	8	1	30	49

Table 6.1 provides the following important information.

- That the study attracted more females than males.
- That there are many teachers with teaching experience of more than ten years, (n = 42).
- All teachers who participated in the study are professionally qualified to become teachers, i.e. they have M+3, which is a requirement of becoming a qualified teacher in terms of the South African Schools Act 84 of 1996.
- That 62% of teachers are not engaged in further studies.

6.4. Teachers' responses from the questionnaire

From the questionnaire, a descriptive analysis was employed to measure the teachers' responses. It should be noted that questions 32 – 38 of the questionnaire had no measurement value, but were included to elicit teachers' input into their knowledge of the concept "demonstrations". As a result, they do not form the core of this report. For analytical purposes, the researcher used the services of North West University (Potchefstroom Campus) statistical services.

In the next paragraphs, the researcher presents teachers' views on each item as recorded from the questionnaire

Item 1: Demonstrations are an essential part of Natural Science teaching

Seventy-four (94%) of the respondents indicated that demonstrations are an essential part of Natural Science teaching. This finding is supported by the literature study that most teachers believe that practical work is a defining feature of Natural Science.

Item 2: Demonstrations are very easy to carry out

The research reveals that teachers have problems with handling demonstrations as a teaching-learning technique in Natural Science. Twenty-four (30%) of teachers indicated that demonstrations are not easy to carry out. Forty-seven (47%) say it is easy to carry out.

Item 3: Our school allocates sufficient time for practical sessions

Only twenty-six (33%) of teachers who took part in the research, agree that their schools allocate sufficient time for practical sessions. The literature study has revealed that time plays an important role in promoting practical work (Section 4.10).

Item 4: Preparing demonstrations takes a long time

Only 49 out of seventy-nine (52%), indicated that demonstrations take too long to prepare. It shows that teachers agree that the amount of time available can be used to do or prepare demonstrations.

Item 5: I discuss outcomes with learners beforehand

Fifty-six (75%) teachers indicated that they indeed discuss outcomes with their learners before-hand. Sixteen (20%) teachers maintain that they do not discuss their learning outcomes before doing demonstrations. It is essential that learners know what the outcomes are so that they can stay focused into achieving those outcomes(Section 4.9).

Item 6: It is good to start demonstrations with a problem statement

78% of teachers agree that it is good to start demonstrations with a problem statement. Teachers seem to agree that learners must be involved in the demonstration process by trying to answer questions posed as a problem statement. This assists the teacher to determine what learners have as a prior knowledge(Section 4.8.2).

Item 7: Before I do demonstrations in class, I test if the apparatus are in good working conditions.

For effectiveness and good demonstrations that do not fail, it is always necessary for the teacher to test apparatus before actual demonstrations are carried out in class. In responding to this item, 82% of teachers agree that they do test if the apparatus are in good working conditions.

Item 8: During demonstrations, I allow learners to touch the apparatus.

When learners participate in learning, they tend to achieve better. 73% of teachers do allow learners to touch the apparatus used for demonstrations.

Item 9: No learner is allowed to move or talk as I demonstrate.

Forty-two (53%) of teachers said that they do not allow movement or talking during demonstrations. Noise can be distracting in the laboratory. For observation purposes, all learners have to be focused on the demonstration without distraction. On the other side a teacher can allow a discussion during demonstrations to get a general understanding from learners.

Item 10: In the absence of resources, I normally use alternative improvised resources.

Forty-nine percent of teachers indicated that they use improvised resources in cases where there are no resources. It remains a challenge for schools to find innovative ways of doing demonstrations without necessarily going into the laboratory or using expensive resources (Section 4.9.5).

Item 11: Learners enjoy demonstrations

Playing is a part that is crucial for learners' growth and the learning process. It is essential to have learning organized in such a way that it is fun, for example, forming a rainbow from a light ray. In this item 68% reported that learners do enjoy demonstrations.

Item 12: Demonstrations waste time

This item was included to test teachers' attitude towards demonstrations as a teaching-learning technique. It is encouraging to the science society that 52% of teachers have a positive attitude towards demonstrations in natural science.

Item 13: I always pause during demonstrations to allow for learners to discuss

Allowing learners to reflect on their thinking process is critical to the process of learning. It is important to allow learners to reflect on what they observe and learn during a demonstration in process. However, the result shows that 62% of teachers allow for a pause during demonstrations for learners to reflect and discuss.

Item 14: Our school has sufficient resources in the laboratory to carry out demonstrations

Only 44% of the teachers agree that schools have sufficient resources in the laboratory to carry out demonstrations. This item reveals that schools do not have adequate resources to deal with the challenge of imparting skills to the learners.

Item 15: I encourage learners to predict results of a demonstration.

