THE ROLE OF DEMONSTRATIONS IN THE TEACHING AND LEARNING OF NATURAL SCIENCE

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ABSTRACT

The new political dispensation in South Africa has brought with it a daunting task in educational development. The teaching and learning of Physical Science at high school level has continued to challenge educators. The quest for science teaching and learning that enhances conceptual development and hence understanding in Physical Science is continuing to be of great importance.

This study was intended to probe and elicit problems encountered by educators in the teaching of Physical Science grade 12. Central to the problem is the perception held by educators about lecture demonstrations. Educators use lecture demonstrations as a means to prove existing scientific theories and not as a means to fulfil the constructivist nature of the approach.

The aim of the study was to give a global view on the role that lecture demonstrations play in the teaching and learning of Physical Science in grade 12. The study was conducted with the aid of learners (N = 109) and educators (N = 20) of schools that are in and around the Potchefstroom district. The investigation was administered by means of a questionnaire to educators and learners as well as a pre- and a post-test to the latter. The results were used to analyse the role lecture demonstrations play in the conceptual development of grade 12 learners.

SUMMARY

The study intends to probe into educators' strategies in conducting science demonstrations in their classes. The problem statement and motivation is outlined in *chapter 1*.

Lack of understanding of how physical science should be taught is associated with educators' poor knowledge of the nature of physics and chemistry. To address this problem the essential features (framework structures) of what physics and chemistry constitute are discussed in detail in *chapter 2*.

In *chapter 3* the curriculum reform in the teaching of physical science is discussed. *Chapter 4* outlines lecture demonstrations as a constructivist teaching strategy in physical science. The chapter covers, essentially, the pre-requisite for a teaching strategy that will enhance conceptual change and development, by firstly defining what the concepts are.

The results of the empirical survey and the discussions thereof are given in *chapter 6*. *Chapter 7* reviews the aim, objectives, hypothesis and the findings of the study and concludes by making the recommendations on how to, with special reference to lecture demonstrations, expand teaching for conceptual change and development in physical science in South Africa.

OPSOMMING

Die doel van die studie is om die onderrig-strategieë wat gebruik word in die aanbieding van demonstrasies in Natuur- en Skeikunde lesings, te peil. Die probleemstelling en motivering word in *hoofstuk 1* in breë trekke bespreek.

Oneffektiewe onderrig van Natuur- en Skeikunde hou direk verband met onderwysers se gebrek aan kennis van die aard van Fisika en Chemie. Die basiese einskappe en struktuur (grondtrekke) waar uit Fisika en Chemie bestaan, word in *hoosftuk 2* bespreek.

Die herskikking van die kurrikulum vir die onderrig van Natuur- en Skeikunde word in *hoofstuk 3* bespreek. *Hoofstuk 4* gee 'n oorsig van demonstrasies tydens lesings as 'n konstruktiewe onderrigmetode in Natuur- en Skeikunde. Die hoofstuk dek hoofsaklik die vereistes wat nodig is om konseptuele veranderinge en die ontwikkeling van onderrig-strategieë te bevorder.

Die resultate van die empirisie ondersoek en bespreking daarvan word in *hoofstuk 6* gegee. *Hoofstuk 7* is 'n samevatting van die doelstelling, hipotese en bevindinge van die studie en sluit af met aanbevelings oor hoe om onderrig aan te pas by die konseptuele verandering en ontwikkeling in die onderrig van Natuur- en Skeikunde in Suid Afrika, met spesifieke verwysing na demonstrasies tydens lesings.

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CHAPTER 1

ORIENTATIVE INTRODUCTION

1.1. PROBLEM STATEMENT AND LITERATURE REVIEW

Despite extensive research on science teaching and educators' development, a gap between the theories, strategies and techniques of teaching and learning continues to exist. As alluded by Roth and Tobin (2001: 746), this gap is most dramatic when considered on a yearly basis. It is experienced by novice science teachers who find out that what they have learned in their university classes do not adequately prepare them for teaching.

Continuous reflection on the process of effective teaching that leads to successful concept formation and the context in which it unfolds, is believed to be an essential ingredient in the development of constructive science teaching. It is widely believed that Natural Science is an experimental discipline, yet it is taught in many classrooms without any means of practical work. According to Bradley *et al.* (1998: 1406) it is interesting to note that the same teachers who do not perform demonstrations in their classes are the ones who vividly say practical work is an integral part of the teaching of physical science.

A reason why concept formation is not enhanced in the teaching and learning of Physical Science is the fact that learners hold alternative conceptions, which they bring to the science class (Stanton, 1989: 7; Driver *et al.* 1985: 3; Gunstone, 1991: 66 & Driver, 1983: 3). The other factor is associated with inappropriate teaching techniques and styles as indicated by Webb (1992: 423). The latter reason as outlined by Van der Linde *et al.* (1994: 48) is related to a lack of exposure to practical work.

Practical work, as described by Van der Linde *et al.* (1994: 49) includes all types of investigations or experimentation by learners on their own or in groups, as well as *demonstrations by teachers.* The intention of this study is to focus on demonstrations.

This study aims to thoroughly investigate the role played by teacher demonstrations in the teaching and learning of Natural Science. Specific attention will be on physics demonstrations.

Since research has shown that a substantial percentage of high school and first year college/university learners are not formal thinkers (Cantu & Herron, 1978: 136), it follows that many learners are unlikely to learn abstract concepts meaningfully. In view of the number and variety of abstract concepts encountered in Natural Science, the learning difficulties inherent in those concepts, and the fact that most learners function at the concrete-operational level, the question is: "*which instructional model is appropriate to enhance learning gain or conceptualization in physical science?*" (Cantu & Herron, 1978: 136).

Since students on the concrete-operational level, as reflected in the *concrete and formal piagetian stages and science concept attainment,* reason in terms of direct experience, it is expected that by making attributes of abstract concepts directly perceptible, comprehension may be improved. Illustrations, diagrams and models have been used for such purposes for years. However, the relative value of such materials for concrete-operational and formal-operational students has not been explored (Cantu & Herron, 1978: 136). This indicates that demonstrations can be useful for in the realization of conceptual change in the teaching and learning of Natural Science.

1.2. RESEARCH AIMS AND OBJECTIVES

1.2.1. AIM OF THE RESEARCH

The aim of this investigation is to identify the role that demonstrations play in the teaching and learning of Physical Science.

1.2.2. RESEARCH OBJECTIVES

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

(a) To give a brief discussion of the teaching techniques/strategies in the natural sciences with particular reference to teacher demonstrations.

(b) To investigate how educators conduct demonstrations.

(c) To investigate effective way(s) of implementing demonstration work in the classroom.

(d) To determine the effect of demonstrations on conceptual development on the grade 12 physical science learners.

1.3. HYPOTHESIS

The hypothesis of this study is stated as: *Lecture demonstrations in Natural Science enhance conceptual development in grade 12 physical science learners.*

1.4. DESCRIPTION OF TERMS

1.4.1. Demonstration

Under this paragraph a description of the term *demonstration* in the teaching and learning of Natural Science will be given. Vreken (1980: 151) outlines definitions attached to the term demonstration by various researchers.

- "*The demonstration method consists of one person who is conducting the experimental work and the learners watch.*" (Arnold, 1971: 291).
- "*A demonstration is the repetition of a series of planned actions designed to illustrate*

certain phenomena." (Petersen, 1965: 90).

- "*A demonstration is a showing.*" (Thurber, 1965: 129).

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

According to Walters (1974: 66) (quoted by Vreken, 1980: 151), the latter definition creates the assumption that demonstrations are solely used to illustrate something, a phenomenon or a technique to learners whose contribution is limited to listening and observing. However, the principle of observation is not only based on the premise of using senses but most importantly it includes active inner experience. In order to ensure that the expected results with demonstrations are reached, as is intended by this study, it is essential that every learner must be actively involved.

1.4.2. Teaching

"Teaching" is one of the concepts that have received the attention of many educationists and educational psychologists. Consequently, the term has acquired a number of definitions depending on the individual's view-point. For instance, in the context of Christian schooling, John van Dyk *et al.* (1990: 156) defines teaching from a positivistic point of view, as "*a multidimensional formative activity consisting of the three functions of guiding, unfolding and enabling*".

From an ontological - contextual point of view, teaching is defined as "*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, attitude or values*" (Nieuwoudt, 1998: 6).

From the assertion made by the latter definitions, it becomes evident that, one of the participants in the act must assume a guide's role and must have knowledge and skills to enable the other to reach the set goals in the particular trade or field of study (Nieuwoudt, 1998: 5). For the purpose of this study, this definition implies that the participant who is a *guide* and has *knowledge* and *skills,* is the teacher who will be the focus point of the demonstration work in Natural Science. The learner or learners, on the other hand, are the participants who are enabled to attain the preset goals regarding knowledge, skills, attitudes and values. With reference to this study, these preset goals will be equated to conceptualization.

1.4.3. Learning

Like teaching, "learning" has different definitions depending on the particular perspective or viewpoint. A number of theories have been developed to define learning. In the didactical situation, an educator uses various methods and lets learners take ownership of learning. According to De Wet (1971: 113) (quoted by Vreken 1980: 132) the educator and learners in teaching and learning respectively achieve this by means of applying a variety of teaching and learning media.

Vreken (1980: 132) aligns himself with the work done by Mackenzie *et al.* (1970: 46) where learning is defined and categorized by Perlberg and O 'Bryant (1968) as a dynamic and interactive process in which:

- The role and experience of the learner are vital components in which he should contribute as well as receive.

- The learner's perception of what is happening is as important as the perceptions of his teacher, and

- The assessment of whose value may be more relevant than that of the learner's examined.

Vreken (1980: 132) and Mackenzie *et al.* (1970: 46) argue that good conventional teaching has always sought to take account of the learner. However, its structure and methods have greatly inhibited it. The inflexible style imposed by large numbers, the needs of timetables and the availability of teaching space, the conventional practices whereby courses are designed, and the teaching based upon the format of an accepted academic discipline, have meant that the emphasis has been mainly on teaching. Once we accept that *learning* rather than *teaching* is the point of departure, we have to ask ourselves different and searching questions.

1.4.4. Natural Science

Natural Science as a learning area in the GET (General Education and Training) Band of the South African education system refers to the learning area which deals with the following four fundamental themes: *the Planet Earth and Beyond; Life and Living; Matter and Materials and Energy and Change.* The theme The Planet Earth and Beyond focuses on the Geography part of the Natural Sciences and Life and Living pays more attention to the Biology part of the Natural Science. *Matter and Material* and *Energy and Change* refer to the Chemistry and Physics part of the natural sciences respectively. The focus of this study will be on the last two themes, referred to as Physical Science. (Physical Science in the FET (Further Education and Training) Band will, according to the proposed new Physical Science curriculum be composed of Physics and Chemistry). Physical Science, according to Brink & Jones (1981: 1) refers to the study of natural laws and processes other than that peculiar to living matter. For the purpose of this study, the term physical science will not encompass disciplines like geography, biology and astronomical sciences although they form an integral part of Natural Science.

In South African context, the themes Matter and Materials and Energy and Change (Grades 4 - 9), as stated in the policy document (1997: NS-2), form an integral part of natural sciences which is committed to, amongst others, broadening access to material, resources, knowledge acquisition and conceptual development.

1.4.5. Conceptualization

Thijs and Van den Berg (1995: 318) define a concept in science as the scientific idea underlying a class of things or events as currently intended by the community of scientists and documented by leading textbooks. A concept acquires its meaning through its network of relationships with other concepts. A person's concept about a particular label, for example *charge*, is a collection of all memory elements (propositions, strings, images, episodes and intellectual skills) that a person associates with the concept label *charge*, and the pattern of their links (White, 1988: 127). According to Stanton (1989: 5) a concept does not necessarily remain static in time, particularly in Natural Science, for it requires continuous modification at the advent of new compelling findings.

This model of looking at the term concept implies that it is possible for two people to have any degree of similarity or differences. Then, it follows that concept formation will refer to a situation whereby a learner has formed a network of related concepts linking it with the memory elements so that it makes a meaningful whole.

The term *conceptualization* is derived from the term *concept.* According to the OED (Oxford English Dictionary) (1980: 976) conceptualization is a mental process that involves the formation of a concept and should be peculiar to the individual who is forming the concept. Conceptualization is not found ready-made in thought but is a product of the process of perceptual construction. It involves more than just intuition and perception. We conceptualize when we cut out and fix, and exclude everything but what we have fixed. That which is to be conceptualized is implanted and is retained within mental structures and thus contains some permanence. Conceptualization may involve phenomena that cannot be affirmed and do not have objective existence, but can be expressed verbally.

1.5. METHOD OF RESEARCH/INVESTIGATION

1.5.1. Literature study

Relevant literature was obtained by means of an EBSCOhost web search on recent publications regarding the topic in scientific and educational journals, local and abroad. The literature study was conducted so as to gain extensive and intensive understanding of the role played by teacher demonstrations in the teaching and learning of Natural Science. The following key words were used to perform the search: *teaching; learning; demonstration; natural sciences; concept; conceptualize and conceptual change.*

1.5.2. Empirical Survey

Data was acquired by various means so as to address objectives (a - d) stated in paragraph **1.2.**

For the objectives **a - d** respectively:

(a) Literature study.

(b) Observation(s) on the present state of affairs regarding demonstrations conducted by educators were made.

(c) From the literature survey combined with creative ideas from experienced science educators and own ideas, effective strategies of conducting demonstrations were devised. Demonstrations were conducted according to the strategies. Pre- and post tests were administered to access the learning gain related to conceptualization.

(d) The results obtained in (c) served as basis to describe and determine the effect of demonstrations on conceptual development.

1.5.3. Population

The study focused on a group of educators (N = 20) who were presently teaching Natural Sciences at grades twelve level and who were residing in and around the Southern and Eastern part of the Northwest province. Learners were also engaged in the study, particularly those learners whose teachers were participants in the study. A sample of learners (N = 109) who were in grade twelve and were physical science candidates from the three secondary schools (Tlokwe, Thuto-Boswa and Thuto-kitso) that are in the Potchefstroom district were considered.

1.5.4. Statistical Analysis

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

1.6. CONCLUSION

The following chapter which is the first part of literature review seek to outline the essential features that constitute natural science, with particular reference to physics. The understanding of the nature of physics is crucial as its features (structural framework) are helpful towards concept formation and conceptual development.

CHAPTER 2

THE NATURE OF NATURAL SCIENCE

2.1. INTRODUCTION

Since the dawn of civilization people have been asking questions about nature, matter, motion, time and space. Most people in this modern scientific age are interested in Natural Science because they are aware that Natural Science, (physics and chemistry), is playing the most important role in shaping their world-view. It is for this reason that, Goswami, (2000: (vii)), maintains that paradigm shifts in physics are crucial to understand if you are to make intelligent decisions about the world and how one acts in the world.

People have always observed nature carefully, and have modified it to suit themselves. The ancient world was dominated by myth and magic, which explained how the world functioned and how human beings related to it. The myths grew out of experience, but were actually a means of articulating speculative thought about the world. The myths revealed a way of thinking that saw the world as the embodiment of personal forces that could be controlled or manipulated by human actions. The myths were not concerned with data, laws or absolutes. They were only concerned with establishing order and stability for the survival of life. For primitive people, intimate familiarity with the natural world was a matter of survival. The first observational science which emerged at the dawning of literate civilization was more concerned with how natural resources, like the stars, influence the life of man and his world (Abers & Kennel, 1977: 3; Bratcher, 2003: 1).

This interest in nature and the natural world as indicated by Ander and Sonnessa (1965: 1) is understandable since the processes in nature affect our lives directly. For instance rain, or lack of it, can have drastic effects on human life. Natural phenomena like earthquakes and lightning instilled fear in primitive man through his ignorance.

Consequently superstition and magic, which are both detrimental to the progress of civilization, are the roots of the fear.

It is perhaps imperative to understand the world-view of the scientists about nature. However, the questions to be asked are probably the following: *What is the scientists' view of nature? Do all scientists have the same view? Why is the scientists' view of nature important to everyone?*

According to Goswami, (2000: 1), most scientists' views of nature hold among other things, the objectivity doctrine, that nature is objective, meaning that nature's workings are independent of the subjects. The other view that scientists hold is referred to as the materialism doctrine, meaning that the objects of nature, including mental objects like thoughts, are made of matter and are reducible to elementary particles of matter and their interactions. This implies yet another view called the doctrine of reductionism. The doctrine mentioned above is said to be a disenchanted view of nature as it clashes with the spiritual belief in the existence of God.

It follows that science can never be neutral and objective as philosophers want it to be. The activities of scientists are embedded in a paradigm and determined by a worldview since they are both products of the human mind. The critical difference between a worldview and paradigm as pointed out by Lemmer (1999: 13) is that a worldview originates from cultural emanation, and a paradigm is devised through development in science and transferred through education.

2.2. WHAT IS NATURAL SCIENCE

Natural Science is the grouping of well-tested observations into ordered and intelligible schemes based on general principles or laws discovered from such observations and capable of being used to predict future phenomena. Encompassed in this Natural Science grouping are firstly, the pure sciences such as Physics, Chemistry, Biology, Astronomy and Geology. The second group is regarded as the instruments with which the sciences

are constructed and they include applied sciences such as Engineering, Medicine, Mathematics and Logic (Taylor, 1940: 1)

As mentioned in section 1.4.4, for the purpose of this study, Natural Science will only encompass physics and chemistry. Therefore it will be essential to briefly consider the nature and the development of each aspect of Natural Science. Studying the structural nature of natural science and the development thereof will probably yield how it should be taught to foster conceptual change and understanding. This is one of the research objectives of this study.