70% of teachers agree that they encourage learners to predict results of demonstrations. This item is linked to item 5 and item 6. In all cases, there is consistency in terms of how teachers handle learning outcomes. Teachers who participated in the study do not seem to encourage informing learners of outcomes that drive a learning activity. Such an approach deprives learners of a motivation for learning as discussed in section 4.4.

Item 16: <u>I do demonstrations before the actual teaching</u>

The purpose of this item was to probe teachers' knowledge of the kinds of demonstrations available. The same intention was demonstrated in item 24. 47% of teachers indicated that they do demonstrations before the actual teaching.

Item 17: <u>Doing demonstrations is a financially costly exercise</u>

Cost has been associated with demonstrations and maintaining the laboratory. This report reveals that 54% teachers support the statement that demonstrations are generally costly (see section 4.5)

Item 18: <u>I am well trained to handle demonstrations</u>

This item was intended to respond to the objectives as spelled out in section 1.2.2. Teachers indicated that they are not adequately trained to handle demonstrations. Only 44% of those who participated in the study feel that they are well trained to handle demonstrations. This view by teachers can undermine teacher confidence in the teaching of natural sciences.

Item 19: <u>Achieving outcomes through demonstrations is guaranteed</u>

53% of teachers indicated that they achieve outcomes intended for, by demonstrations. These teachers imply that demonstrations can be used as a teaching tool to achieve learning outcomes.

Item 20: <u>I prefer doing a spectacular experiment before I teach</u>

61% of teachers report that they prefer to do a spectacular experiment before they teach. The purpose of this item was to confirm the use of demonstrations by teachers (Section 4.9). Do teachers feel that demonstrations are better suited before, during or after instruction? In terms of this report teachers use demonstrations mainly after they have taught a particular concept.

Item 21: Demonstrations are better suited to summarise the lesson

72% of teachers state that demonstrations are better suited to summarise the lesson. To these teachers, a better place for demonstrations is after instruction.

Item 22: Learners are encouraged to record their predictions before the actual demonstration

76% of teachers indicated that they encourage their learners to record their predictions before doing the actual demonstration. The difference is that in item 5 learners are requested to discuss, whereas in item 22 learners are requested to make a record. From the teachers' report, it seems as if learners are more comfortable with writing than verbally expressing their views (Section 4.8.1).

Item 23: Our school has electricity, which makes demonstrations very easy

Most laboratory work requires lighting, which is propelled by electricity. This item was intended to reflect progress made in electrifying our schools. 75% of teachers indicated that their schools have electricity, which makes demonstrations very easy (Section 3.6.3).

Item 24: It is always good to teach before doing demonstrations

In this item, 81% of teachers indicated that it is good to teach before doing demonstrations

Item 25: I sometimes speak during demonstrations

78% of the teachers indicated that they speak during demonstrations. Speaking assist in directing observers/learners towards vital points intended by the demonstrations (Section 4.8.1).

Item 26: Not all demonstrations are expensive

For this item, the researcher chose to reveal all the statistical results for the item. 59% of teachers agree that not all demonstrations are expensive, 22% are not sure and 19% disagree with the item.
It is interesting to note that 22% of teachers are not sure if demonstrations are expensive or not. Do teachers really know what demonstrations are? This item reveals that cost may be a limiting factor for schools to conduct demonstrations.

Item 27: Learners are encouraged to discuss their predictions before the actual demonstrations.

Good demonstrations should have a problem statement (Section 4.5). To promote learners' participation, a teacher can ask them a simple question like "what do you think will happen...?" In this way, a teacher can get feedback of the level of understanding and on misconceptions held by learners if any. In this item, 58% report that they encourage their learners to discuss their predictions before the actual demonstrations.

Item 28: I carry out at least one demonstration in a week

To determine the frequency of the demonstrations in natural science, item 28 was included in the questionnaire. 47% of teachers indicate that they carry out at least one demonstration in a week. Because for this question a motivation was allowed, general excuses for not doing demonstrations are time constrain and lack of resources.

Item 29: Demonstrations are necessary to teach scientific work

Teachers agree that demonstrations are necessary as the medium for teaching scientific skills. 71% of teachers support this statement.

Item 30: I understand demonstrations

This item was included, with a space for motivation to determine teachers' knowledge of and insight into demonstrations. 72% of teachers indicated that they know what demonstrations are. A motivation was given by asking, "What is demonstration". Teachers' responses indicated exactly what a demonstration is in their own words (see section 6.4).

Item 31: Demonstrations are effective in the teaching of natural science

76% of teachers who took part in the study agree with this statement. It seems as if there is a general appreciation for the value of demonstrations in natural science.

Item 32: A good demonstration lasts for a few minutes or more

67% of the teachers in the study indicated that a good demonstration could last for a few minutes. This item was intended to evaluate the time constrain in the implementation of demonstrations.

Relationships between variables

A practical significant relationship between professional rating and the use of demonstrations were found.