2.2.1. ESSENTIAL PHYSICS FEATURES

Various authors and researchers perceive Physics as a body of knowledge that consists of among others, the following essential features (Wesi, 2003: 12 & Wilson, 1999: 1):

2.2.1.1. Definitions

Genuine disputes involve disagreement about whether or not some specific proposition is true. Since the people engaged in a genuine dispute agree on the meaning of the words by means of which they convey their respective viewpoints, each of them can propose and assess logical arguments that might eventually lead to a resolution of their differences. Merely verbal disputes, on the other hand, arise entirely from ambiguities in the nature of the language used to express the viewpoints of the disputants. A verbal dispute disappears entirely once the people involved arrive at an agreement on the meaning of their terms. Doing so reveals their underlying agreement in belief and viewpoint or world-view. In cases of verbal genuine disputes, the resolution of every ambiguity only reveals an underlying genuine dispute. Once that's been discovered, it can be addressed fruitfully by appropriate methods of reasoning. These methods of reasoning call for a close look at definition(s).

There are different kinds of definitions and the term itself has a number of meanings that include:

- a brief account of a word, phrase or a concept, and
- The quality of a graphic or auditory reproduction.

The kind of definition essential to this study is referred to as an operational definition that is discussed hereunder.

Very few quantities in physics need to be explicitly defined, and for such quantities an *operational definition* is essential. Such fundamental quantities include length, mass and time. Other quantities are defined from these through mathematical relations.

An operational definition is a definition that describes an experimental procedure by which a numeric value of the quantity may be determined. It is a procedure agreed upon for translation of a concept into measurement of some kind. For example, a length is operationally defined by specifying the procedure for subdividing a standard of length into smaller units to make a measuring stick, then laying that stick on the object to be measured (Kemerling, 1997: 13).

2.2.1.2. Concepts

We learn all empirically based knowledge from our senses. The starting of knowledge must therefore be a perception in nature. From an elementary stage, a child use his senses to feel, touch, taste and smell. He is then fascinated by the information his senses send to him. From the fascination of the encountered information he then passes from perceptual awareness to conceptual understanding. The transition is by no means mechanical as it depends on a number of factors including the child's mental development and interest. It is for this reason that people have different perceptions to the same concept. For instance, if you ask a group of children to draw a table, they will come up with various shapes with

different number of legs. In achieving a perception of a table one needs to know the essential features of a table. That is, one must have many perceptions of many tables before one abstracts out of other possibilities, the essential qualities of a table (Sund & Trowbridge, 1973: 16).

Thijs and Van den Berg (1995: 318) define a concept as "the scientific idea underlying a class of things or events, as currently intended by the community of scientists and documented by leading textbooks. A concept acquires its meaning through its network of relationships with other concepts."

A person's conceptual view never ceases to grow. It expands with knowledge, experience and culture. As a result, a concept may have a different meaning to two people. An individual is said to have no concept about a particular percept if there is absolutely nothing that he can associate with the concept's percept. Otherwise whatever an individual knows about a particular percept is his concept about that percept. A concept is therefore possessed to a greater or a lesser degree, and there is no simple answer to the question regarding the presence or the absence of a concept in the individual's cognitive domains (White, 1988: 46).

Concepts form an important part of the body of physics. Percepts are related to concepts and different concepts are in turn related to one another to form the body of the discipline. In the educational context, the relationship between concepts can be illustrated by means of *concept maps*. Then it follows that concept formation will refer to a situation whereby a learner has formed a network relation of concepts linking it with the memory elements so that it makes a meaningful whole (Wesi, 2003: 23; Sund & Trowbridge, 1973: 17).

2.2.1.3. Explanations

Very often one has to respond to the question *why?* This type of question calls for reason(s) for happenings. One can look for an explanation for a scientific phenomenon,

or for a particular concept, or even for an explanation for the cause of events and laws. This then implies that explanations are closely related to other essential features, as they seem to unify or serve as a link between one feature and the subsequent one.

Harr'e (1960: 26) defines the term *explanation* as giving reasons for happenings. However, explanation of a particular happening has the following features: explanation will

- give a reason for the happening by mentioning a certain feature or features of the antecedent situation,

- either implies or states directly the relevance of the feature or features in question to the happenings for which an explanation is wanted.

Based on the features mentioned, it follows that there should be different kinds of explanations. The following section deals with kinds of explanations as perceived by Harr'e (1960: 26):

2.2.1.3.1. Linear explanation

A linear explanation refers to a situation where one is supposed to account for a certain happening that took place with a statement of another particular happening. An example of a question that seeks for a linear explanation will be: "*why does a ball fall when placed above the surface of the earth?"* A linear explanation for such a question would be, "*gravity pulls it downwards.*" The most important fact about linear explanation is that there must be a connection between the two happenings, like in the example provided. The understanding of this kind of explanation leads us to the second.

2.2.1.3.2. Hyperbolic explanation

In a hyperbolic explanation, the general connection of an antecedent to the happening in question is given and the particular situation that is the cause is understood. Hyperbolic in this instance suggests that there is a difference in logical status between the explanation and what is to be explained. If we consider the hyperbolic explanation to the question posed earlier in the previous paragraph, the response would be: "a *ball falls because the force of gravity pulls it towards the centre of the earth."*

2.2.1.3.3. Detailed explanation

A detailed explanation of a phenomenon refers to a combination of the linear and hyperbolic explanations. When we give a detailed explanation we set out in detail those antecedent happenings which are to be regarded as causes, we then state explicitly the requisite generalizations that justify the relevance of each. In this kind of explanation, it is essential to ascertain that every aspect of the phenomenon intended to be explained is understood.

A detailed explanation for the question "*why do objects fall when placed above the surface of the earth?"* would be, "*taking the earth as the frame of reference, the ball is placed within the gravitational field of the earth and it responds to the field, hence it accelerates towards the earth. Any mass placed within the gravitational field of the earth will experience a force, which is termed the force of gravity."*

2.2.1.3.4. Analogical explanation

If an analogy is used as an explanation, formal requirements of explanation are expressed in a different way, a way that leads to their being a basis for understanding something. Understanding, as it will be indicated in **section 2.3.3**. is always facilitated by the use of familiar rather than an unfamiliar mode of expression. If a single happening is considered, understanding would obviously be facilitated if we replaced a general

explanation in the theoretical terms of an unfamiliar theory by one which expressed the same relation concretely in terms with which we are familiar.

In explaining how a jet attains its speed, the explanation can be given by the analogy of the firing of a gun. A gun has a tendency of going in the opposite direction to that of the bullet after firing, a process referred to as recoiling. The analogy for this situation can be set as though the bullet is equivalent to the exhaust gases and the gun to the engine. This analogy and many others may be used to teach and help learners to understand the real situation as it clearly illustrates Newton's Third Law of motion about action and reaction forces.

2.2.1.3.5. Hidden mechanism

In most instances a causal explanation explains only one kind of event. In science very often one has to find explanations that cover many kinds of happenings, where simple causal explanations will not be successful. For this reason we have to devise a kind of explanation that is comprehensive enough to explain the entire event and yet that can be used to give the causes of many different kinds of events.

The following example will clarify the situation. The striking of the hours, the movements of the various hands, the ticking noise emitted, and the other features of the clocks can be explained all at once by describing the mechanism of a clock. Once we understand the mechanism we can state the cause of any one kind of happening on the face of the clock by referring to the relevant part of the mechanism. It follows therefore that understanding the hidden mechanism broadens our understanding of many associated events.

2.2.1.3.6. Explanatory theory

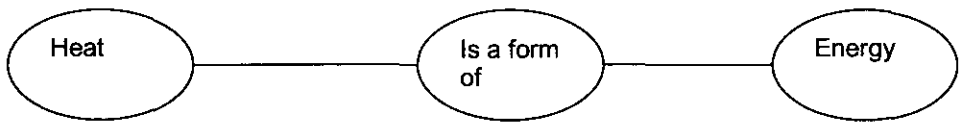
In an explanatory theory the depth of the explanation develops and ultimately includes the more restricted kinds of explanation discussed in the previous paragraphs. Analogical

explanations and hidden mechanism feature prominently in this kind of explanation. By supplying a hidden mechanism of sufficient breadth, an explanatory theory can account for many minor causal explanations. For instance, from the hidden mechanism one can see just how one sort of happening is relevant to and hence can be the cause of another sort of happening. The mechanism itself is often of such a kind that one can gain an understanding of it mostly through one or more analogies.

2.2.1.4. Propositions

According to Wesi (2003: 46), White and Gunstone (1993: 5) a proposition is formed when two or more concept labels or percepts are connected by linking words to form a unit that makes sense. Propositions express facts, opinions or beliefs. Proposition are formed according to the general format below.

An example of a proposition would then be:



A proposition, according to Gochet (1980: 2), is invoked to account for the meaning of sentences in a theory of meaning. Therefore it follows that a proposition belongs to a class of the deducible sentences.

Prior (1976: 17) further asserts that a proposition is a sentence signifying something true or false in the manner of a judgement. This sentence must either affirm or deny a relation between concepts as is the case with the example stated above.

2.2.1.5. Theories

Lindsay (1957: 21) describes a theory as *"an imaginative construction of the mind that employs ideas suggested by experience and also by arbitrary notions whose origin is difficult to trace. Together through ideas and notions theories form a kind of mental picture of things as they might be."*

According to Putnam (2003: 1), a theory can never be proven because nothing in theory has a demonstrable physical nature that can be isolated and examined. All that can be proven in a theory is that it fits empirical data. However, this only establishes that theory is an added on feature, it does not indicate its correctness.

According Kotz and Purcell (1991: 9) a theory is "*a unifying principle that explains a body of facts and the laws based on them.*" It is an invention of the human mind and it is capable of suggesting new hypotheses. When something is advocated to be a theory of X, the degree of belief that it correctly describes and explains X, is generally high. Unlike laws in physics, theories do change, as new facts are uncovered. After performing sufficiently reproducible experimental results a theory may be formulated to suggest the existence of a law of nature.

Simanek (1997: 1) holds that theory is a well-tested mathematical model of some part of science. In physics a theory usually takes a form of an equation or a group of equations, along with explanatory rules for their application. Theories are said to be successful if (1) they synthesize and unify a significant range of phenomena, (2) they have predictive power, either predicting new phenomena or suggesting a direction for further research and testing.

Theories (physical) are a collection of postulates that can be analyzed for internal consistency and for deductions that can be tested against observations. Laws on the other hand can be the direct result of theory building or they can be born directly by inductive use of observation (Reany, 1983: 3).

The following are a few characteristics of theories held by Harr'e. Harr'e (1972: 23) holds that a theory is expressed in sentences, diagrams and models that may be verbal and/or in pictorial structures. A theory whose prediction is not borne out by experiment or by observation must be modified. Otherwise some defect in the experiment should be demonstrated. A theory must serve as the basis for explanation. In order to fulfil this daunting task, a theory must explain how the particular phenomena came about. A theory must also refer to the mechanisms of nature, not just to the quantitative results obtained by studying those mechanisms in action.

Agazzi (1988) asserts that although theories are structurally descriptive of the possible world, they are constructed with a view of being descriptive of pictures of the real world and hence the dependence on experiments. The possible world that a given theory describes must include the features of the domain of objects that the theory is about and this entails not only the empirically known features, but also those which are as yet not known but which should exist according to the model. In order to fulfil this requirement, a theory has to undergo certain tests of referentiality. Concerning these additional features, a theory has to submit itself to the judgement of experiments which, besides supporting or weakening its referentiality claims, have the immediate effect of increasing the amount of empirical data it is obliged to account for.

2.2.1.6. Hypothesis

The hypothesis according to Ashley (1903: 143) has generally been treated as the part of scientific procedure, which marks the stage where a definite plan or method is proposed for dealing with new or unexplained facts. It is regarded as invention for the purpose of explaining the given, as a definite conjecture which is to be tested by experience to see whether deductions made in accordance with it will be found true in fact. The functions of the hypothesis therefore are to unify, to furnish a method of dealing with things. A hypothesis must be formed in such a way that is likely to be proved valid.

Hypothesis is defined as an untested statement about nature, a scientific conjecture or an educated guess (Simanek, 1997: 1; Ashley, 1903: 143). Formally a hypothesis is made prior to doing experiments designed to test it.

More generally a hypothesis is a simple speculation about one of three possible things:

- The existence or the structure of something taken as real or modelled as abstract,
- The mathematical relationship between variables of science, and
- The statistically significant relations on variables or events (Reany, 1983: 3).

Unlike laws, hypotheses never graduate to theories. Both models and hypotheses, according to Reany (1983: 3) have been found instrumental in the human invention of physical laws and theories that work.

2.2.1.7. Paradigms

Goswami (2001: 8) defines a paradigm as a super theory that acts as an umbrella under which, at a given time, scientific theories are developed and experiments are conducted within a given field of endeavour. A paradigm, of any given field, is not fixed perfectly complete as it can either be challenged or developed as new information is collected from experimental data. This may happen as a result of inconsistencies within the context of the existing paradigm.

Kuhn (1970) describes a paradigm as a collection of beliefs shared by scientists, a set of agreements about how problems are to be understood. The definition reveals the fact that scientists should be viewed as a community. Like any other community, scientific community cannot practice its trade without some set of accepted beliefs. These beliefs are based on the premise that they should serve as the foundation to a lifelong educational endeavour. Each community is guided by a paradigm, which in turn guides the research

efforts of scientific communities. This is the criterion that separates and identifies a field as a science. When a paradigm shift occurs, a scientist's world is qualitatively transformed and quantitatively enriched by fundamental novelties of fact and theory.
A paradigm is, therefore, perceived to be the underlying philosophical concept that structures the thinking in disciplines.

2.2.1.7.1. How is a paradigm created?

Kuhn (1970) asserts that a scientific inquiry begins with a collection of facts. This collection of facts is implicit and relevant to the belief of a specific discipline within the science field. Still at this elementary stage, it is essential that researchers experienced in the field describe and interpret the collection of facts. It is at this phase that a pre-paradigmatic school emerges. A pre-paradigm can only gain the status of a paradigm if its theory explains all facts with which it can be confronted. This implies a detailed scientific research. As a paradigm grows in strength and support, other pre-paradigmatic school or thought and previous paradigms become indistinct.

2.2.1.7.2. How does a paradigm shift occur?

It is stated earlier that natural science is continually bombarded with facts and information as new findings are brought forth. Natural science is not aimed at novelties of facts or theory and as a successful discipline, it often finds none. However new and unsuspected phenomena are constantly uncovered in scientific research and new theories have been invented by scientists. A paradigm shift may occur when there is a conflict between science and its paradigm, or when the paradigm is insufficient to explain phenomena (Lemmer, 1999: 12).

According to Kuhn (1970) a paradigm shift may occur in the following two different ways:

- **Through discovery**

A revolution in the world of scientific paradigms occurs when one or a group of scientists or researchers at a certain time encounter some striking irregularities that do not agree with the prevailing paradigm. Researchers recognize these irregularities through extensive observations. They discover that nature has probably violated the paradigm-induced expectations. These irregularities give rise to a crisis on the prevailing paradigm of the particular discipline. The area of the irregularity is then fully explored and theories and facts are subjected to thorough rethinking and re-evaluation. The paradigm change will be successfully completed when it is adjusted so that the irregularities become the expected. The procedure neither proves nor disproves scientific failure but indicates that scientists are able to see nature in a different way. In essence, a paradigm shift occurs primarily as a result of the discovery of new facts (Kuhn, 1970).

- **By invention**

As is the case with discovery, the invention of a new theory is also brought about by the awareness of irregularities. This new theory emerges as it is solved in many different ways. Failures in an existing theory are revealed by:

(1) Observed discrepancies between theory and fact.

(2) Changes in social or cultural climate, and

(3) Criticism of existing theory.

It should be borne in mind that like a theory, a paradigm resists change and is extremely resilient. However if a paradigm shift does occur through invention it will be as a result of a new theory (Kuhn, 1970).

2.2.1.8. Postulates

A postulate is an axiom stipulated as part of a purely formal deductive system. It is also perceived as something assumed without proof as a basis for reasoning or as a self-evident, or even a fundamental principle. A scientific postulate defines quite specifically what may be called science. To some it may seem to restrict freedom of thought and creativity, but the proof of its power is in the great benefits that science provides to the world in our health, wealth and our leisure. It is important to note that the greatest creativity is always done within the productive boundaries, that is, postulates. Therefore if one chooses to pursue natural science, one must agree to use the rules that govern the discipline. One of the greatest characteristics of a scientific postulate is that it provides a strong logical framework for scientific investigation.

2.2.1.9. Conventions

A convention is, according to Wesi (2003: 36) an agreement made between two or more people or parties. These agreements are then followed as rules or customs.

Hereunder follows definitions for the term conventions as given by the Funk & Wagnalls Standard dictionary quoted by Jordaan (1984: 81):

- A convention is a formal or stated meeting of delegates or representatives, especially for legislative, political, religious or professional purpose.

- A convention is a general consent, or something established by it, precedent custom, specifically a rule; principle; form or a technique in conduct or art.

Jordaan (1984: 82) asserts that conventions can be classified under two main categories namely *general* and *notational* conventions.

2.2.1.9.1 General conventions

In the subsequent section dealing with models it will be revealed that scientific models can be divided into two categories, namely, models of real existence and those that relate to hypothetical entities that may or may not exist. It is from the latter category that a third class can be formulated. If the existence of entities can be proved, their status will therefore change to that of the first category. If however proof of non-existence is given, the status of the model changes to that of the third class, which do not relate to any real or hypothetical entity.

Conventional current is classified under such models. According to this model, electric current is assumed to be in the direction from high charge concentration (positive) to low charge concentration (negative) of the source of electricity, or from a high potential (positive) to a low potential (negative). An analogical explanation to this is likened to water flowing from a high-pressure area (positive) to a lower pressure area (negative) of a system.

2.2.1.9.2. Notational conventions

Greeks contributed immensely to the development and structure of physics. It is for this reason that Greek letters and symbols are used in mechanics. The Greek letter *delta* (Δ) for instance denotes by convention *a change in* some variable. A lot more of the alphabets are conventionally used in Mathematics and Chemistry (Jordaan, 1984: 89).

Like the conventional electric current, conventions are merely established for convenience and to avoid ambiguity. They are not necessarily based on physical experiments. They only serve the purpose of ensuring that there is uniformity and consistency in the usage of terms. Examples are nomenclature in organic chemistry, and the usage of *SI* units (Wesi, 2003: 46).

2.2.1.10. Principles

Harre´ (1970: 206) refers to a principle as a general statement which determines the way we view the phenomena we study. It is a statement whose falsity we are not lightly to admit. The difference between a principle and other statements lies not in the fact that principles are neither ultimate nor the intrinsic, but rather in the attitude that we adopt towards a statement of principle. Therefore a statement becomes a principle, not because of some special structural feature or because of any special kind of meaning, but because it plays a certain role in our thinking.

2.2.1.11. Laws

Science would have little appeal to a probing and curious mind if it was a mere collection of observational data, with no attempt to organize such data into a meaningful intellectual structure. In this structure, disparate parts are to be correlated to each other in some precise way. Science encompasses the drive to discover the causal relationships among the individual bits of data that we are constantly aware of as we observe the universe around us. The stream of data to which we are constantly subjected probably flows past the majority of people without stirring their curiosity. They do not desire to know the significance of the data or how the data may be understood in terms of basic interrelationships that govern all phenomena. Amongst those scientists whose curiosity is stimulated by these data streams are physicists, who always seek explanations to that data stream (Mortz & Weaver, 1989: 51).

In defining a law, Mortz & Weaver (1989: 52), base their argument on the premise that not all concepts that enter into the laws of physics are defined, but that as few as possible of such concepts are introduced. The physicist builds his laws on these indefinables as a base. He uses them and works with them only if he can introduce an operational way of measuring them so that measurement replaces definition.

If we consider a series of events associated with a given particle, even if the particle is fixed with reference to a fixed position, it would still define a series of events over a certain period of time. If the particle is allowed to move from point to point and connect all these points or events by a curve, then this curve will be called the orbit or path of the particle. It follows then that a law "*is a universal statement that enables us to determine the orbit of such a particle under all circumstances*" (Mortz & Weaver, 1989: 52).

A law in physics is a summary or generalisation of observed and measurable behaviour. It is a systemization of what is observed experimentally. Physics laws are usually in the form of simple statements that can be understood without going into complicated mathematics. These statements usually describe the quantitative relationships between measurable quantities involved. This property of physical laws makes them very useful tools in physics (Lindsay & Margenau, 1957:14).

It is this property of quantification that makes physics laws powerful tools for making predictions.

According to Mortz & Weaver (1989: 52) physicists follow a particular order in the process of discovering a law. The first phase is the experimental or observational physics that entails collection of data in the form of measurements of various simple events. An experimental physicist in a laboratory performs this. The data collected from observed events is then translated to numerical data. A theoretical physicist then discovers the laws that account for the events revealed by the experimentalist. This tandem activity of the experimentalist and the theoretician is that its two components are intimately interrelated in the sense that the experimentalist, in designing his experiments, is guided by the theoretician, and the latter checks the truth of his theory by using the data of the experimentalist. Laws in physics are established after performing sufficient reproducible experiments covering an aspect of physics. Laws have a qualitative and a quantitative part. For example, Newton's law of universal gravitation starts with a qualitative part that states that, every particle in the universe attracts and is attracted by every other particle. The law closes with the quantitative part that says the magnitude of the attractive force

between the particles is directly proportional to the product of their masses and inversely proportional to the square of the distance between the particles.

2.2.1.12. Models

Kgwadi (2001: 15) asserts that the concept "model" has a fairly elastic meaning as it stretches from causal to philosophical interpretations. It follows therefore that it is almost impossible to define the concept. However around the fourteenth century meaningful attempts to define models were made. Hereunder, Kgwadi (2001: 16) quotes definitions of models given by various researchers:

"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" (Atkins, 1994: 3).

A model is a representation of an object, structure, event, idea or a relationship. This representation creates a vehicle through which the object, event or idea can be conceptualized or understood. The importance of models in science goes beyond their use as major tools in teaching and learning. Models are one of the main products of science in that the progress of science is normally marked by the production of a series of models. Modelling is therefore a major element in scientific methodology (Reany, 1983: 2 & Gilbert, 1994: 1).

A model is a simplified version of a system that permits calculations to be made and yields physical insight as well (Resnick et al. 1992: 511).

A model in physics is a simplified version of a system that would be too complicated to analyze in full without the simplifications (Young, 1992: 4).

"A model constitutes an artificial reality that can be investigated on mental, visual and material niveau" (Van Oers, 1988: 128).

It is evident that the definitions supplied above are very broad. This is brought about by the fact that attempts to define models end up with a definition that is generally very inclusive. Inclusive definitions run a risk of leaving out the essence of the content in meaning intended to be attached to a concept and ultimately saying nothing. An example of such an inclusive definition of a model is given by Apostel (Bertels & Nauta, 1969) quoted by Smit (1996: 219):

Any subject using a system A that is either directly or indirectly interacting with a system B, to obtain information about system B is using A as a model for B.

Smit (1996: 219) asserts that if this definition is anything to go by, it will be as good as considering a telephone directory as a model for a telephone system. In order to avoid giving inclusive definitions in models, it is rather important to consider how models are classified.

Models are classified into two categories: models of existence or being and subjective models. Models of existence, according to Santema (1978) quoted by Smit (1996), persistently try to model the godlike creation of the world. Subjective models on the other hand are human creations. Subjective models are subdivided into yet two types, which are knowledge and make or manufacture models. The diagrams below indicate classification of models as perceived by Santema and Klause, and the second one shows Harr'e's taxonomy of models.

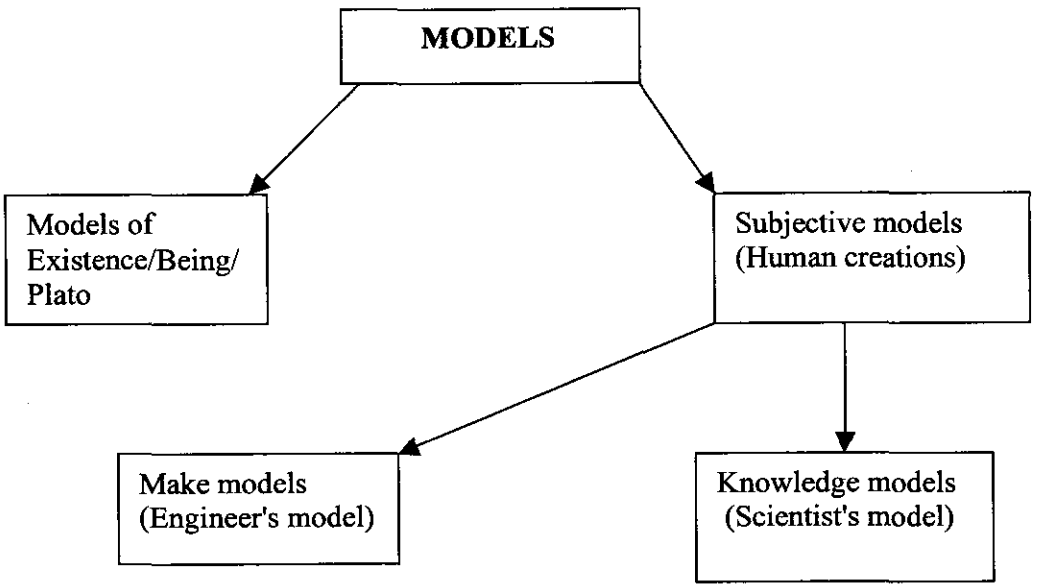


Figure 2.1.Classification of models by Santema and Klause (Smit: 1996)

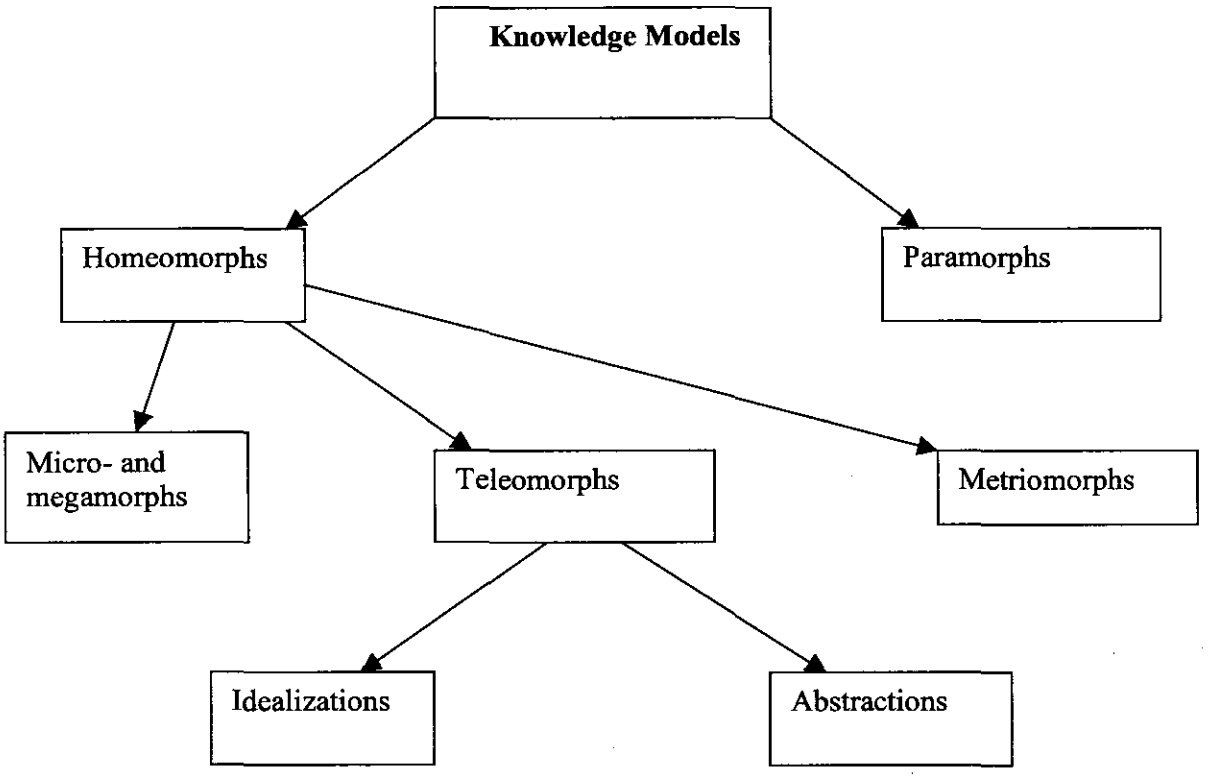


Figure 2.2. Harre's taxonomy of models (Smit: 1996)

It is mentioned in **section 2.2.2.** that science, Physics in particular, attempt to understand the basic principles or laws that govern the operation of the world in which we live. This attempt can be achieved through the use of models. Knowledge models are scientists' models as they are between man and reality. Man knows reality through scientific models. The scientific model is the creation of the human mind that helps man to obtain knowledge of reality.

2.2.1.12.1. Function of models

Hereunder follows the function of models as listed by Smit (1996):

- Fundamentally the function of a model is to give scientists knowledge of reality.

- Models are also used to explain phenomena. Smit asserts that each model has a functional domain as for example the phenomena of interference and diffraction lie within the functional domain of the wave model.

- Models play a prominent role in the prediction of phenomena.

2.2.1.12.2. Model features

In his work Smit (1996), quoted by Lemmer (1999) listed general features based on the nature of models:

- Models are creations of the human mind.

- A model summarizes and gives structure to scientific knowledge on a topic.

- A model brings together knowledge of vastly different aspects of reality.

- A model can be a representation of a real entity, but it is not the real thing itself.

- Models in physics are in general not replicas, copies or real representation of the entity that is modelled.

- Models are temporary by nature.

- Physics models are either abstract mathematical models with no spatial image associated with the model or a model that can be visualized.

- Physics models are community property shared by members of the physics community.

- Physics models must fit into the structure of physics, they must co-exist in harmony with other models.

- Physics models form part of theories.

- Scientists often construct material models of entities and objects, usually as educational resources.

2.2.1.13. Procedures

The two terms scientific procedures and method are so close to each other that even their definitions are related. They are both goal orientated in that they are carried out with the intention to achieve a particular preset objective. In both cases certain sequences has to be followed.

2.2.1.13.1. Procedure

A procedure is a naturally occurring or designed sequence of operations that produce some outcome.

2.2.1.13.2. Scientific method

A method is defined as a series of steps taken to accomplish an objective. A scientific method is a rigorous process by which new ideas about how some part of the natural world works are put to the test. It is further used to describe a step by step recipe or process that is generally followed by scientists in their quest to find new information in research (Carey, 1998: 4).

The scientific method is the way scientists investigate the world and produce knowledge about it. The production of knowledge is carried out in a systematic approach in that controlled experiments are used.

A scientific method as alluded by Millar (1990: 48) proceeds under the following sequence:

- Observations.
- Hypothesis.
- Prediction.
- Verification.
- Evaluation.

2.2.1.14. Experiments

Physics, and other natural sciences like chemistry, are reasonable enterprises based on valid experimental evidence, criticism and rational discussion. They provide us with knowledge of the physical world, and it is experiments that provide the evidence to substantiate this knowledge. Experiments play many roles in science. One of their

important roles is to test theories and to provide the basis for scientific knowledge. They can also call for a new theory either by showing that an accepted theory is incorrect, or by exhibiting new phenomena that is in need of explanation. Experiment can provide hints toward the structure or mathematical form of a theory. It can provide evidence for the existence of the entities involved in our theories. Finally, an experiment may also have a justification of its own, independent of theory (Franklin, 2003: 1)

The concept experiment is described as the creation of experience. Experiments involve many more notions than just controlled self-perceptions. Performing an experiment implies focusing of attention on a certain relatively small portion of experience. This refers to an abstraction of a restricted region from the totality of physical phenomena. This means that the person performing an experiment has pre conceived ideas concerning this group of sense perceptions. The ideas referred to above arise from previous observations and reflections about the experimenter's observations. From these ideas the experimenter is stimulated to ask questions which he believes can only be answered by the experiment (Lindsay, 1968: 17 and Lindsay & Margenau, 1957: 4).

Lindsay and Margenau (1957: 4) further maintain that the concept experiment implies a certain directed activity from the experimenter. The experimenter goes through certain operations with the hope that he might bring experience which he has not had in the passive state. An experiment is based on prior experience and on a considerable amount of reflection on that experience.

According to the traditional view, experiments are designed to put theories to test, and theories deserve this honourable denomination fully if the test is successful. It can therefore be said that experiments depend genetically and logically on theories since they are conceived and designed as explicit questions formulated by means of the concepts of a theory and with a view to testing it. On the other hand it can also be said that theory depends on experiments as far as its legitimacy is concerned, for the negative result of a relevant experiment would imply the elimination of the theory in question, thereby affecting its very existence (Agazzi, 1988).

2.2.2. PHYSICS

Lindsay and Margenau (1957: 13) define physics, as "*a science that is a method for describing, creating and understanding human experience*". Physicists describe experience; they create experience by performing experiments and demonstrations. Having accomplished these essentials, they seek further to enlarge experience by understanding what they have done. To a physicist, new experience involves the development of a theory.

Creation of experience in Physics is not taken passively by the observer, although it is how it started. People would simply look at the occurrence and later try to reason with what they experience as best as they could. The fact that observations produce experience new to man, the creation thereof is based on prior knowledge; considerable amount of reflection on experience and psychological factors (Lindsay, 1968: 17).

According to Stoker, (1974: 2) (quoted by Vreken, 1980: 12), the concept physics has its origin from a Greek term, which means "*nature*". Therefore, physics has been perceived as a science that studies natural phenomena. Around the nineteenth century, physics was then perceived to be a ramification of philosophy.

Hereunder Vreken, (1980: 13) quotes the general definitions of physics as viewed by various researchers and physicists;

- "Physics is the science of matter and energy" (Lindsay, 1971: 13).

- "Physics is the science of matter and is concerned with its fundamental structures, properties and behaviour" (Beiser, 1978: (i)).

- "Physics is truly a basic science, encompassing as it does a range of subject matter from atoms to galaxies and even beyond, into the miniature world of subatomic

particles and the unimaginable large arena of the nature of the universe" (Hooper & Gwynne, 1977: 2).

- "Physics is a science whose objective is 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" (Alonso & Finn, 1971: 2).

- "Physics is the process in which the nature of the participating substances does not change" (Alonso & Finn, 1971: 2).

In answering the question *"what does physics meddle with exactly?"* Vreken (1980: 13) gives the example cited by (Kane & Sternheim, 1978: (xi)) that *physicists attempt to understand the basic principles or laws that govern the operation of the natural world in which we live.* This response according to Vreken (1980: 13) identifies and brings out the reason for practicing physics.

2.2.3. CHEMISTRY

Despite the monumental records that show that the Egyptians, among other nations, had a considerable knowledge of processes essentially chemical in nature, there is however no certain evidence that they ever pursued chemistry in the spirit of science. Their operation of chemistry was of the manufacturing processes, empirical in character and utilitarian in result (Thorpe, 1924: 1).