P_rating	Q28 1	Q28 2	Q28 3	Q28 4	Q28 5	Row Totals
2-Way Summary Table: Observed Frequencies (Motsh Marked cells have counts > 4 Exclude condition: v7=1 or v7=6						
2	0	1	2	0	0	3
Row %	0.00%	33.33%	66.67%	0.00%	0.00%	
3	5	8	3	4	10	30
Row %	16.67%	26.67%	10.00%	13.33%	33.33%	
4	10	6	8	4	5	33
Row %	30.30%	18.18%	24.24%	12.12%	15.15%	
5	2	3	3	2	1	11
Row %	18.18%	27.27%	27.27%	18.18%	9.09%	
Totals	17	18	16	10	16	77

Statistic	Chi-square	df	p
	Statistics: P_rating(4) x Q28(5) (Motsh Exclude condition: v7=1 or v7=6		
Pearson Chi-square	12.76183	df=12	p=.38660
M-L Chi-square	13.48821	df=12	p=.33459
Phi	.4071093		
Contingency coefficient	.3770601		
Cramér's V	.2350447		

Table 6.2 The relationship between professional rating and the use of demonstrations

Table 6.3 shows the relationship between professional rating and teachers who do demonstrations. The effect size for this relationship is w = 0.41 and might indicate practical significance. This further implies that teachers with more background in science tend to do demonstrations more often than those who just possess a teachers' diploma.

6.5. Results from the qualitative part of the questionnaire

The other part of the objectives (see Section 2.2) was to provide responses from teachers on how they define the concept " demonstrations". It is imperative that the researcher should present at least few of their responses to item (30) on the questionnaire.

Demonstration(s) is / are :

- Is to do practical and to give evidence.
- It is a practical investigation.
- It is a showing to learners on steps of responding to scientific processes
- Doing something practical to get evidence.
- Showing practically the evidence of the concept that you are teaching by using experiments or teaching aids.

These quotes above reflect the teachers' knowledge of the concept. This presentation was necessary to respond to section 1.2.2 on research objectives. From these quotes and guided by discussions in chapter 4 on the definition of demonstrations, the researcher can conclude that there is a fair understanding of what demonstrations are.

From the observations made during the analysis of the results, it is evident that natural science teachers are still encountering problems with how to handle demonstrations as a teaching-learning technique. These problems are as a result of the lack of laboratory funding, level of training and time allocation for practical work. This finding is consistent with the requirements of section 1.2.2. Most of the teachers apply demonstrations strictly after teaching. Responses to question 21 on the questionnaire show that cumulatively 72% of teachers use demonstrations as a means to summarise their lessons.

The literature study confirms that demonstrations are a good teaching tool in the hands of the teacher (see Section 4) to enhance understanding. To effectively sustain the implementation of Outcomes-based model of education, there must be continuous in-service training of teachers for purposes of guidance and support. From the analysis of results, resounding 39% states that they do not feel adequately trained to handle demonstrations with 16% of teachers stating that they are not sure of the level of their training. Only 44 % of teachers believe that they can handle the challenge of implementing demonstrations.

6.6. Conclusions from teachers' questionnaires

The empirical results drawn from the responses of teachers indicate that demonstrations as a teaching-learning technique in natural science can be used to provide insight into the most appropriate way of implementing demonstrations within a classroom situation. This study involved teachers working with both large and small number of classes. There remains therefore, a great deal of variations between individual teachers' teaching situations that this study had not been able to take into account.

A positive feature that emerges from this study is that there is enthusiasm from the side of teachers to participate in research activities and this energy can be used to begin science study groups and in-service training for teachers who still have conceptual difficulty in understanding the concept of demonstrations.

6.7. Interviews : teacher responses

Interviews were carried out with ten teachers who took part in the study. Each was interviewed individually and then a group discussion was held with 54 teachers. This was done to establish general knowledge around demonstrations. In terms of the Outcomes-Based Education model, the role of the teacher is that of a facilitator and classroom manager. Teachers were asked if the textbooks that they were using are responsible to the teaching of science through demonstrations.

80% of those interviewed agree that the learner support material was related to the teaching of science topics they had studied. This is not to purport that there are no challenges posed by the current textbooks. It seems as if most respondents are quite enthusiastic about the textbooks that they are using because they point out what activities needs to be demonstrated by teachers and those that have to be done by learners.

Teachers are not informed about the benefits of demonstrations as a teaching-learning technique. Many teachers use demonstrations for descriptive purposes only. See appendix 1, question 34 and 35. When requested to supply the kinds of demonstrations, almost all responded with illustrative demonstrations. Their views reflect and limit the use of demonstrations to an expensive laboratory. For these teachers, a demonstration can only be done by the teacher in the laboratory and only then allow learners to experiment with what the teacher has shown. In as much as this assertion is true, there are other scenarios where a teacher can just do a demonstration to a large audience. This thinking shows that it is vital to teach learners the scientific way of doing science. This approach requires methods that are acceptable and the necessary scientific skills (Van der Linde *et al.*, 1994:50)

6.8. Conclusions

This chapter presented a detailed analysis of data collected from teachers through the use of a questionnaire and between the researcher and the subjects of the study. Results from the data analysis and necessary discussions were put in detail. The next chapter presents challenges faced during this study and provides recommendations that will aid further research on the topic.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1. Introduction

The purpose of this chapter is to present the concluding remarks and recommendations of the study. These remarks and recommendations are based on the research hypothesis and objectives of the study. This chapter will firstly refocus the reader to how the chapters evolved and then provide recommendations for further research as provided for from this study.