Accumulation of massive facts by the Egyptians, Chaldens, Hindus and other nations of antiquity were fertilized by the theoretical speculations of the Greeks. This has eventually lead to chemistry attaining the dignity of a science (Holmyard, 1925: 1).

After the seventeenth century men were found willing to occupy themselves in chemical pursuits in order to gain insight into the nature of chemical change, and importantly to

learn the causes and conditions of its action. The word chemistry has its origin from *chemi* meaning the "black land", which refers to the ancient name Egypt was known about. The art of *chemi* was consequently referred to as the "Egyptian art" (Thorpe, 1924: 2; & Armitage, 1920: 1).

Chemistry may be defined as the scientific study of the structure of substances or matter, how they react when combined or in contact with one another and how they behave under different conditions, whether microscopic, particulate or macroscopic, (Oxford, 1989: 193)

2.3. LEARNING OBJECTIVES OF THE NATURAL SCIENCES

According to Lindsay and Margenau (1957), Physics is concerned with a certain portion of human experience. From this experience, a physicist construct a physical world, a concept that arises from a peculiar combination of certain observed facts and the reasoning provoked by their perception.

2.3.1. Creation of experience in Natural Science

Before we proceed with how experience is created in Natural Science, it is important to define what *experience* is. Lindsay (1968: 17) defines experience as the "*sum total of everything that happens to each one of us in all our working, and perhaps even in our sleeping hours, along with the reflections on these happenings made by our minds*". The *happenings* mentioned in the definition stated above are sometimes termed by philosophers and psychologists as sense-impressions, sensations, and sensory perceptions. The definition of the term experience refers basically to the interaction of man through his senses, sense of touch; seeing; smell; etc, and his mental reactions to these sensations. These sensations are creating ideas about the objects of our perceptions and their relation to each other. Experience therefore is and should not be taken as something passive and is stimulated by the interaction of man and his world.

Natural Science, physics in particular, was largely observational in nature. It did not involve the control that was later introduced through the medium of experiment. Before the experimental era, people would just simply look around themselves and try to reason with what they experience as best they could and accidentally come upon some signs of order. At a later stage man realized that experience received in this manner is limited in extent and made the overwhelming important discovery that man himself can create experience by setting up arbitrary arrangements of objects and perform operations on them with the aim of seeing what will happen (Lindsay, 1968).

Lindsay and Margenau (1957) assert that to have a clear view of what experience is about, it will be essential to assume and accept that:

- the creation of experience imply the possibility of experience and knowledge as the metaphysical basis upon which any science fundamentally rests,

- the sense perception of normal people is genuine and to abstain from quarrelling about the meaning of normality in this connection,

- the possibility of the exchange of knowledge, which means, the understanding of others' sense perceptions and reflections in terms of one's own is granted, and

- There must be a resounding agreement between people, and also there must be a certain degree of uniformity concerning experience.

2.4. OBJECTIVES OF TEACHING PHYSICAL SCIENCE

The curricula intend to produce a life long learner who is both confident, independent and multi skilled. This can be encouraged by a teacher who is responsible, professionally competent and in touch with current developments, especially with Natural Science and the teaching thereof. By current developments, reference is made to the approach that can impact positively to the concept formation in the learners' minds. One of the aims of the

present science curriculum development in Singapore is to prepare students for acquisition of cognitive thinking and investigative skills, that is, science process skills. It is therefore a common belief that the latter, science process skills, can be acquired through the laboratory experimentation, hence in high schools in Singapore a third of the curriculum time is devoted to laboratory work (Goh *et al.* 1989: 430).

In South Africa, Natural Science as a learning area has nine (9) specific outcomes as outlined in the national policy document, (NS - 6: 1997). They are stated as follows:

- Use process skills to investigate phenomena related to the Natural Sciences.

- Demonstrate an understanding of concepts and principles, and acquired knowledge in the Natural Sciences.

- Apply scientific knowledge and skills to problems in innovative ways.

- Demonstrate an understanding of how scientific knowledge and skills contribute to the management, development and utilization of natural and other resources.

- Use scientific knowledge and skills to support responsible decision-making.

- Demonstrate knowledge and understanding of the relationship between science and culture.

- Demonstrate an understanding of the changing and contested nature of knowledge in the Natural Sciences.

- Demonstrate knowledge and understanding of ethical issues, bias and equities related to the Natural Sciences.

- Demonstrate an understanding of the interaction between the Natural Sciences and socio-economic development.

In their work, Van Rensburg and Bitzer, (1995: 137), identified a set of generalizable competencies students of chemistry should acquire that would be important to them throughout their professional lives, namely:

- Adapting to and participating in change.
- Dealing with problems.
- Making reasoned decisions in unfamiliar situations.
- Reasoning critically and creatively.
- Adopting a more universal or holistic approach.
- Practicing empathy.
- Appreciating the other person's point of view.
- Identifying own strengths and weaknesses and undertaking appropriate remediation through continuing and self directed learning.
- Collaborating effectively in groups.

To add to the aims of practical work in chemistry, Van der Linde *et al.* (1994: 50), include the following, although idealistic:

- Development of the spirit of enquiry.

- Development of manipulative skills.

- Encouragement to become creative by applying scientific principles in different situations.

- Cultivation of an open mind and realization of the limitations of man.

Moving from the idealistic yet attainable aims cited above, Lagowski provide the more explicit aims, (1989: 12), in practical work, which are:

- To illustrate and clarify principles discussed in the classroom by actual contact with materials.

- To give the students a feeling of the reality of science by an encounter with phenomena which otherwise might be to him/her no more than words.

- To make the fact of science easy enough to learn and impressive enough to remember.

- To give the students some insight into basic scientific laboratory methods, to let him/her use hands, and to train him/her in their use.

2.4.1. Teaching for Understanding

Traditionally one of the goals of Natural Science education has been the acquisition of propositional knowledge. Propositions are discussed on **section 2.2.1**. Propositional knowledge refers to the knowledge that something is the case. However Natural Science learners should also acquire procedural knowledge. Procedural knowledge differs from propositional knowledge as the former consists of certain specific skills like: motor and mental or cognitive skills and the application thereof (Martin, 1991: 102).

A closer look at the specific outcomes of Natural Science outlined in the National Policy document, one finds out that more emphasis is on the concept *understanding* in so much that of the nine specific outcomes, six directly include the concept and the other three mention it by inference. It is the delight of teachers when learners do not merely learn the facts in Natural Science but understand it. It becomes evident from the policy document that the schools should produce learners who should demonstrate understanding of scientific knowledge in order to uplift their societies. But the fundamental question to ask is *what understanding means*? If understanding or to understand is a process, how does it proceed, and lastly how do you measure if someone has understood. The next section is an attempt to answer the question.

2.4.2. Defining "understanding"

There are very few concepts tremendous difficulty is encountered when an attempt is made to define them. Understanding is one such concept. Most concepts are defined in terms of propositions, but it cannot be done with this concept, understanding. Some of the reasons why it is such a difficult concept to define are that, it is used widely and it takes on different meanings, depending on the scale and nature of what is to be understood (White, 1988: 49). White (1989: 56) argues that the word, understanding, is so loosely used that it may even refer to a state of mind, a feeling of mastery and to a process, the act of comprehending.

Before an attempt to define the concept understanding is made, it is imperative to note that according to White, (1989: 50) there is no central core of knowledge which is essential to the understanding of a discipline or even of a concept.

The English Oxford Paperback dictionary (1994) defines understanding as an individual's perception of a situation. This seems to verify the point made by White that, understanding depends on an individual's viewpoint since there is no central core of knowledge.

Gardner, quoted by Lemmer (1999: 18) defines understanding as the "*capacity to take knowledge, skills and concepts and apply them appropriately in new situations. If someone only parrots what he or she has been taught, we do not know whether the individual understands. If that individual applies the knowledge promiscuously, regardless of whether it is appropriate, then I would not say he or she understands either. But if that individual knows where to apply and where not to apply, and can do it to new situations, that individual understands*".

From the definitions given above it follows that for one to understand a particular concept, one must have knowledge in ones memory about the concept. Understanding then must require a sound knowledge structure of a particular concept. There are various types of knowledge, which are propositions, images, episodes, intellectual skills, strings and motor skills. White and Gunstone (1993: 5) assert that the degree of understanding will be much higher if the set of various types of the elements of knowledge structure is meaningful and rich. The coherent system of each of the knowledge structures and relation of their elements also improve the degree of understanding of an individual.

According to White and Gunstone (1993: 7) a simple definition cannot encompass all the facets of such a complex concept. It is complex in order to be applicable to a wider range of targets. For instance, if one claims to understand democracy, it would mean that, one attaches to understanding a set of propositions, strings, images, episodes and intellectual and motor skills that one associates with the label, democracy. The richer the set, the better its separate elements are linked with each other and the clearer each element is formulated, hence greater understanding. The understanding of a concept is a continuous function of the person's knowledge, and not dichotomous nor linear in extent.

The following paragraph briefly describes the types of knowledge as stated by White and Gunstone (1993: 3 - 5).

2.4.2.1. Propositions

A proposition is an encoding of a meaning where the meaning is fixed and the form of representation is flexible.

2.4.2.2. Strings

Strings differ from propositions in that whereas the meaning in a proposition is fixed, in strings the meaning is not fixed.

2.4.2.3. Images

Images are mental representations of sensory perceptions that are often visual but can be related to any of the senses

2.4.2.4. Episodes

Episodes refer to memories of events that you think happened to you or that you witnessed.

2.4.2.5. Intellectual skills

Intellectual skills are capacities to carry out classes of tasks

2.4.2.6. Cognitive strategies

Cognitive strategies are broad skills used in thinking and learning

Thus far, properties or characteristics of understanding have been discussed. A generic definition of the word understanding could be given as, *the ability to use knowledge, to cope with situations* (White, 1988: 49). This definition implies that, it can only be

concluded that one has understanding of a concept if one has acquired the knowledge and is able to apply that knowledge in various given circumstances or situations.

White and Gunstone (1993: 1) give another interesting definition of understanding. They classify understanding as a higher form of learning than rote acquisition of knowledge. This definition concurs with the one given earlier in that, both definitions refer to understanding as the act of acquiring knowledge in a systematic way, not just by memorization or by rote learning. This is important because by rote learning one just reproduces what is learnt without interpreting or attaching meaning to what is learnt. If knowledge is acquired, one must be able to apply the knowledge acquired in order to prove that one understands.

Vreken (1980) aligns himself with Gardner, White & Gunstone (1993) when they state that for an individual to understand there must be a good relationship between the knowledge that the individual already possesses and the new information. According to Vreken, an individual understands if he can:

- Recognize knowledge in new or similar situations.
- Apply knowledge.
- Explain related phenomena.
- Interpret related occurrences.
- Translate knowledge from one code to another.

2.4.3. The process of understanding

From the given definitions above, we can conclude that you can be considered to understand if you can effectively apply the acquired knowledge in various situations. It is

also important to note, from the definition, that understanding is a process, it does not just happen. For instance, when a person reads a text, the message cannot be comprehended unless all or, certainly the great majority of the person's sentences can be converted into propositions that the person is familiar with and understands. These propositions should be described, or should be such that they can be acquired and related immediately to elements already present in the memory.

The process of comprehension depends on the understanding of the person's memory elements that are formed or recalled on receiving the message. Therefore, in order for one to understand, certain mental activities are necessary, which are: concentrating; active thinking; prediction; observation and explanation (White & Gunstone, 1993: 58; Perkins, 1993: 4; Blythe *et al.* 1998: 1)

2.4.4. Assessing Understanding

Throughout the development of authentic teaching and learning, one question has stood foremost in the minds of educators: *the developing of authentic assessment*, particularly assessment of understanding.

Proof of understanding according to Simmons (1994: 1) implies that learners are able to perform the following tasks:

- employ knowledge in flexible and novel ways,
- develop coherent networks of concepts,
- use what they learn in school to understand the world around them, and
- Develop an interest in life-long intellectual pursuits.

To teach for understanding requires close attention to assessment. Therefore teachers will have to seek evidence of understanding through the learners' performance. From the attempt made by various researchers to give a detailed explanation of what understanding is, it comes out that understanding is too complex to be assessed adequately by a single style of test and a single score on its assessment (White & Gunstone, 1993: 14). But how does one then assess understanding?

Various researchers White (1988), White and Gunstone (1993), Simmons (1994) and Blythe *et al.* (1998) aver that it is useful to use the following assessment techniques to test for understanding:

2.4.4.1. Concept mapping

Traditionally learners were asked to write essays to show if they understand a particular concept or concepts. This is seen as obstacle to both learners and educators as it takes a long time for learners to create and educators to mark. Essays, as argued by White and Gunstone (1993: 15) do not precisely give proof of the fact that learners can structure the concept clearly, and most importantly link concepts or ideas.

Concept maps are aimed at showing how someone sees the relation between concepts, ideas or between a percept and a concept in the form of a proposition. Specifically concept maps focus more on the structure and how learners perceive the linking of concepts. To gauge learners' understanding calls for more than asking questions or treating topics as though they are isolated entities.

2.4.4.2. Predict - Observe - Explain approach

POE, as it is known, probes understanding by requiring learners to carry out three tasks: firstly, predicting the outcome of some event and justifying their prediction, secondly, describing what they see happen and finally reconciling any conflict between prediction and observation. An important purpose of education as indicated by White and Gunstone

(1993: 44) is for learners to learn how to use the information they acquire to interpret events and learning experiences. POE is direct in assessing because it focuses on one particular event. It also ensures the learners' attention and conceptual development. This model is dealt with in detail in section 4.12.

2.4.4.3. Interviews about instances, events and concepts

This calls for the learners' deep probe in that it checks whether the learners can explain their decision concerning the particular event, instance or concept. The extent to which the learner explain and the kind and level of explanation he gives, (see section 2.2.1.1) may be a good measure of how well and effectively the individual understands. These concepts can also be extended so as to assess the learners on their beliefs; opinions; strings; images; episodes and even intellectual and motor skills provided there is relevance to the concept. This is the conversation between the learner and the teacher. The conversation is managed in order to test the learners' understanding (White & Gunstone, 1993: 82).

2.4.4.4. Drawings

In assessing learners by using diagrams one encourages the learners to put their ideas and minds in diagram or picture form. The collection of all memory elements, (propositions, strings, images, episodes and intellectual skills) seem to be enhanced by visual pictures. This then is in agreement with the way concepts must be formed in one's knowledge structures. Alesandrini (1981: 358) aligns himself with this line of reasoning when he argues that pictorial learning strategies indicate that learning is improved when pictures or drawings supplement verbal materials. If we agree that practical work is but one of the strategies that can be used to acquire knowledge, and the resources used refer to the "pictures" referred to by Alesandrini, then it is not difficult to see the connection between the two.

Alesandrini (1981: 358) asserts that, when learners are given a chance to draw their own pictures while studying, and are asked to generate mental pictures while reading or studying, they will conceptualize and understand with ease.

2.4.4.5. Word associations

Word association does to a large extent the same task as concept mapping. The basic difference between concept mapping and word association is that there is a relatively high degree of own pattern of relation of concepts in concept mapping as opposed to word association. In word association the educator deduces the word(s) from a complex analysis of the network of words.

2.4.4.6. Tests

Testing related concepts in physics could be a measure of assessing understanding to some extent. However, certain guidelines must be adhered to when testing for understanding. The test must be valid and reliable; that is, it must test what it is intended to test.

2.5. CONCLUSION

Science is not a natural history, nor the accumulation of facts. It is the building of a picture of the universe. It is the intellectual enterprise aimed at understanding how the world operates. It is also a body of knowledge about events of the world and a method of inquiry. It differs largely from other enterprises in that it is done under the discipline of the experimental method and it uses specific logic and the scientific method of inquiry.

The empirical approach of science is based upon the assumptions that the universe is intelligible; man can study nature and discover natural laws; that there is reality to space, time and matter; and that all natural phenomena can be explained in terms of physical and chemical states. Describing nature in this manner is said to be mechanistic.

In the next chapter the focus will be on the curriculum development for natural science in schools, particularly South African schools. The reasons for educational paradigm shift in the South African curriculum will be discussed to attempt to address the research objectives listed in section 1.2. This chapter also forms part of the literature review.

CHAPTER 3

THE OUTCOMES-BASED CONTEXT

3.1. INTRODUCTION

Concerns that the education system cannot adequately prepare learners for life and the work environment of the twenty first century have prompted people across the world to explore new ways of designing education. In several countries, including South Africa, educators and policy makers are attempting to change the way of emphasizing measuring the effectiveness of education from concentrating on traditional inputs to results and outcomes.

Since the traditional education system had shortcomings, a paradigm shift was inevitable. As discussed in section 2.2.1.7, a paradigm shift does not refer to seeking an alternative answer to the existing problem, but it involves a whole new approach to a problem, based on a totally new point of departure and coupled with completely new thinking structures. A paradigm shift in Outcomes Based Education will mean that the terminology, wording, method of assessing and approaches should not resemble anything of the past, but should directly be translated into the outcomes (Olivier, 2001: 29).

3.2. CURRICULUM REFORM

The influence of progressive education during the first half of the twentieth century brought about a profound change in the concept of what a curriculum should be. The need for a radically new curriculum was the inevitable result of a number of forces that include:

- Changes in the perception of what knowledge is, scientific knowledge in particular (Tanner & Tanner, 1980: 6)

- Changes in the knowledge of the learning process as a result of the learner-study movement.

- The need to link formal school studies with the life of the learner, and

- The changing demands of the wider society (Cohen, 1993: 795; Tanner & Tanner, 1980: 6).

Nevertheless, in the process of rejecting traditional conceptions and perceptions about what the curriculum should be, progressive educators were far from a convention, that is a universal agreement, as to how the curriculum should be defined (Tanner & Tanner, 1980: 6). Extensive interest arose in curriculum development to such an extent that it has recently become a course to study. However attempts were made by various authors to define the concept curriculum. Some of the definitions were influenced by tradition as will become clear in the next paragraph.

3.2.1. Defining curriculum

Stenhouse (1975: 4) defines a curriculum as an attempt to communicate the essential principles and features of an educational programme in such a form that it is open to critical scrutiny and capable of effective translation into practice.

Zais (1976: 6) asserts that the word curriculum has its root from Latin, which means "racecourse". Consequently educators at school level have for a considerable time regarded a curriculum as the relatively standardized ground covered by learners in their race towards the finishing line, the finishing line being grade twelve.

In defining a curriculum Olivier, (1968: 4) encompassed a number of features and concluded that, a curriculum is:

- All the experience the learner has regardless of when or how they take place.

- All the experience the learner has under the guidance of the school.
- All the courses a school offers.
- The systematic arrangement of certain courses designed for certain learner purposes.
- Courses offered within a certain subject field.
- The program in a specialized professional school.
- Those courses taken by an individual.

Posner & Rudnitsky (1982: 8) perceive the function of a curriculum as to indicate *what* is to be learned, where as the goals indicate *why* it is to be learned and the purpose of the instructional plan is to indicate *how* to facilitate learning.

Carl *et al.* (1988: 21) perceive a curriculum as a broad concept that embraces all planned activities, and thus also subject courses that take place during the ordinary school day. Curriculum also includes all after-school planned activities such as societies and sport. Carl *et al.* concur with Tanner and Tanner (1980: 6) in that they agree that a curriculum have a broader meaning as it is discussed in the features hereunder.

3.2.2. Important features of curriculum

Tanner and Tanner (1980: 6); Zais (1976: 6) gave a broad dimension a curriculum should focus on. They considered the following aspects of a curriculum as important to focus on:

3.2.2.1. Curriculum as the cumulative tradition of organized knowledge

Over the years most educators held to the traditional concept of curriculum as the body of subjects or subject matters set out by educators for learners to cover. This perspective allowed any subject to be either added or withdrawn from the curriculum. This then later led to the belief amongst traditionalists that any conception of curriculum must embrace the *permanent* or *essential* studies. The former refers to the view held by perennialists that the curriculum should consist principally of the permanent studies such as mathematics and grammar rules. On the other hand the latter is concerned with the fact that the curriculum must consist essentially of disciplined study in areas such as mother tongue and systematic use of grammar; mathematics; sciences; history and foreign languages.

Perennialists' philosophy is derived from the word perennial which refers to people whose teachings are enduring for an indefinite traditional era. Perennialists believe that one should teach the things of everlasting importance to all people everywhere. They believe that the most important topics develop a person. As a result a particular strategy with modern perennialists is to teach scientific reasoning and not just facts. They may even demonstrate the reasoning with original accounts of famous experiments. The perennialists argue that this demonstration gives learners a human side to the science and shows the reasoning in action. The difference between perennialists and essentialists is their points of focus. Perennialists focus on personal development whilst essentialists focus on essential skills. Essentialists' curricula thus tend to be much more vocational and fact based, and far less liberal and principle-based (Tanner and Tanner, 1980: 6).

The problem with the perennialist as perceived by Tanner and Tanner (1980: 6) is that their position fails to recognize the modern scientific studies and the changing state of knowledge. The premise of the perennialist is that the best exemplars of the past, the permanent studies are valid for the present and for all time. The other assumption made by perennialists is that the sole purpose of education is the cultivation of the intellect, and that only certain studies like grammar have that power. The perennialist stance embraces

the long refuted doctrine of mental discipline and rejects any consideration of the interests and needs of the learner, which is a key element of outcomes-based education.

Although the essentialists recognize the place of the learner of natural sciences in a curriculum, the learners' interests and needs are still of limited concern. Therefore the curriculum needs to be structured accordingly. The concept of discipline regards knowledge as dynamic and it places the methods of science as central to the development of new knowledge. This is contrary to the belief held by perennialists and essentialists who argue that a learner is a vessel to be filled or a muscle to be exercised. The concept of discipline regards disciplined inquiry as the key to intellectual development (Tanner & Tanner, 1980: 9; Schwab, 1962: 197; Bestor, 1956: 48).

3.2.2.2. Curriculum as modes of thought

A curriculum is considered to be the increasingly wide range of possible modes of thinking about individuals' experiences, not the conclusions but the models from which the conclusions derive. Modes of thought could be interpreted as extending beyond the confines of the established disciplines, thereby extending the curriculum significantly beyond the conception that education is a guided recapitulation of the process of inquiry which gave rise to the fruitful bodies of organized knowledge comprising the established disciplines. It is for this reason that curriculum developers and policy makers advocate the idea that there should be meaningful integration across learning areas as there is a certain degree of interdependency in learning areas in Natural Science (Tanner & Tanner, 1980: 10; NS-6, 1997; RNCS-13, 2002).

3.2.2.3. Curriculum as race experience

Race experience embodies not only the cumulative tradition of knowledge but also the total culture of a society, that is, it refers to the common elements that make a society more than a mere aggregation of individuals. According to Tanner and Tanner (1980: 12) progressive communities endeavour to shape the experiences of the young so that instead

of reproducing current habits, better habits shall be formed and thus the future adult society should be an improvement of their own. This is done in the light that certain aspects of our way of life, certain kinds of knowledge; attitudes and values are regarded as so important that their transmission to the next generation is not left to chance. Therefore the society entrusts the educational profession with the task of ensuring that the crucial aspects mentioned above are upheld. This is in accordance with the sixth specific outcome of the Natural Science learning area as mentioned in **section 2.3.2.** This outcome states that learners should demonstrate knowledge and understanding of the relationship between science and culture.

3.2.2.4. Curriculum as experience

The traditional conception of curricula as if it is merely a body of school subjects or subject matters came under attack from progressive educators for two reasons. The argument against this view firstly advocates the continuity between the traditional subject matter and the learner and secondly and most importantly, the school studies are not relevant to the realities and demands of life. It is for this reason that progressive educators and policy makers advocate that all school learning areas and activities be centred on the specific needs and interests of the learner (Tanner & Tanner, 1980: 14).

At the heart of South Africa's outcomes-based education curriculum is an emphasis on putting the learners first. This learner-centred approach has entailed a paradigm shift in the approach to learning and teaching, away from the traditional syllabus-orientated, content-based transmission model of teaching and learning to the one based on outcomes. It is therefore imperative that the curriculum to a large extent includes learners' interest and needs (Kraak, 1999: 43; Malcolm, 1999: 93; Tanner & Tanner, 1980: 14).

3.2.2.5. Curriculum as guided learning experience

The definition of curriculum as stated in section 3.2.1. has changed from content of courses of study and lists of subjects and courses to all the experiences that are offered to

learners under the auspices or direction of the school. This according to Zais (1976: 8); Tanner and Tanner (1980: 14) seem to reflect the educational state of affairs more accurately than most definitions attached to the term curriculum.

This approach is verified as the school is established in order to educate and develop along certain lines the learners placed in its charge. This development is achieved through the experience that the learners have, and so it seems reasonable to conclude that the curriculum, as a blueprint for education, consists ultimately of the experiences that are planned for learners. The implication of the definition provided above is that everything that influences the learner must be considered during the process of curriculum construction (Zais, 1976: 9; Tanner & Tanner, 1980: 15)

3.2.2.6. Curriculum as guided living

It has been noted that virtually every institution in society like family, church, business sectors and industries has a curriculum. Apart from non-educational functions of some of these institutions, and apart from the fact that most such institutions do not ordinarily utilize the concept curriculum to denote the nature of their operations, schools perform a constellation of educational functions that are not performed by any other institution.

Chiefly among these are the systematic organization and interpretation of the knowledge and skills of race experience for the growth of the rising generation. It is unfortunately the school that is concertedly responsible for the systematic reconstruction of the knowledge paradigms and skills of race experience for the growth of the rising generation. This orchestral function of the school encompasses a program of systematic instruction across learning areas and the evaluation thereof that is unmatched by any other institution (Tanner & Tanner, 1980: 19).

3.2.2.7. Curriculum as an instructional plan

Nieuwoudt (1998: 1) and Tanner and Tanner (1980: 23) contend that no matter how well designed, organized and disseminated the curriculum is, very little will amount to good if the instructional plan is not both feasible and well implemented by educators. It is for this reason that curriculum planners and designers are involved in an ongoing process of evaluating and redesigning learning programs that will or are intended to equip learners with relevant, meaningful and useful knowledge, skills, attitudes and values. However to achieve all these, an alternative integral and holistic view of an effective instructional plan should be implemented, in a school's curriculum and practiced to the fullest.

Nieuwoudt (1998: 9 - 11) argues that the instructional plan will be effective if the key features of teaching are upheld. These key elements of effective teaching are as follows: the *teaching intention or goal;* the *learning content*; the *educator/teacher*; the *learner; interaction in the teaching situation* and the *contextuality of teaching.* The educator's role and the learner role will be discussed in detail in the subsequent sections of this study.

3.2.2.8. Curriculum as a technological system of production

Towards the end of the twentieth century the notion of curriculum as a production system was beginning to be embodied in the doctrine of specific behavioural objectives, in performance contracting and in accountability. With modern demands in society, activity analysis incorporated the progressive idea of linking the curriculum to life experience. The activity analysis was designed to secure educational outcomes in an efficient way, corresponding to the performance analysis of employees in the world of industry and business (Tanner & Tanner, 1980: 25).

3.2.2.9. Curriculum as ends

A dualistic view on curriculum as ends and instruction as means is perceived and supported by many researchers. This is so because curriculum design revolves around

consideration of ends, that is, the outcomes an educational system hopes its learners will achieve. It is therefore crucial to note that the conception of a curriculum as a plan should be extended and be perceived as the desired consequences (outcomes) of instruction (Tanner & Tanner, 1980: 25).

From the sections discussed above it is clear that a curriculum is a highly complex information transmitting system. It generally acts upon inputs from elementary education to convert this raw material into a semi-finished product to be shipped out into practice. This is the intention of outcomes-based education in South Africa.

3.2.2.10. Summary on Curriculum

Among the many abstract concepts in educational literature, curriculum remains a difficult one to capture. A more refined differentiation seems to be a three fold distinction that has proved to be useful worldwide when talking about curricular activities. These are as policy making, design and development, as well as evaluation and implementation. These three cover a much broader spectrum as they include system level (macro), the school level (meso) and the classroom level (micro).

Van den Akker (1998: 421) argues that it is ideal to be as comprehensive and diverse yet focused when dealing with the curriculum which should cover the following representations:

- The ideal curriculum, which is the curriculum that focuses on the original vision underlying a curriculum. This includes the basic philosophy, rationale and the mission.

- The formal curriculum: the formal curriculum elaborates the vision in a curriculum document.

- The perceived curriculum: this entails the curriculum as interpreted by the educators and other users.

- The operational curriculum: this refers to the actual instructional process in the classroom as guided by the previous representations.

- The experiential curriculum: this refers to the actual learning experiences of the learners.

- The attained curriculum: this refers to the resulting learning outcomes of the learners.

The history of science curriculum reform raises our awareness of the continuity and durability of science instructional practices. As long as proposed changes in the science curriculum are aimed at making the existing curriculum more efficient and active, signs of progress can be traced. We need more comprehensive approaches which take into account the many perspectives that belong to a systematic view, and which start with a realistic time frame in mind.

3.3. AIM OF CURRICULUM REFORM

Central to the aim of curriculum and educational reform in South Africa as perceived by Pretorius (1998: vi) is firstly the emergence of the *global economy* which calls for a high educational standard in a country. Developed countries maintain that to have a strong economy you have to invest substantially in dynamic corps like education.

The rise and stability of the country's economy gives rise to *technological inventions*. Failing to react promptly to technological development has an adverse effect on the standard of living of the nation. Productivity and quality in production processes are of the utmost importance to stay economically competitive. Enhanced productivity is made possible by technological change. According to Pretorius (1998: vi) well-trained educators, learners and workers in general can handle changing technology more

effectively. This implies a greater need for employment of highly skilled workers. Therefore the training of the existing corps of workers, the idea of lifelong education and the creation of a culture of learning had to be revisited. It is for this reason that modern economies have their root deeply embedded in natural science (NS-6, 1997).

The third factor of curriculum reform is related to *organization of work.* In the traditional setup management was responsible for planning, creative thinking, leadership and control in both the educational and economic sectors. In the context of the economic changes countries including South Africa, have slowly become aware that education should be provided in ways that are fundamentally different to the traditional school situation. It is for this reason that the first five specific outcomes of Natural Science address the need and the intended implementation of scientific knowledge and skills, and the demonstration of responsible decision making processes (Pretorius, 1998: vii; NS - 6, 1997).

3.3.1. Implications of Globalization on Education

Given the increasing economic globalization and restructuring in the world political and economic systems and the requirements for knowledge and information within that system, educational needs, in terms of structure; function; curriculum and approach at all school levels have changed. These educational requirements for the workforce of the future are extremely important Cogburn (1998: 25).

Education is generally seen as a formal process of instruction which is based on the theory of teaching, to exchange and share formal knowledge. The role of knowledge within the economy is that it may lead to a whole range of industries and new developments in the natural science disciplines. Some of the challenges for knowledge include that learners should be more familiar and comfortable with concepts and challenging situations so as to be part of the global community. The direction taken by the South African community seem to be successful with the paradigm shift in the education system as mentioned in section 3.5. (Cogburn, 1998: 26).

The subsequent section discusses the aim of the curriculum reform by referring to the previous status quo.

3.3.2. Traditional Curriculum

The traditional South African education system had to be revisited as the curriculum had the following shortcomings:

- The curriculum was too structured, prescriptive and not easily adaptable, with little room for educational initiative.

- Traditional curriculum processes were too restricted and without any stakeholder participation in the decision making process.

- The accent fell on academic education, while skills training remained behind.

- A large gap existed between education in the formal educational sectors and training by employers.

- Too great an emphasis was placed on differentiation in the form of a wide variety of subjects.

- The curriculum was content-based.

- The curriculum was teacher-centred, as opposed to being learner-centred.

- Learner achievement was measured in terms of symbols and percentages which are often no real indication of actual performance.

- Learner achievement was compared to that of other learners which led to excessive competition.

3.3.3. New dimension

In the South African context, curriculum 2005 is organized into areas of learning that serve as the basis for developing learning programmes. This is done because it is argued that in the real world situation you will never find answers to problems that people face in simple, one dimensional and single subject solutions. Information, data or knowledge leading to solutions are always drawn from various sources and not from narrow-based subjects alone. Areas of learning familiarise learners with the ability to think broader than narrow subjects. As a result the Natural Sciences are a learning area that encompasses Physics, Chemistry, Biology and Geography. It also cuts across other areas such as Mathematics (Olivier, 2002: 93).

Olivier (2002: 99) outlines the comparison between the traditional and the outcomes-based learning in the following table.

Table 3.1. Comparison between traditional and OBE learning.

Traditional content based learning	**Outcomes-based learning**
Based on rote learning	Based on critical thinking and reasoning
Learning is seen as a linear input/output process	Learning is seen as an integrated and system process
Learners were mainly passive when exposed to content	Learners are active and involved in the learning process
Little communication took place	Communication is critical
Syllabus is broken down into subjects and is content driven	Learning is outcome and process driven and connected to real life situations
The process is textbook/worksheet driven	The process is learner and outcome centred
Teacher centred	Teacher is a facilitator

Syllabus is rigid and non-negotiable	Learning programmes are seen as guides
Emphasis is on what the teacher hopes to achieve	Emphasis is on the outcomes, that is, what the learner achieves
Curriculum development process not open to public	Wider stakeholder involvement is encouraged

3.4. Structure of OBE

According to Robert (1996); Spady and Marshall (1991); Udvari-Solner and Thousand (1995) Outcomes-Based Education is an educational philosophy organized around several basic beliefs and principles. It starts with the belief that all learners can learn and succeed. Institutions where education proceeds control the conditions of success through the supply of quality, authentic learning experiences and therefore the learners' success is the responsibility of the educator. OBE is organized from a focus on learner's outcomes and designed downward to the unit levels.

3.4.1. Principles guiding OBE

Udvari-Solner and Thousand (1995) assert that OBE is guided by four principles:

3.4.1.1. The clarity of focus

This principle implies that all aspects of education (curriculum, instruction, and assessment) are centred on what stakeholders (educators, parents, community, business sectors, etc.) want learners to demonstrate by the end of their schooling career.

3.4.1.2. Expanding opportunity

This principle recognizes that learners learn in different ways and at different rates, and that various methods and contexts are needed to optimize learning.

3.4.1.3. High expectations

This principle advocates the belief that all learners should demonstrate success in their own way, as they are able to do significant things.

3.4.1.4. Designing down

This principle turns the traditional method of designing curriculum upside down. The long-range or ultimate outcomes are established first, and then the curriculum is designed with a stern focus on where learners are expected to end. The diagram below displays the sequence.

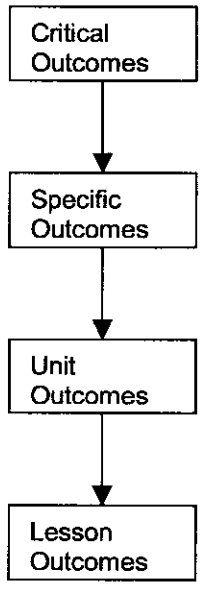


Figure 3.1. The design down of the OBE curriculum

3.4.2. Essential characteristics of OBE

The following are perceived as essential characteristics of outcomes-based education by Houston as quoted by Robert (1996):

- The learning instruction should be defined in terms of outcomes to be achieved.
- The instruction is personalized/individualized.
- The learning experience of the individual is guided by feedback.
- The learning programme is systematic.
- Emphasis is on exit, not entrance requirements.
- Instruction is modularized.
- The learner is accountable for performance to complete the learning programme.