7.2. Summary of chapters

The objectives of this study are outlined in section1.2.2. The intention of this study was to probe into the teachers' knowledge of and insight into demonstrations as a teaching-learning technique. The function of the introductory chapter was to introduce the reader to the topic, to outline what previous work was done on the topic, what kind of problems were encountered and why these specific problems were considered for research. To this end, the problem statement and the rationale for undertaking this research are outlined in chapter 1.

Chapter 2 and 3 were used to form the literature sections of the report and contain the theoretical content that is essential for understanding this project. This literature was based on the recommendations of other researches. Chapter 2 in particular provides detailed information that can aid teachers to understand the fundamental knowledge about the nature of natural sciences.

Chapter 4 forms the core of the research since it outlines the major factors around demonstrations as a teaching-learning technique. It gives a scientific basis for evaluating objectives as set out in section 1.6. The perspective adopted for presenting demonstrations is that of a constructivist perspective. A demonstration as a concept is defined in detail in section 4.2, Section 4.7 and 4.8 provide functions of demonstrations in a science classroom.

Chapter 5 gives a clear explanation of the methodology employed in this study and how it was used to find possible answers to the problems posed by this study. Chapter 5 provided a detailed description of the components of the methodology that is the nature, applicability, strength and weaknesses, validity and the population used in the research as a field of study.

Chapter 6 was reserved for data analysis and discussions. The data captured is presented in tables to indicate teachers' responses, which were accordingly subjected to interpretation and consideration through scientific practices. This chapter reflected the overall results of the study.

Chapter 7 review the aims and the objectives, which provided the basis for undertaking this research project. Guided by the findings in chapter 6, this chapter provide recommendations to add more information for the expansion of the teaching of natural science throughout the country.

7.3. Challenges

In as much as sufficient caution was taken to divorce the researcher from actual participation in the study, the temptation was overwhelming. It was a worthwhile challenge to conduct matters of this research so that the technical methods employed in this project were conscious instrumentalities of realizing the meaning of knowledge.

For teachers, the problem of turning a classroom into a pseudo-laboratory, and then proceeding to turn it into an intellectual account is more pressing than that of using a mere textbook to teach scientific concepts. Teachers themselves are under tremendous pressure to become scientists in a schooling system.

Time taken to conduct this research was in itself a great challenge. This research was done during times when schools were busy with other pre-examination programmes, which might have deprived the teachers sufficient time to be genuine with their responses. The most challenging aspect of this research was that it was carried also in a turbulent period of teacher transfers as a result of Resolution 2 of 2003, which was rationalizing the institutions through teacher transfers (redeployment).

7.4. Conclusions based on empirical study

7.4.1. Demonstrations as a teaching-learning technique

7.4.1.1. Conceptual challenge

The empirical results drawn from the responses of teachers indicate that demonstrations as a teaching-learning technique can positively influence learning. The literature review in chapter 4, shows many benefits of the demonstration as a teaching technique, yet teachers still have conceptual difficulties with demonstrations.

7.4.1.2. Hypothesis

With a value of d = 0,8 which reflects a large effect, the researcher can report that demonstrations can be considered an effective teaching-learning technique. The hypothesis of the study is valid (see section1.3 and section 6.6).

7.4.1.3. Implementation

Teachers are still facing problems on how to implement demonstrations as a teaching-learning technique in a classroom. Teachers perceive demonstrations as good for review purposes, yet there are many uses of demonstrations that can be applied in a classroom. This shows that teachers are not aware of the benefits that are associated with the use of demonstrations as a teaching-learning technique (See appendix 1, question 34 and 35). When requested to supply the kinds of demonstrations, their responses were illustrative and descriptive demonstrations. These views reflect and limit the teachers' use of demonstrations into an expensive laboratory. For these teachers, a demonstration can only be done by the teacher in the laboratory for learners to copy what the teacher does and then allow learners to experiment what the teacher has shown already. The implication is that teachers do not have the scientific skills to use demonstrations as a teaching-learning technique. This approach requires methods that are acceptable to science and the necessary scientific skills, (Van der Linde et al., 1994:50)

7.5. Conclusion

This study indicates that teachers believe that demonstrations still have an important role to play in the learning of natural science. Most respondents support literature findings that demonstrations are still a powerful method to bring about a favourable change in attitude (Du Toit, *et al.*, 1992). Teachers who participated in this survey show that in the South African context demonstrations can still offer greater benefits if well understood and implemented. Demonstrations as a teaching and learning technique must be put very high on the agenda of in-service teacher training. Consumers of the education system and the education department should support the efforts geared at promoting teaching in the South African context. This can be successfully implemented if pre-service and in-service training centres are empowered financially and time is allocated for the implementation of these programmes. Through a closer co-operation among schools and science teachers, the teaching of science can be improved to find a competitive space in the international arena.

The important aspect of measuring the effectiveness of and the knowledge that teachers possess in demonstrations is for them to make the informed choice about which teaching method to adapt, certain conditions must prevail. There must be a full knowledge about various methods available and where they are best suited. That aspect of the research has not been exposed to this study. In fact, the teachers' responses to the questionnaires shows a lack of knowledge about various kinds of demonstrations.

Teachers pointed out that the time allocated for practical work within the school timetable is not sufficient. It is therefore difficult to report on the performance of teachers in terms of their practical, communicative and recording skills. These factors could be subjected to further research.

7.6. Recommendations

- Additional work is needed to explore the limits of this type of a teaching and learning technique, with particular emphasis on its benefits, effectiveness and relevance in an outcomes based model of learning. This information once acquired will substantiate the need for investment into practical work.
- It is further recommended that the in-service programs be expanded as a measure of urgency to assist in ensuring that teachers are brought into

the same wavelength as our international counterparts on using demonstrations as a teaching-learning technique.

- The concept of in-service training, which has been abandoned for so long, needs to be brought closer to schools through clustering of schools to bridge the gap of cost and sustainability. In this way, schools can begin to network among themselves to exchange both knowledge and skills.
- There must be a departmental support in ensuring that all schools have at least a functional laboratory. To respond to the cost values, for a start, schools must consider using small-scale laboratories, which are safer and affordable (See discussions on section 4.5).
- Since most schools do not have internet facilities to access information, the department of education can promote science through teacher written scientific newsletters to inform learners directly of the present developments in natural science.

7.7. Summary

The main focus of this study was to investigate how teachers use demonstrations as a teaching-learning technique in natural sciences, and to give a report on challenges that the teachers face in the use of demonstrations. The study has pointed out the challenges that the teachers face in the implementation of demonstrations within a classroom. In addressing the objectives of section 1.2.2 of this study, recommendations were made to provide for improvements in the use of demonstrations within the classroom. The conclusion is that teachers have difficulties in the implementation of demonstrations as a teaching-learning technique in natural science.

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APPENDIX 1

EDUCATOR'S PERSONAL INFORMATION

1. Name of your school ....
2. Grade currently teaching

   Grade 6 ☐ Grade 7 ☐ Grade 8 ☐ Grade 9 ☐
3. What are your highest qualifications ....
4. a) No. of years as a science teacher ....

   b) Gender...
5. a) Are you currently involved in further studies? Yes ☐ No ☐

   b) In response to your answer above, what is your field of study?

   ....
6. Rate your professional qualification in terms of M+.

   M+ 2 ☐ M+3 ☐ M+4 ☐ M+5 ☐ M+6 ☐ M+7 ☐
7. Highest qualification in Natural Sciences (Chemistry or Physics).

   UDES ☐ H.E.D / ACE ☐ BSc ☐ Hons.BSc ☐ MSc ☐ PhD ☐

   Hons.Bed ☐ M.Ed ☐ D.Ed ☐

EDUCATOR'S QUESTIONAIRE

Carefully read the following statements and respond by marking with an (x) in the appropriate number that best describe your situation.

Key				
Strongly Agree	Agree	Not Sure	disagree	Strongly Disagree
1	2	3	4	5

1.	Demonstrations are an essential part of Natural Science teaching	1	2	3	4	5
2.	Demonstrations are very easy to carry out	1	2	3	4	5
3.	Our school allocates sufficient time for practical sessions	1	2	3	4	5
4.	Preparing for demonstrations takes a very long time	1	2	3	4	5
5.	I discuss the outcomes of the demonstrations with learners beforehand	1	2	3	4	5
6.	It is good to start demonstrations with a problem statement	1	2	3	4	5
7.	Before doing demonstrations in class, I test if the apparatus are in good working conditions	1	2	3	4	5
8.	During demonstrations, I allow learners to touch the apparatus	1	2	3	4	5
9.	No learner is allowed to move or talk as I demonstrate	1	2	3	4	5
10.	In the absence of resources, I normally use alternative improvised resources	1	2	3	4	5
11.	Learners enjoy doing demonstrations	1	2	3	4	5
12.	Demonstrations waste time	1	2	3	4	5
13.	I always pause during demonstrations to allow for learners to discuss	1	2	3	4	5
14.	Our school has sufficient resources in the laboratory to carry out demonstrations	1	2	3	4	5
15.	I encourage learners to predict the results of a demonstration.	1	2	3	4	5
16.	I do demonstrations before the actual teaching	1	2	3	4	5
17.	Doing demonstrations is a financially costly exercise	1	2	3	4	5
18.	I am well trained to handle demonstrations	1	2	3	4	5
19.	Achieving outcomes through demonstrations is guaranteed	1	2	3	4	5

20.	I prefer doing a "spectacular" experiment before I teach	1	2	3	4	5
21.	Demonstrations are better suited to summarise the lesson	1	2	3	4	5
22.	Learners are encouraged to record their predictions before the actual demonstration	1	2	3	4	5

Motivate...
....
....