3.4.3. Intention (Aims)

The move from a content-based to an outcomes-based education system was made due to the growing concern around the ineffectiveness, non-productivity and wastefulness of the previous education system that was largely teacher centred. The traditional approach to learning and teaching promoted convergent thinking and was mostly driven by examinations. The new educational paradigm is intended to shift from one, which has been content-based to one, which is based on outcomes. This intends to equip all learners with the knowledge, competencies and orientations needed for the workplace (NWED, 1999 - 6).

According to Cretchley and Castle (2001: 488) outcomes-based education is intended to improve the rationality, coherence and quality of education and training and to broaden access to them by mature adults, with all the economic and social benefits this may bring. Outcomes-based education is associated with the discourse of lifelong learning and open access to learning, in which it is assumed that people learn throughout their lives, both formally and informally. Within the context of outcomes-based education it is therefore the intention of the system not to perceive workplaces and communities as sites for the application of knowledge imported from institutions of higher learning, but are in themselves sites for the production of knowledge.

Spady and Marshall, (1991: 70); Brandt, (1993: 66); Kudlas, (1994: 32 – 33); Dlugosh, Walter; Anderson & Simmons, (1995: 182); Brady, (1996: 85) quoted by Pretorius (1998: xi) outlined some of the important intentions and aims of outcomes-based education and explained why most countries, developing and developed, practice the system. These countries are said to be attracted to outcomes-based education because:

- It is a learner-centred approach built on the principle that all learners can achieve well if allowed enough time to do so.

- Time and assistance are provided for each learner to meet his or her own potential.

- Learners are focused on what should be learnt, as they know the outcomes in advance.

- In the system, educators are offered the opportunity to be flexible in their teaching/facilitating methods, since the emphasis is on whether the learner reaches the required outcome, and not on procedure.

- Learners are given multiple opportunities to demonstrate whether or not the outcome has been reached.

- Learner advancement is based on demonstrated achievement.

- Leaner achievement is not measured in terms of the achievement of other learners, but solely on whether a learner has reached the required outcome or not.

- Learners are expected to accept greater accountability in reaching the required outcome and grade.

- For self-motivated learners who reach the required outcomes successfully, there is the freedom and flexibility to expand their learning to further enriching activities.

- The outcomes or culminating demonstrations of significant learning must be of high quality.

- Outcomes-based education emphasizes high expectations for all to succeed.

- Involvement of a wide range of stakeholders in determining the required outcomes is essential. Therefore, community needs tend to be addressed more directly.

- The accent no longer focuses on memorizing factual knowledge, but on skills needed for everyday living and requirements of the workplace.

- The emphasis also falls on embedding quality problem-solving skills rather than on memorizing a given amount of scientific information.

- Outcomes-based education is focused on the future and can adapt to the changing needs of the community more readily.

- Outcomes-based education is a long-term commitment based on the notion of continuous improvement. It therefore creates opportunities for local communities to strive for excellence through strategic planning.

Education systems regard outcomes-based education as the model that can address future needs more satisfactorily than the system used in the past, as well as implement technological inventions and changes that have taken place in the work environment.

It is important to note that Outcomes-based Education is a management system that includes an approach to manage curriculum control; curriculum design; assessment and reporting; educators and educators' accountability; change and innovation. It is for this reason that Outcomes-based Education appeals to different interest groups in different ways depending on the aims of each group.

There are various models of OBE, which differ essentially in terms of choices of outcomes and different management systems to achieve them. Malcolm (1999: 80 - 90) highlights the essential differences between the *common ground* and *focus on difference* models of OBE, which are the building blocks of South Africa's outcomes-based education system.

3.4.4. Terminology (Key concepts and essentials in OBE)

It is one of the objectives of this study, as mentioned in section 1.2.2 to find out whether lecture/teacher demonstrations do enhance conceptual change. It is therefore important to focus on the types of outcomes that are envisaged in the teaching and learning of Natural Science.

3.4.4.1. Critical outcomes

Critical outcomes are personal, thinking and life skills, which are the abilities that people, need in order to be active, responsible and successful members of society. They provide means to build a career and make the person more effective in executing a job. These outcomes express the intended result of education and training in a broad and macro sense as they are linked to personal and national goals and aims. They are generic and cross-curricular and are linked to all learning areas, as well as to all spheres of life.

Critical outcomes are central in constructing and achieving qualifications across all learning areas as they are the elements that enable learners to move from dependence to independence and ultimately to higher levels of productivity, innovative thinking and creativity (NS-13, 1997; Olivier, 2001: 34).

Olivier (2001: 35) asserts that when learners accomplish critical outcomes, they will be able to:

- Reflect on and explore a variety of strategies to learn more effectively.
- Participate as a responsible citizen in the life of local, national and global communities.
- Be culturally and aesthetically sensitive across a range of social contexts.
- Explore education and career opportunities; and
- Develop entrepreneurial opportunities.

Attaining these skills enable learners to acquire new competencies, improve existing competencies, formulate new ideas, reformulate existing ideas and continuously shape and reshape values and attitudes towards life and work.

3.4.4.2. Specific outcomes

Specific outcomes are according to Olivier (2001: 36) knowledge, skills and values embedded in the areas of learning. They express the results of narrowly defined aspects of learning. Specific outcomes are context-linked and contribute to the achievement of critical outcomes.

The nine Natural science specific outcomes are listed in section 2.3.2. The specific outcomes, among others, are:

- Achievements learners should be able to demonstrate in a specific context in particular areas of learning at a specific level;

- A comprehensive package of achievements to be accomplished in order to constitute a learning programme;

- A mode to assess the progress of learners;

- The basis for selecting subject matter needed to achieve outcomes;

- The basis for selecting cognitive learning objectives and technical skills that will enable learners to achieve end-product outcomes; and

- Supportive towards the achievements of unit standards, credits and qualifications together with assessment criteria.

3.5. THE ROLE OF NATURAL SCIENCE IN OBE

The choice of task from the spectrum of the general to the specific; the way a task influences the design of the curriculum; the methods of classroom education and the assessment of learners' performance are all functions of intellectual and practical skills. These activities allow the learners to explore the world of natural science and develop a full understanding of scientific phenomena and the procedures of scientific exploration and investigation. Natural science as a learning area envisages a teaching and learning culture that recognizes, in a South African context, a variety of learning styles. These styles do not only help learners to scientific knowledge acquisition and production thereof, but also help them to understand global issues (RNCS-22, 2002).

The impact of Natural Science as a learning area promotes scientific literacy. This is evident as Natural Science, according to the Revised National Curriculum Statement (2002: 22), focuses on:

- *Scientific investigation.*
- *Constructing scientific knowledge.*
- *Science, society and environment.*

3.6. ASSESSMENT

Assessment is not something that is tacked onto learning; it is an essential ongoing component of instruction that guides the process of learning. Ongoing assessment uses *demonstrations*, learners' explanation of concepts, mapping out of concepts or any other thought demanding tasks to ensure learners' understanding (White & Gunstone, 1993). As stated by Simmons (1994: 1) assessment is the horse that leads the cart to understanding.

Research holds that if we are going to generate any sustainable reforms, we need to examine not only our educational methods but also our ultimate educational aims (Cohen, 1993: 798). Current methods of assessment focus on the most superficial aspects of learning. The outcomes-based model of education intends to expose students to the necessity of making valuable decisions, of solving the real-life problems that focus on genuine inquiry. In the systems process, we cannot afford to limit education's goals to a simple body of intellectual knowledge no matter how comprehensive. To make this possible, education must be able to integrate what happens in a classroom to what the society expects. A question is what kind of citizens do we want to create? We would expect schools to create responsible citizens, capable of acting effectively and with an understanding of the impact of their actions on others.

The way learning achievements are assessed is inextricably linked to and based on the characteristics of the curricula, the learning programs, learning intervention and the subsequent learning process. Because content-based learning programs emphasize knowledge, the assessment will complement it, resulting in what the learner can learn and remember. Outcomes-based assessment according to Olivier (2001: 108) means assessing specific outcomes as they are mastered when integrated learning processes are followed within a specific context to achieve a pre-set outcome. By so doing, assessment will be moving from a judgmental focus to incorporate assessment of other essential attributes of learning. In this way, the nature and extent of assessment is more diagnostic in order to guide, redirect and assure learners of their progress.

3.6.1. Function of assessment

Pring (1995: 97) states that assessment is an integral part of teaching because the educator is constantly assessing what the learners know, why they are encountering difficulties and what has been achieved as a result of the teaching process. Aims, techniques and social purpose of assessment have recently been on the forefront of the public debate on education, so much so that, the function of assessment had to be spelt out.

Pring (1995: 97) asserts that assessment has a number of important functions that include:

- Giving comprehensive information of what learners know and understand or can do with the aim of finding out whether there are problems or not;

- The indication that says which learner performs better than other learners. This is done so as to differentiate in the teaching process;

- Diagnosing what the learning difficulties are;

- Giving a comparison of performance to see if standards are maintained or outcomes are achieved; and

- Giving an overview of how one school is progressing with reference to the next.

Assessment therefore surveys attainment of achievement or diagnoses learning difficulties. It also provides comparative data or evidence of school performance. It is also important to remember that the same assessment cannot fulfil each of the said separate functions. So a type of assessment used to assess each particular function has to be carried out clearly (Pring, 1995: 97).

3.6.2. Types of assessment

The way in which learning proceeds impacts directly on how assessment takes place. Outcomes-based assessment consists of a series of activities that take place to obtain information and evidence about a learner's progression and competence in achieving outcomes. Different techniques and methods are used to gather evidence to assess progress and conceptual change throughout the learning process. The focus of outcomes-based teaching and learning is on what learners *know* and *can do* at the end of the learning experience. The outcomes that have been formulated must be achieved by learners at all levels but with varying degrees of complexity in the processes (Olivier, 2002: 30; Van Rensberg, 1998: 28).

3.6.2.1. Summative assessment

According to Marnewech and Rouhoni, (1996: 280) summative assessment refers to the type of assessment that takes place at the end of a learning experience and is almost norm referenced, that is, it is always referred to a norm or standard. Usually a summative assessment means a major test or examination at the end of the school term or year. The aim thereof is to find out how much scientific knowledge or content, in Natural Science,

learners can show or remember. This is traditionally how promotion to the next grade was determined.

3.6.2.2. Formative assessment

Formative assessment according to Marnewech and Rouhoni, (1996: 280) takes place during the learning process. This type of assessment aims to inform the learning experience for each learner. Formative assessment on the other hand aims to help learners grow and progress.

3.7. CONCLUSION

Instruction and learning are processes, which occur in contexts, and thus require particular approaches. With a product-oriented approach to instruction and learning the focus is on the end product of learning. The amount of knowledge that learners possess after instruction and learning, is a measure of success. With this approach much emphasis is on what is learnt than how it is learnt. Central to the process, a teacher manages the student in a structured and controlled environment aimed at transferring knowledge, which is memorized for fact retention. On the other hand with Outcomes Based Education, the process shifts towards a process-oriented approach. The outcome remains important but more emphasis is how the outcomes are achieved. A teacher's role goes to teaching how to learn to liberate a student from reliance and rote learning, the process is referred to as strategic teaching. In this approach a teacher is a facilitator of what is to be learnt, and strategic teachers can present learners with opportunities to develop their learning potential and to develop into strategic and self-regulated learners. According to Schuell (1988: 27) this learning is an active, constructive, cumulative and goal oriented process. In the process a learner must do certain tasks to assist his processing of information such as;

- Being able to elaborate and relate new information to prior information.

- Being able to retain and process information that must be geared towards achievement of goals.

- Having expectations that motivate for the attaining of the goals.

As it is clearly put by Carl *et al.* (1988: 1), a system that is not continuously evaluated and investigated holds the danger of becoming stagnant and of raising the level of frustration of those involved. Persons involved ought not to be caught within a system that does not give enough space for renewal and experimentation.

The next chapter seeks to find the teaching techniques employed in the teaching and learning of natural science with the specific focus on lecture demonstrations. This is part of the review of the literature aimed at addressing objective **a, c** and **d** in section 1.2. Effective ways of implementing lecture demonstrations in class will be discussed. Most importantly, the chapter seek to find out from literature how concepts are formed in individuals and how conceptual development unfolds in lecture demonstrations.

CHAPTER 4

LECTURE DEMONSTRATION AS A TEACHING STRATEGY

4.1. INTRODUCTION

Several fundamental gaps in the background of learners may seriously impede on their grasp of scientific concepts and lines of reasoning. Their educators and other stakeholders seek to achieve these qualities in the teaching and learning of Natural Science. The belief that learning is the result of the interaction between what the learners are taught and their current ideas or perceptions has led to a widespread study of learners' scientific misconceptions (Posner *et al.* 1982; Driver *et al.* 1985; Driver, 1983; Driver & Easely, 1978; Viennot, 1979).

Learning science is related to learners' and educators' conceptions of science content, the nature of science conceptions, the aims of science instruction, the purpose of particular teaching events and the nature of the learning and teaching process. According to Duit and Treagust (1998: 5) learners' view of learning and the learning process is limited in that they conceptualize learning as the transfer of prefabricated knowledge that then is stored in memory. As a result, science is primarily learnt as an accumulation of facts.

This chapter seeks to find out whether lecture-demonstration enhances conceptual change, hence understanding, by looking at how concepts are formed and changed under the impact of new ideas or new information. This will be achieved by means of firstly a literature study on constructivism as a theory and strategy in science teaching and learning and later by means of an empirical survey. Emphasis will be on lecture demonstrations as that is at the core of this study.

4.2. CONSTRUCTIVISM AS AN EDUCATION THEORY

The theory of constructivism is said to have been influenced by the Piagetian learning theories. This is supported by the idea brought by Anderson (1987: 14) quoted by Frauenknecht (1998: 139) in terms of the role learners play or should play during the learning experience. The focus of this theory (constructivism) is that people do not learn passively but are always actively engaged in trying to make sense of the world around them.

The theory of constructivism is based on three premises. It firstly believes that knowledge is constructed in the mind of the learner (Novodvorsky, 1997: 242). Learners thus relate all relevant knowledge about a concept to a learning experience. According to the second premise of the constructivist theory learners come to class with prior personally constructed knowledge and beliefs that may either be relevant or irrelevant to the scientific concepts (Gunstone, 1991: 67; Hewson, 1981: 33 & Novodvorsky, 1997: 242). The third premise is based on the fact that learning is a lifelong process that is not confined to a specific period in the life of individuals (Novodvorsky, 1997: 242).

Constructivist views about teaching and learning have gained acceptance among educators as a viable framework for understanding learning and developing models of effective teaching. As such, constructivism has become an intricate aspect of current educational reform and is included in the national science education reform programme (Haney *et al.* 2003: 366).

Taylor *et al.* (1994) and Aldridge *et al.* (2000) quoted by Haney *et al.* (2003: 366) define the theory of constructivist teaching by means of five essential components that are said to help describe an effective classroom learning environment. They are:

- Scientific uncertainty.

- Learners' negotiation.

- Shared control.

- Critical voice.

- Personal relevance.

From the essential components of constructivism listed above it follows that educators who employ this theory would present scientific knowledge as arising from human experience and values, evolving and insecure, and culturally and socially determined. The principle of mutual participation and immediate feedback in this regard are fully exercised (Haney *et al.* 2003: 366).

Frauenknecht (1998: 139) asserts that learners must be challenged to change or restructure their preconceptions to make sense of their intellectual environment.

4.3. KNOWLEDGE CHANGE

The rationale of natural science as stated in the South African policy document (1997: NS – 5) seeks 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. Chinn and Brewer (1998: 99) argue that when learners learn different concepts, for example, weight and mass, there is a fundamental change in conceptions such that the conceptual system completely changes.

4.3.1. Factors initiating knowledge change

In determining factors that initiate knowledge change, it is imperative to determine the events that precede instances of knowledge change. According to Chinn and Brewer (1998: 100) knowledge is triggered by the events involving *new data, new conception and reflection.*

4.3.1.1. New data

In learning, data correspond to problems that the learner is trying to solve. Data is presented to the learner by a person (educator) or can be discovered by the learner (self-discovery). According to Chinn and Brewer (1998: 101) the relationship between the new data and current knowledge is crucial in that, new incoming data can have one of the following relationships to old knowledge:

- **Inconsistent data**

Inconsistent data are data that contradicts one's current beliefs. Inconsistent data lead learners to be dissatisfied with their current theories, which pave the way for theoretical and conceptual change (Chinn & Brewer, 1998: 101).

- **Unexplainable data**

Unexplainable data are those that cannot be explained using current knowledge. Although unexplainable data do not conflict with current knowledge, current knowledge is insufficient to generate a complete explanation (Chinn & Brewer, 1998: 101).

- **Awkward data**

Awkward data are data that can be explained using current knowledge, but only in an inelegant or clumsy manner (Chinn & Brewer, 1998: 101).

- **Consistent data**

Consistent data can be explained using current knowledge. An explanation for consistent data does not pre-exist in current knowledge (Chinn & Brewer, 1998: 101).

➢ **Matching data**

According to Chinn and Brewer (1998: 103) the simplest form of knowledge acquisition occurs when data exactly match prior knowledge. For instance, when a person who understands electric circuits sees a simple circuit with a light bulb, the person has encouraged a new instance of old knowledge. The new instance can be stored in memory, but the explanatory knowledge does not change.