23.	Our school has electricity which makes demonstrations very easy	1	2	3	4	5

Motivate...
....

24.	It is always good to teach before doing demonstration	1	2	3	4	5

Motivate...
....

25.	I sometimes speak during demonstrations	1	2	3	4	5

Motivate...
....

26.	Not all demonstrations are expensive	1	2	3	4	5

Example..
....

27.	Learners are encouraged to discuss their predictions before the actual	1	2	3	4	5

Motivate..

....

28.	I carry out at least one demonstration in a week	1	2	3	4	5

Motivate..

....

....

29.	Demonstrations are necessary to teach skills in Natural Science	1	2	3	4	5

Motivate..

....

....

30.	I understand demonstrations	1	2	3	4	5

What is demonstrations..

....

....

31.	Demonstrations are effective in the teaching of Natural Science	1	2	3	4	5

Motivate..

....

....

32.	A good demonstration lasts few minutes or more	1	2	3	4	5

Motivate..

....

....

33. Give as many advantages as you can on the benefits associated with the use of demonstrations.

....

....

....

34. Name the kinds of demonstrations that you know.

....

....

....

35. When are demonstrations suited for teaching. Before or after instruction?

....

....

....

36. What is the length of your average demonstration?

....

....

....

37. In your own words define demonstrations.

....

....

....

38. Did you study / train to do demonstrations at college / university? Give the kind of experience.

....

....

....

APPENDIX 2

Category	Frequency table: Grade (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	4	4	5.06329	5.0633
2	10	14	12.65823	17.7215
3	23	37	29.11392	46.8354
4	42	79	53.16456	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Qualify (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
HED	8	8	10.12658	10.1266
UDES	15	23	18.98734	29.1139
BA HONS	4	27	5.06329	34.1772
ACE	14	41	17.72152	51.8987
HONS BED	10	51	12.65823	64.5570
JPTD	1	52	1.26582	65.8228
BSC	8	60	10.12658	75.9494
DSP	1	61	1.26582	77.2152
B-TECH	1	62	1.26582	78.4810
BTECH	1	63	1.26582	79.7468
UDEP	4	67	5.06329	84.8101
FDE	1	68	1.26582	86.0759
STP	2	70	2.53165	88.6076
PTD	3	73	3.79747	92.4051

Category	Frequency table: Gender (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
M	33	33	41.77215	41.7722
F	46	79	58.22785	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Studies (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	30	30	37.97468	37.9747
2	49	79	62.02532	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: P_rating (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	1	1	1.26582	1.2658
2	3	4	3.79747	5.0633
3	30	34	37.97468	43.0380
4	33	67	41.77215	84.8101
5	11	78	13.92405	98.7342
6	1	79	1.26582	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q_NS (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	34	34	43.03797	43.0380
2	25	59	31.64557	74.6835
3	11	70	13.92405	88.6076
4	8	78	10.12658	98.7342
5	1	79	1.26582	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q1 (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	51	51	64.55696	64.5570
2	23	74	29.11392	93.6709
3	4	78	5.06329	98.7342
4	1	79	1.26582	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q2 (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	8	8	10.12658	10.1266
2	29	37	36.70886	46.8354
3	18	55	22.78481	69.6203
4	10	65	12.65823	82.2785
5	14	79	17.72152	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q3 (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	10	10	12.65823	12.6582
2	16	26	20.25316	32.9114
3	13	39	16.45570	49.3671
4	20	59	25.31646	74.6835
5	20	79	25.31646	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q4 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	18	18	22.78481	22.7848
2	23	41	29.11392	51.8987
3	13	54	16.45570	68.3544
4	24	78	30.37975	98.7342
5	1	79	1.26582	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q5 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	31	31	39.24051	39.2405
2	25	56	31.64557	70.8861
3	7	63	8.86076	79.7468
4	6	69	7.59494	87.3418
5	10	79	12.65823	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q6 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	40	40	50.63291	50.6329
2	21	61	26.58228	77.2152
3	9	70	11.39241	88.6076
4	6	76	7.59494	96.2025
5	3	79	3.79747	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q7 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	46	46	58.22785	58.2278
2	19	65	24.05063	82.2785
3	5	70	6.32911	88.6076
4	5	75	6.32911	94.9367
5	4	79	5.06329	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q8 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	28	28	35.44304	35.4430
2	30	58	37.97468	73.4177
3	8	66	10.12658	83.5443
4	7	73	8.86076	92.4051
5	6	79	7.59494	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q9 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	17	17	21.51899	21.5190
2	25	42	31.64557	53.1646
3	9	51	11.39241	64.5570
4	16	67	20.25316	84.8101
5	12	79	15.18987	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q10 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	12	12	15.18987	15.1899
2	27	39	34.17722	49.3671
3	21	60	26.58228	75.9494
4	8	68	10.12658	86.0759
5	10	78	12.65823	98.7342
6	1	79	1.26582	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q11 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	33	33	41.77215	41.7722
2	21	54	26.58228	68.3544
3	9	63	11.39241	79.7468
4	8	71	10.12658	89.8734
5	8	79	10.12658	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q12 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	13	13	16.45570	16.4557
2	17	30	21.51899	37.9747
3	8	38	10.12658	48.1013
4	17	55	21.51899	69.6203
5	24	79	30.37975	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q13 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	21	21	26.58228	26.5823
2	28	49	35.44304	62.0253
3	9	58	11.39241	73.4177
4	12	70	15.18987	88.6076
5	9	79	11.39241	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q14 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	5	5	6.32911	6.3291
2	30	35	37.97468	44.3038
3	10	45	12.65823	56.9620
4	17	62	21.51899	78.4810
5	17	79	21.51899	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q15 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	22	22	27.84810	27.8481
2	33	55	41.77215	69.6203
3	12	67	15.18987	84.8101
4	7	74	8.86076	93.6709
5	5	79	6.32911	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q16 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	14	14	17.72152	17.7215
2	23	37	29.11392	46.8354
3	10	47	12.65823	59.4937
4	15	62	18.98734	78.4810
5	16	78	20.25316	98.7342
23	1	79	1.26582	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q17 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	20	20	25.31646	25.3165
2	23	43	29.11392	54.4304
3	16	59	20.25316	74.6835
4	6	65	7.59494	82.2785
5	13	78	16.45570	98.7342
23	1	79	1.26582	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q18 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	12	12	15.18987	15.1899
2	23	35	29.11392	44.3038
3	13	48	16.45570	60.7595
4	17	65	21.51899	82.2785
5	14	79	17.72152	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q19 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	13	13	16.45570	16.4557
2	29	42	36.70886	53.1646
3	21	63	26.58228	79.7468
4	4	67	5.06329	84.8101
5	12	79	15.18987	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q20 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	18	18	22.78481	22.7848
2	30	48	37.97468	60.7595
3	11	59	13.92405	74.6835
4	6	65	7.59494	82.2785
5	14	79	17.72152	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q21 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	23	23	29.11392	29.1139
2	34	57	43.03797	72.1519
3	9	66	11.39241	83.5443
4	6	72	7.59494	91.1392
5	7	79	8.86076	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q22 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	32	32	40.50633	40.5063
2	28	60	35.44304	75.9494
3	9	69	11.39241	87.3418
4	7	76	8.86076	96.2025
5	3	79	3.79747	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q23 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	32	32	40.50633	40.5063
2	27	59	34.17722	74.6835
3	4	63	5.06329	79.7468
4	12	75	15.18987	94.9367
5	4	79	5.06329	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q24 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	37	37	46.83544	46.8354
2	27	64	34.17722	81.0127
3	8	72	10.12658	91.1392
4	7	79	8.86076	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q25 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	25	25	31.64557	31.6456
2	37	62	46.83544	78.4810
3	7	69	8.86076	87.3418
4	3	72	3.79747	91.1392
5	7	79	8.86076	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q26 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	21	21	26.58228	26.5823
2	26	47	32.91139	59.4937
3	17	64	21.51899	81.0127
4	5	69	6.32911	87.3418
5	10	79	12.65823	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q27 (MotshoaneJ)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	24	24	30.37975	30.3797
2	22	46	27.84810	58.2278
3	13	59	16.45570	74.6835
4	18	77	22.78481	97.4684
5	2	79	2.53165	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q28 (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	17	17	21.51899	21.5190
2	20	37	25.31646	46.8354
3	16	53	20.25316	67.0886
4	10	63	12.65823	79.7468
5	16	79	20.25316	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q29 (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	33	33	41.77215	41.7722
2	23	56	29.11392	70.8861
3	15	71	18.98734	89.8734
4	4	75	5.06329	94.9367
5	3	78	3.79747	98.7342
23	1	79	1.26582	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q30 (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	28	28	35.44304	35.4430
2	29	57	36.70886	72.1519
3	19	76	24.05063	96.2025
4	2	78	2.53165	98.7342
22	1	79	1.26582	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q31 (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	27	27	34.17722	34.1772
2	33	60	41.77215	75.9494
3	10	70	12.65823	88.6076
4	6	76	7.59494	96.2025
5	3	79	3.79747	100.0000
Missing	0	79	0.00000	100.0000