4.3.1.2. New conceptions

New conceptions refer to any sort of externally provided abstract knowledge, such as a rule or a theory that counts as an explanation for some data. New conceptions are typically presented by an educator (or another person), a peer, or some resource material. New conceptions which can be accompanied by new data can be of two broad types: firstly new conceptions can be contradictory to current knowledge, and secondly, new conceptions can be consistent with current knowledge (Chinn & Brewer, 1998: 101).

4.3.1.3. Reflections

Knowledge change through reflection can be triggered by internal inconsistency among current theoretical conceptions, inconsistency among current theories and known data, excessive complexity of current conceptions, or the ability of the current theory to explain known data (Chinn & Brewer, 1998: 101).

4.4. FACTORS INFLUENCING KNOWLEDGE CHANGE

4.4.1. Prior knowledge

Prior knowledge is perceived by most researchers to have powerful effects on the learning process (Chinn & Brewer, 1998: 104, Toh, 1991: 89; and Thijs & Van den Berg (1995: 318). Chinn and Brewer (1998: 104) contend that the following aspects about

learners' prior knowledge impede knowledge change and hence conceptual change in the teaching and learning of natural science.

- **Entrenchment of prior knowledge**

A conception is entrenched to the extent that it has strong evidentiary support, that is, it participates in a broad range of explanations and that it satisfies strong personal or social goals. According to Chinn and Brewer (1998: 104) and Chinn and Brewer (1993: 44) entrenchment of prior conceptions makes theory change in response to anomalous data and inconsistent theories much less likely.

- **Quality of background knowledge**

Background knowledge refers to knowledge that is not part of a particular theory, but that can come into play when a person learns a theory. Background knowledge therefore can influence learners' response to anomalous data. The quality of this background can also influence learning from analogies (Chinn & Brewer, 1998: 105).

- **Learners' naïve philosophy of science**

Learners' conceptions of what science is and what scientists do can influence how they learn. For instance the belief that science is an enterprise of accumulating facts (rather than an enterprise of constructing theories to account for data) can inhibit learning of new theories (Songer & Linn 1991) quoted by Chinn and Brewer (1998: 105).

4.4.2. Characteristics of input information

When educators present *new* information to learners, this input can include new data, new rules, new explanatory models or theories. Many complex issues arise regarding how the characteristics of information interact with prior knowledge to influence learning. It is therefore critical for educators to ensure that information input is done with explicit

learning strategies that do not use complex and confusing analogies as these analogies may lead to alternative conceptions Chinn & Brewer, 1998: 105).

4.4.3. Processing strategies

The type of processing strategy employed by the learner can have strong influences on the course of knowledge acquisition and conceptual development. Therefore the choice of teaching and learning strategies should be determined by the learning outcomes the learners set for themselves and also on what educators hope their learners should achieve (Chinn & Brewer, 1998: 106).

4.5. CONCEPT FORMATION

It is a common practice by the scientific community to make general agreements on what a particular concept should mean. These agreements are based on valid investigations and reliable theoretical reasoning. Such agreements may take the form of an imposed definition or a generally accepted way of reasoning. However, a concept is formed through a process in which an individual recognizes similarities or identical elements in a set of objects; he thus abstracts these resemblances from the other properties of the set of objects that are not relevant to the concept (Stanton, 1989: 5 & Bolton, 1977: 9).

Research has established that learners enter their classrooms with ideas about the natural world that are not in line with accepted scientific beliefs. All reasoning not in line with accepted arguments is considered scientifically wrong and is referred to as alternative concepts. According to Thijs and Van den Berg (1995: 318) an alternative conception in science refers to a conception which in some aspects is contradictory to, or inconsistent with the concept as intended by the scientists. Such inconsistencies are manifested in the manner in which individuals relate the concepts with each other. Learners' own ideas and understanding of concepts are referred to as alternative conceptions if they have some robustness and persistence across ages and levels of schooling.

Thijs and Van den Berg (1995: 326) found that most conceptions held by students in completely different environments and cultural backgrounds are similar. This finding implies that culture and differences in man-made aspects of the environment have limited influence on the formation of concepts in physics by students. The patterns of concept formation in science parallel its historic development and have some aspect of universality. The influence of culture on concept formation may manifest only in remediation strategies for reducing existing alternative conceptions, but not necessarily on the formation of alternative conceptions. These findings were made in studies conducted amongst students in communities of different cultures and socio-economic background (Thijs & Van den Berg, 1995: 325).

According to Posner *et al.* (1982: 211) learning is concerned with ideas, their structures and the evidence for them. Learning is not simply the acquisition of a set of correct responses and verbal repertoire, or a set of behaviours. Thus learning, like inquiry, is best viewed as a process of conceptual change.

Bolton (1977: 9) asserts that there are two major theories of the nature of concept formation which are apparently in conflict. There is the traditional theory that is based on the premise that concepts are formed through a process in which a person recognizes similarities or identical elements in a set of objects. The person abstracts these resemblances from the other properties of the set of objects that are not relevant to the concept. In this theory a concept is perceived as a representation of the generalities one has observed among one's many particular perceptions.

The opposing point of view to the traditional theory is that a concept is formed, not by the subject merely attending to such general features, but by having a particular hypothesis about certain features of one's environment. Due to this hypothesis, the subject can search for evidence which supports or invalidates it. In the process of development subjects come to organize their hypotheses to form conceptual systems and in the sense it is said that the person constructs his own view of the world Bolton (1977: 1).

4.6. CONCEPTUAL CHANGE

From the theory based on constructivism, it has been proven that learners come to class with personally constructed knowledge and ideas about the world. These preconceptions stand in the way of the teaching and learning process (Driver *et al.* 1985: 3). It then becomes imperative to change the learners' perspectives or conceptions about their ideas prior to engaging in the intended learning experience. This process of changing learners' views is referred to as conceptual change (Kempa, 1988: 22).

Conceptual change is defined by Chi (1992) quoted by Hewson *et al.* (1998: 201) as the occurrence of changes either within or between existing knowledge structures, with a radical conceptual change involving a shift between two epistemologically distinct categories (e.g. from thinking of force as an entity to force as an event or a process).

Posner *et al.* (1982: 212) assert that there are two distinguishable phases of conceptual change in science. The first is based on ordinary scientific work which is done against the background of central commitments, or paradigms. These paradigms or central commitments define problems, indicate strategies for dealing with them and specify criteria for what comes as solutions.

The second phase of conceptual change occurs when these paradigms require modification. It is at this stage that a scientist or a learner with scientific conceptions is faced with a challenge to his basic assumptions. If inquiry must proceed, the scientist or learner must acquire new concepts and a new world-view. According to Kuhn this leads to scientific revolution (Posner *et al.* 1982: 212).

Conceptual change in an individual happens in a number of different ways. There can be the *addition* of new conceptions through further experience, through personal development by the individual concerned or through contact with other people. There can be a *reorganization* of existing conceptions, triggered both externally by some new idea and internally as the result of some thought processes. There can be the *rejection* of

existing conceptions as a result of a conceptual reorganization or because of its displacement by some new conceptions (Hewson, 1981: 385).

Frauenknecht (1998: 144) quotes Hewson (1981) and Posner (1982) who suggest that conceptual change is influenced by:

4.6.1. The dissatisfaction with the present ideas or conceptions

Posner *et al.* (1982: 214) and Hewson (1981: 387) contend that learners or scientists are unlikely to make major changes in their concepts until they believe that less radical changes will not work. Thus before a conceptual change occurs, it is reasonable to suppose that an individual must have collected a store of unsolved puzzles or anomalies and have lost faith in the capacity of his current or existing concepts to solve these problems. Hence a person with an existing concept C is not going to exchange it to C` without good reason to be dissatisfied with C.

4.6.2. The intelligibility of new ideas

Posner *et al.* (1982: 386) and Hewson (1981: 387) assert that the individual must be able to grasp how experience can be sufficiently structured by a new concept to explore the possibilities inherent in it. Thus a person who is faced with a new conception will not be able to incorporate it rationally into his or her existing conceptions if he or she cannot make sense of it. That is in order to find C` intelligible, the person concerned has to be able to identify or construct a coherent representation of C`. According to Hewson (1981: 387) this would require that the person be able to see that C` was internally consistent although it would not necessarily be seen to be reconcilable with other knowledge.

4.6.3. The plausibility of new ideas

According to Hewson (1981: 388) a person who is faced with a new conception which is to be rationally incorporated into his or her existing conceptions, must be able to see that

a world in which C` is true, is reconcilable with his or her own conception of the world. Such a conception would possess initial plausibility. Thus Posner *et al.* (1982: 214) conclude that any new concept adopted must at least appear to have the capacity to solve the problems generated by its predecessors; otherwise it will not appear a plausible choice.

4.6.4. The fruitfulness of the new idea

A person who is faced with a new conception would not incorporate it without good reason, particularly if it is at the expense of an existing conception. That person has to find the new conception to be fruitful. Hewson (1981: 388) contends that this phenomenon can occur under different circumstances. It could be that it solves problems experienced by C, that is, what is anomalous with respect to C`. In such a case, simply being plausible is sufficient for C` also to be fruitful. It could be that C` suggests new approaches or new experiments. Posner *et al.* (1982: 214) hold that a new concept should suggest the possibility of a fruitful research program.

4.7. Forms of conceptual change

4.7.1. Assimilation

Assimilation occurs when learners use existing concepts to deal with new phenomena. According to Piaget quoted by Roadruck (1993: 1026) knowledge is constructed by the individual based on his interactions with the environment and his understanding of it. The organization or coordination of the individual's experiences that give the individual a viable understanding of the world is described as structures. As the individual encounters new experiences he assimilates these into his existing cognitive structures.

Frauenknecht (1998: 138) describes assimilation in terms of the cognitive process by which new perceptual matter or stimuli are integrated into existing cognitive structures. The process of assimilation allows for the growth of cognitive structures called schemata,

which are already established. Assimilation does not attempt to change the schemata significantly.

4.7.2. Accommodation

This radical form of conceptual change occurs when learners' current concepts or perceptions are inadequate to allow them to grasp new phenomena successfully. This leads to the situation where learners replace or re-organize their central conception (Posner *et al.* 1982: 212).

This implies that accommodation does allow for the creation of new cognitive structures or the modification of the existing ones. This self-regulatory process or equilibration enables the individual to build new mental structures, conserve and enrich existing structures, and coordinate equivalent schemes in order to develop knowledge that better fits the environment (Roadruck, 1993: 1026).

As stated in section 4.4., learning, like inquiry, occurs against the background of learners' current conceptions. Whenever learners encounter a new phenomenon, they must rely on their existing concepts to organize their investigations. Without such concepts it is impossible for learners to ask questions about a phenomenon, to know what would count as an answer to the question, or to distinguish relevant from irrelevant features of the phenomenon (Posner *et al.* 1982: 212).

Frauenknecht (1998: 138) reduces the difference between assimilation and accommodation to the fact that, in assimilation, a new concept is forced into existing cognitive structures, while in the case of accommodation , the individual is forced to change his/her cognitive structures to fit the new ideas.

4.7.3. Conceptual understanding

Conceptual understanding is the ability to apply knowledge across a variety of instances and circumstances. Conceptual understanding differs from declarative knowledge in that the latter involves a memorization of an association between two or more entities. Conceptual understanding involves the ability to apply knowledge across a variety of previously unencountered instances. According to Darmofal *et al.* (2002: 1) conceptual understanding is considered lasting if the concept represents:

- An idea having lasting value beyond the classroom.
- Resides at the heart of the discipline.
- Requires uncoverage of alternative conceptions, and
- Offer the potential to engage learners.

4.8. TEACHING FOR CONCEPTUAL CHANGE AND DEVELOPMENT

In teaching for conceptual change and development it is essential that the range of ideas related to the topic held by learners and the educator are made explicit. As in the case of lecture demonstrations the ideas need to be contributed by both learners and the educator. In the process both parties become aware of, understand and possibly become committed to ideas that they had not previously encountered or considered seriously (Hewson *et al.* 1998: 203).

Learners' ideas, be it scientific or alternative conceptions, may be valued sufficiently to become part of classroom discourse. A proliferation of ideas will suggest the need to choose between them, leading perhaps to a status reduction for some. Educators may engage learners to make predictions that might contradict their naïve conceptions on a particular demonstration, observing and later explaining their observations using their own words (Hewson *et al.* 1998: 204).

When learners give different explanations of a particular phenomenon or a set of phenomena in a classroom, they are in effect laying out the explanations themselves as objects of cognition. Commenting on, comparing and contrasting these explanations, considering arguments or predictions to support or contradict one or other explanation, and choosing one of these possible explanations are all metaconceptual activities. As a result, educators need to be cautious of the learners' cognitive development in teaching for conceptual change and conceptual development. As Gunstone (1994) quoted by Hewson *et al.* (1998: 205) pointed out it is essential for a learner to be metacognitive in order to go through the conceptual change process.

4.9. Conclusion

From the discussion above it is evident that teaching for conceptual change and development requires a lot from educators. They need to know the content of the science curriculum, its associated teaching and learning strategies, the range of learners' alternative and scientific knowledge with regard to topics and an understanding of the conceptual issues significant in the historical development of the topic concerned. Educators also need to be well vested in the nature of or the essential features of natural science as mentioned in section 2.2.1.

Teaching for conceptual change and conceptual development requires educators to set goals for instruction, to create appropriate contexts for classroom activities and most importantly to pose thought provoking questions that have relevance and meaning to the learners.

4.10. PRACTICAL WORK AS A TEACHING STRATEGY IN NATURAL SCIENCE

Practical work is one of the many teaching strategies that is used in the teaching and learning of natural science. Roberts (2004: 113) points out that practical work is a means to an end, and not an end to itself. Practical work according to Roberts (2004: 115) comes in many guises such as:

- Skill practical.
- Observation tasks.
- Technological tasks.
- Investigations and exploratory tasks, and
- Illustrative experiments.

The last two are more related to lecture demonstrations as the educator can bring out substantive; conceptual or procedural ideas depending on the context.

4.10.1. Advantages of practical work

There are numerous advantages for using practical work in science teaching. It has a value more than just as a means of teaching ideas. Woolnough and Allsop (1985: 31) and Wellington (1998) quoted by Roberts (2004: 113) reduce the various classifications of the advantages of practical work to the following fundamental aims:

- Developing practical skills and techniques (cognitive arguments about visualizing, illustrating or affirming theory, understanding).
- Developing a problem solving scientist (affective arguments, to do with motivating, exciting, helping to remember).
- Getting a feel for phenomena (skills arguments, learning manual dexterity as well as higher order activities such as observation, measurement, predictions, explanations, and inference).

The importance of the theory of constructivism is evident from the plethora of recent studies of learners' conceptions of science related ideas and phenomena. These studies point to the personally constructed nature of the learners' conceptions. According to Gunstone (1991: 66) there is considerable evidence that learners enter science classrooms already holding personally constructed ideas and beliefs which are often at odds with the tenets of science and remarkably resilient in the face of classroom teaching.

Tamir (1991: 14) asserts that central to practical work are two key words, *discovery* and *inquiry*. He further argues that science involves highly complex and abstract subject matter and as a result most learners would fail to comprehend such concepts without introducing appropriate strategies that induce conceptual change.

4.10.2. The role demonstrations play in teaching and learning of natural science

According to Roadruck (1993: 1026) lecture demonstrations are grouped with those educational experiences that educators should use to promote concept formation and attainment and the development of formal thought.

Learners make predictions using their personal conceptions and then modify these conceptions based on the outcome of the demonstrations. Traditional laboratory demonstrations usually have an objective to verify a principle or a concept that the learners already have learned from the instructor. In this way the emphasis is on a quantitative analysis of data, (Etkina *et al.* 2002: 351).

Demonstrations are a valuable tool for every natural science educator. Demonstrations only become a teaching tool when the educator helps the learners to assimilate concepts by carefully designing, arranging and practising the demonstration, planning questions to be asked, and following up the demonstration with a thorough discussion (Roadruck, 1993: 1025).

The inclusion of concrete experience, that is, the opportunities to actually touch, smell, see and manipulate materials that would lead to concept formation appears to be important. But concrete experiences are not particularly useful if what the learner does is limited to touch, smell, see and manipulation without being forced to think about what he is doing. It would then appear that those educational experiences which encourages the intellectual debate of ideas, the weighing of evidence, and an emphasis on making sense out of observed facts are ones that lead to the development of formal thought and concept attainment (Roadruck, 1993: 1026).

4.11. NATURE AND PURPOSE OF DEMONSTRATIONS

According to Etkina *et al.* (2002: 351) in the history of physics most classical demonstrations fall into one of the following three groups:

4.11.1. Observational experiments

Observational demonstrations occur when physicists study an unknown phenomenon, that is, when they attempt to develop a new model. Very often at this stage scientists could not make theoretical predictions of what was going to happen.

4.11.2. Testing experiments

Testing experiments are usually conducted to test or disprove a certain hypothesis or idea. Physicists performing these experiments could use a theoretical model to make a prediction about what they expected to observe if their model was correct.

4.11.3. Application experiments

Application experiments utilize and synthesize physics concepts developed and tested earlier.

4.12. TYPES OF LECTURE DEMONSTRATIONS

4.12.1. *Traditional* Approach (demonstration)

Demonstrations in traditional natural science instruction are used as lecture demonstrations, high school demonstrations, and laboratory demonstrations. However there are two pedagogical techniques used for lecture demonstrations. In a traditional approach, learners observe an experiment or a demonstration, then the instructor, which is normally a teacher, explains what happened and why. In reformed approach, learners predict what is going to happen before the demonstration is carried out, and then they reconcile their predictions with the observations that follow. The latter has proven to be more effective than the former. This approach is described as the Predict – Observe – Explain (POE) approach (see Etkina *et al.* 2002: 351 & Gunstone, 1991: 69).