Category	Frequency table: Q32 (MotshoaneJ) Count	Cumulative Count	Percent	Cumulative Percent
1	17	17	21.51899	21.5190
2	36	53	45.56962	67.0886
3	8	61	10.12658	77.2152
4	8	69	10.12658	87.3418
5	10	79	12.65823	100.0000
Missing	0	79	0.00000	100.0000

Variable	Descriptive Statistics (MotshoaneJ)									
	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Percentile 33.33000	Percentile 66.67000	Std.Dev.
Years	79	9.860759	8.000000	2.000000	26.00000	6.000000	13.00000	7.000000	11.00000	5.256825
Q1	79	1.430380	1.000000	1.000000	4.00000	1.000000	2.00000	1.000000	2.00000	0.654051
Q2	79	2.911392	3.000000	1.000000	5.00000	2.000000	4.00000	2.000000	3.00000	1.272892
Q3	79	3.303797	4.000000	1.000000	5.00000	2.000000	5.00000	3.000000	4.00000	1.380769
Q4	79	2.582278	2.000000	1.000000	5.00000	2.000000	4.00000	2.000000	3.00000	1.183298
Q5	79	2.227848	2.000000	1.000000	5.00000	1.000000	3.00000	1.000000	2.00000	1.377003
Q6	79	1.873418	1.000000	1.000000	5.00000	1.000000	2.00000	1.000000	2.00000	1.125088
Q7	79	1.759494	1.000000	1.000000	5.00000	1.000000	2.00000	1.000000	2.00000	1.145954
Q8	79	2.151899	2.000000	1.000000	5.00000	1.000000	3.00000	1.000000	2.00000	1.220431
Q9	79	2.759494	2.000000	1.000000	5.00000	2.000000	4.00000	2.000000	4.00000	1.397940
Q10	79	2.746835	3.000000	1.000000	6.00000	2.000000	3.00000	2.000000	3.00000	1.275693
Q11	79	2.202532	2.000000	1.000000	5.00000	1.000000	3.00000	1.000000	2.00000	1.352867
Q12	79	3.278481	4.000000	1.000000	5.00000	2.000000	5.00000	2.000000	4.00000	1.501595
Q13	79	2.493671	2.000000	1.000000	5.00000	1.000000	4.00000	2.000000	3.00000	1.338516
Q14	79	3.139241	3.000000	1.000000	5.00000	2.000000	4.00000	2.000000	4.00000	1.308103
Q15	79	2.240506	2.000000	1.000000	5.00000	1.000000	3.00000	2.000000	2.00000	1.145954
Q16	79	3.202532	3.000000	1.000000	23.00000	2.000000	4.00000	2.000000	4.00000	2.666890
Q17	79	2.860759	2.000000	1.000000	23.00000	1.000000	4.00000	2.000000	3.00000	2.678184
Q18	79	2.974684	3.000000	1.000000	5.00000	2.000000	4.00000	2.000000	4.00000	1.358494
Q19	79	2.658228	2.000000	1.000000	5.00000	2.000000	3.00000	2.000000	3.00000	1.259691
Q20	79	2.594937	2.000000	1.000000	5.00000	2.000000	4.00000	2.000000	3.00000	1.391540
Q21	79	2.240506	2.000000	1.000000	5.00000	1.000000	3.00000	2.000000	2.00000	1.211221
Q22	79	2.000000	2.000000	1.000000	5.00000	1.000000	2.00000	1.000000	2.00000	1.109400
Q23	79	2.101266	2.000000	1.000000	5.00000	1.000000	3.00000	1.000000	2.00000	1.236153
Q24	79	1.810127	2.000000	1.000000	4.00000	1.000000	2.00000	1.000000	2.00000	0.948358
Q25	79	2.113924	2.000000	1.000000	5.00000	1.000000	2.00000	2.000000	2.00000	1.165611
Q26	79	2.455696	2.000000	1.000000	5.00000	1.000000	3.00000	2.000000	3.00000	1.298890
Q27	79	2.392405	2.000000	1.000000	5.00000	1.000000	4.00000	2.000000	3.00000	1.213363
Q28	79	2.848101	3.000000	1.000000	5.00000	2.000000	4.00000	2.000000	3.00000	1.433023
Q29	79	2.253165	2.000000	1.000000	23.00000	1.000000	3.00000	1.000000	2.00000	2.599153
Q30	79	2.189873	2.000000	1.000000	22.00000	1.000000	3.00000	1.000000	2.00000	2.407658
Q31	79	2.050633	2.000000	1.000000	5.00000	1.000000	2.00000	1.000000	2.00000	1.060947
Q32	79	2.468354	2.000000	1.000000	5.00000	2.000000	3.00000	2.000000	2.00000	1.289359