Trowbridge and Bybee (1990: 234) outline the different ways in which demonstrations can be presented. These include: *lecture/teacher demonstrations*; teacher-learner demonstrations; learner-group demonstrations; individual learner demonstrations and guest demonstrations.

4.12.2. The Predict-Observe-Explain approach

The POE, as the Predict-Observe-Explain approach is based on the classical model of research where a hypothesis is stated and reasons are given for why this may be true. Thereafter relevant data is gathered and results are discussed. The POE approach involves learners predicting the results of the demonstration and discussing the reasons for their predictions, observing the demonstration and finally explaining any discrepancies between their predictions and observations (Kearney *et al.* 2003: 13; Kearney, 2003: 589).

4.12.3. Multimedia Demonstration

Multimedia instruction refers to the combination of communication media: text; hypertext; graphics; still images; sound; interactive video and animations directed and coordinated by the computer and portrayed on the computer screen, (Jenkinson, & Fraiman, 1999: 283).

4.13. IMPLICATIONS OF THE USE OF DEMONSTRATIONS IN THE TEACHING AND LEARNING OF NATURAL SCIENCES

Scientific understanding, as promoted by demonstrations, involves learners' learning of concepts and forming models of science as well as the development of their abilities to be engaged in scientific enquiry according to contextual demands. Learners exposed to lab work such as demonstrations are involved in the world of ideas representing the world of things. They are engaged in purposeful observation of and intervention into the world by using specially developed apparatus. Conceptual and procedural knowledge are intertwined and can be enhanced by demonstrations (Psillos & Niedderer, 2002: 21).

4.14. VISUAL IMPACT

Detailed discussion of how visual impact or lack of, can affect the learning outcome or conceptual development will be outlined in subsequent sections.

4.15. GUIDELINES FOR EFFECTIVE LECTURE-DEMONSTRATIONS

According to O'Brien (1991: 934) lecture demonstrations can guide learners to constructive and accurate concept formation and in the process help them to become competent in natural science. It can also help them with the application of concepts in everyday life. As with other instructional strategies, careful planning is essential so as to increase the probability of success.

4.15.1. Planning

Roadruck (1993: 1026), O'Brien (1991: 934), Trowbridge and Bybee (1990: 232) contend that to plan an efficient and effective demonstration requires extensive organization and consideration of the following points:

4.15.1.1. Identifying concepts and principles

It is crucial to firstly, before you engage on demonstrations ensure that you have identified the relevant concepts and principles you want to show to the class. Educators should explicitly identify the purpose of the demonstration beforehand. By so doing you will, as an educator be able to direct the design of the entire demonstration to the attainment of the said concept and principle (Trowbridge & Bybee, 1990: 233; O'Brien, 1991: 934).

4.15.1.2. Breaking down complex principles

In the event that the principle envisaged to prove or show is complex, one should break it down into concepts accompanied by several examples. While a given phenomenon may effectively demonstrate a number of disparate concepts, it is advised that educators should avoid overtaxing learners' conceptual abilities by attempting to teach too much at one time (O'Brien 1991: 934; Trowbridge and Bybee 1990: 232).

4.15.1.3. Choice of activity

At this stage it is essential for the educator to show the concepts he/she wishes to emphasize. It will also be helpful to consult the sources at the end of the chapter or study unit for possible suggestions regarding activities (Trowbridge & Bybee, 1990: 233).

4.15.1.4. Designing the activity

With outcomes-based learning the learning process focuses on the outcome. To start learning by first defining the outcome, or finding the exact challenge, is in most cases more complex than to master the supportive knowledge or to find solutions for already existing problems. Therefore, the activities before the actual demonstration phase should be thoroughly designed so that they involve learners as much as possible with clear outcomes (Olivier, 2002: 96; Trowbridge & Bybee, 1990: 233)

4.15.1.5. Equipment

Educators should always ensure that equipment that is intended to be used for a particular demonstration lesson are gathered and assembled on time. It has to be ascertained that the equipment is in good working conditions and tested beforehand (Trowbridge & Bybee, 1990: 233).

4.15.1.6. Preparation

During the preparation phase it is crucial to go through the intended demonstration at least once before the class begins so as to ensure that all equipment is in order and the outcome is clearly outlined (Trowbridge & Bybee, 1990: 233).

4.15.1.7. Questioning

Thinking is an active mental process, and the only way in which learners learn to think is by having an opportunity to do so. It is for this reason that Trowbridge and Bybee (1990: 233) use questioning as an inductive way of demonstration. An inductive demonstration has the advantage of stressing inquiry, which encourages learners to analyse and make hypotheses based on their knowledge. It is therefore important for the educator to outline questions he/she will ask during the demonstration.

4.15.1.8. Visual aids

Very often visual aids are used to supplement the demonstration. At this stage educators are encouraged to consider how they will use such equipment (Trowbridge & Bybee, 1990: 233).

4.15.1.9. Evaluation techniques

The learning outcomes to be achieved by the learners, sometimes describe how, under what conditions and at what levels learners must demonstrate retainment of knowledge or insight. Educators have a choice in evaluating learners on the demonstrations. They can opt for:

- **Written techniques**

Learners can take notes and record data during the demonstration and later write a summary of the demonstration. Learners may alternatively be asked to answer questions or prepare diagrams to establish whether they can apply the demonstrated principles (Trowbridge & Bybee, 1990: 233).

- **Verbal techniques**

Learners may be asked to summarize the purpose of the demonstration, or they may be given problems in which they will have to apply the principles they have learnt (Trowbridge & Bybee, 1990: 233).

4.15.1.10. Time

Whilst in the preparation phase, it is important to check the duration of the demonstration, that is, whether the demonstration will be appropriate for a single or a double period so as to adjust the time slot accordingly. Educators are encouraged to

conduct the demonstration rapidly to keep the learners attentive. Prolonged and complicated demonstrations are generally undesirable because they do not hold the learners' attention (Trowbridge & Bybee, 1990: 233).

4.15.1.11. Planning

When planning a demonstration, it is essential to do it well, with the intention that it will be used for several years. This will help to reduce the time span for the same demonstration in future. A demonstration should be evaluated immediately after it has been conducted so as to determine its weaknesses and strengths (Trowbridge & Bybee, 1990: 233).

4.15.2. Actual demonstration

4.15.2.1. Visibility

In a research project conducted by Roth *et al.* (1997: 520) it was discovered that often during demonstrations learners do not focus on what is intended to by the educator due to obscured visibility. It is for this reason that O'Brien (1991: 935) and Trowbridge and Bybee (1990: 233) contend that educators should ensure that all equipment is clearly visible to all members of the class and that the educator is also fully visible. In the case of small apparatus an overhead projector may be used.

4.15.2.2. Voice

In order to keep learners interested and attentive, educators should speak loudly enough to be heard at the back of the classroom. The tone and volume of the voice should be modulated to avoid monotonous delivery. When learners respond to questions or when they ask questions, it should be done so that other members of the class can hear as well (Trowbridge & Bybee, 1990: 233).

4.15.2.3. Presentation

The constructivist view of learning suggests that learners build their own frameworks of ideas by fitting their new sensory experiences in their pre-existing mental structures. Learners construct their own knowledge, strongly influenced by what they already know and the construction is facilitated by social interactions. In this way learners build their own sense of reality. This theory, (constructivism), encourages educators to recognize the views and ideas which learners bring to the classrooms and provide experiences that will help them build on their current knowledge of the world. Constructivist classrooms rely on learners sharing and discussing their own personal interpretations of the world, hence written and oral communication become vital in this process (Kearney *et al.* 2003: 13; White & Gunstone, 1993: 42).

In presenting the demonstration, educators are encouraged to engage in the POE approach as it enhances learners' understanding by requiring them to carry out three tasks:

Firstly, learners will be asked to predict the outcome of the principle or concepts investigated and justify their predictions. It is during this stage where educators can learn about learners' alternative conceptions. Learners then secondly observe the demonstration while the educator highlights essential facts. Finally the educator facilitates reconciliation between predictions and observations. It is crucial to note that educators play a facilitator's role in the process and learners do the discovery (Kearney *et al.* 2003: 14).

Roth *et al.* (1997: 511) contend that demonstrations should not be presented in a traditional way where an educator is the sole active participant in the teaching-learning environment. The result of such a presentation is seen in the learners' failure to extend the application of principles demonstrated.

When presenting a demonstration the content must be accessible to learners. This will be of great help as most learners are functional below the formal operation level. The content level needs to begin at best at the concrete level because very often demonstrations are nearly abstract and intellectually inaccessible to our naïve learners (Roadruck, 1993: 1026).

4.15.2.4. Questioning techniques

Trowbridge and Bybee (1990: 233) argue that the way in which demonstrations are presented impact on the learners' concept formation. Therefore there are certain important aspects that educators should dwell on when presenting the demonstration. These include:

- Displaying excitement and making the demonstration come alive.

- The setting of the equipment for demonstrations.

- Starting a demonstration with everyone's involvement, probably with a challenging question.

- Getting learners' attention by placing, for instance, a Van de Graaff generator on the demonstration table. This would motivate learners' inquiring minds.

- Teach inductively.

- Constantly ask questions about what you are doing, what is happening, what learners think is the cause of the occurrences and what the demonstration is proving, illustrating or verifying.

- Educators should always know the purpose of the demonstration. Always accommodate learners' questions and inputs on the demonstration.

- Give positive reinforcement, that is, as an educator it is important to recognize learners' responses and give them praise so that they are encouraged to give more input. By so doing alternative conceptions that learners bring to class can be attended to.

- Allow at least three seconds after asking a question to give those learners who are said to be slow an opportunity to think about the response.

4.15.2.5. Use of media

Trowbridge and Bybee (1990: 234) stress the fact that educational media like chalkboards, overhead projectors and computers should be used to describe the purpose of the demonstration because pictures do not only attract learners attention but stimulates their thought as well.

4.15.2.6. Conclusion

In concluding a lecture demonstration, it is advisable to have learners summarizing what has occurred and what was the purpose thereof. This summary according to Trowbridge and Bybee (1990: 234) helps to fix the purpose of the demonstration in learners' minds. It is also imperative for educators to evaluate their teaching-learning encounter. This can either be verbal or in a written form to enable the educator to improve or if necessary to repeat the encounter.

4.16. Justifying Lecture-Demonstrations

Lecture demonstrations may be justified for the following reasons:

- Lower costs.

- Availability of equipment.

- Economy of time.

- Fewer hazards from dangerous materials.

- Direction of the thinking process.

- Showing the use of the equipment.

4.17. CONCLUSION

Learning science involves learning to use the ideas and features of science to interpret, explain and explore events and phenomena in the natural world. This is a long term process which is difficult to achieve as it is not a straightforward exercise to translate knowledge about learning into strategies for more effective teaching (Asoko, 2002: 153).

Well conducted dramatically presented demonstrations will draw learners' attention. However demonstrations must be more than just a show. If they are to be educationally defensible, they must engage the learner in an interaction with significant natural science content. To achieve its purpose in developing an understanding of the content, lecture demonstrations must be part of a lesson that gets learners actively involved with the event and the content it seeks to impart. The demonstrator must involve the learners in the experience through questioning, predicting, offering of explanations and the testing of those explanations.

It was discovered in a study conducted by Crouch *et al.* (2004: 836) that giving learners a couple of minutes to predict the outcome of the demonstrations and record their predictions is economic use of time and most importantly yields better understanding.

Crouch *et al.* (2004: 836) assert that involving learners by having them predict the outcome of the demonstrations is a simple step towards increasing learners' engagement and improving learning from demonstrations.

The next chapter outlines the research methodology followed in this study. It focuses on the use of questionnaires as a measuring instrument. It outlines data collection, data analysis, the population under survey and the processing of the data.

CHAPTER 5

RESEARCH METHODOLOGY

5.1. INTRODUCTION

This chapter intends to outline the method and procedure employed in this research. The subsequent sections will reveal the details of the research.

5.2. LITERATURE STUDY

The literature survey on this study was done extensively to elicit the work previously done on concept formation and conceptual development brought about by lecture demonstrations by Asoko, (2002: 153) and Lynch & Zenchak, (2002: 1). According to these authors science educators often employ demonstrations to show scientific principles in action. However, there may be some problems with the practice. This study is on school level and is limited to the school syllabus's scientific content (Heyns *et al.* 1990).

Relevant references were obtained by means of an EBSCO host web search for publications relevant to this topic in scientific and educational journals and on the Internet. The developmental background done previously on the topic played a major role in the compilation of this study (see Vreken, 1980). The materials cited in this study were obtained from the North-West University (Potchefstroom campus).

The first part of the literature study (chapter 2) gave an overview of the nature of natural science with specific emphasis on physics. The essential features such as the framework of physics were dealt with in detail so as to give an understanding of what components constitute natural science (physics). The understanding of the nature of physics is crucial as its features (structural framework), are helpful towards concept formation and conceptual development.

The second part of the review of the literature (chapter 3) covered outcomes-based education within the context of natural science. In this chapter reasons for curriculum reform are outlined with the hope of reaching a meaningful paradigm shift in South African education, in particular in natural science education.

The last part of the literature survey covered lecture demonstrations as a teaching strategy in natural science (section 4.10 & 4.15). Constructivism as a theory in the teaching and learning of physics is touched upon (section 4.2.). Effective ways in teaching for conceptual development are explored as a means to address the objectives stated in section 1.2 and to prove the research hypothesis (section 1.3).

5.3. EMPIRICAL RESEARCH

5.3.1. Population

The population targeted for this study consisted of 20 science educators teaching physical science (physics and/or chemistry) at grade 12 level at schools situated in Potchefstroom, Fochville and Ventersdorp and a group of 109 grade 12 learners who are enrolled at these schools.

The schools and consequently the learners and educators were randomly selected. According to Stoker (1989: 103) randomness is at the core of the process of obtaining a representative part of the population by means of probability sampling. In random sampling the selection 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 assume that the characteristics of the sample approximate the characteristics of the total population (Leedy & Ormrod, 2001: 211 & Stoker, 1989: 104). The results of the study can thus be generalized.

5.3.2. Nature of research

In order to pursue the objectives of this study, a quantitative survey was done. Lecture demonstrations were presented to the groups of Grade 12 science learners at their schools. The demonstrations were based on the following topics in mechanics: *momentum, change in momentum and energy*. This is a section of the Grade 12 physical science curriculum (Heyns *et al.* 1990).

In order to assess learners' learning gains by means of demonstrations relevant to the mentioned topics, the pre– and post-test method was employed. Before any demonstrations were conducted learners were given a pre-test (Appendix 5). Educators then conducted the lecture demonstrations. Learners' involvement was considered to be the critical aspect of the activity. After conducting the demonstrations, explanations to small group discussions, followed by class discussions were held.

Six weeks after the lecture demonstrations the post test (Appendix 5) was administered to the same groups to determine the learning gain and hence the conceptual development attained by means of the lecture demonstrations.

5.3.3. Data collection

Gay and Airasain (2000: 211) contended that gathered data are rarely numerical as they are both rich in detail and lengthy. The most frequently used data collection strategy employed in research involves interviews and/or observations. The key element to the success of this strategy is the integrative and interpretative skills of the researcher.

Because interpretations arise from the interplay of existing understanding (prior knowledge) and the observer's world, what one observes depends on what one already knows. It is for this reason that it is widely accepted that observations are interpretations (Feyerabend, 1976; Hanson, 1965; Hodson, 1992; Rorty, 1989) quoted by Roth *et al.* (1997: 512). That means whilst a learner is observing he/she is engaged in a series of

mental activities of interpreting and drawing conclusions on the occurrences. In this study data were collected by means of observations, questionnaires and personal interviews (Appendix 2).

The questionnaires developed and utilized in this study were administered to a group of learners in the three schools described in section 5.3.1. A separate questionnaire was administered to a group of educators in the areas described in section 5.3.1 (appendices 2 & 4). Learners were allocated forty five (45) minutes and educators thirty (30) minutes to complete the questionnaire. The time allocated to complete the questionnaires seemed to be reasonable as both groups managed to complete it before the allocated time elapsed. The researcher supervised the completion of the questionnaire at the respective schools to ensure that the subjects of the study (learners and educators) do not encounter difficulties and that the conditions under which the questionnaires were completed were similar. As is stated before the pre– post-test method was used to measure the learning gains obtained by the lecture demonstration method.

During and prior to the pre-test there were no science demonstrations relevant to the physics sections included in this study (refer to section 5.3.2.).

After the pre–test learners were exposed to lecture demonstrations conducted by their educators. As it was stated earlier the learners' involvement was considered to be the critical aspect of the activity. Educators used the Predict-Observe-Explain (POE) approach in executing the demonstrations. In this approach learners are encouraged to predict the outcome of the demonstration before it is conducted. At this prediction stage the educators attempted to retrieve learners' pre-constructed knowledge regarding the phenomenon in question. For instance, different coins were placed on the demonstration table as shown in the diagram (Diagram 5.1.). Learners were then asked to predict what would happen if A (a 50c coin) collides with B (a R5 coin) held firmly down by the thumb of a learner. They were also asked to compare the velocity V of coin A before collision with that of coin C (V_1) (a 20c coin) after collision. This demonstration was conducted to probe understanding of the concept momentum conservation and

momentum as being the product of the mass and velocity of an object. An example of the demonstrations conducted is given below (extracted from Appendix 5). In total 8 demonstrations were conducted.

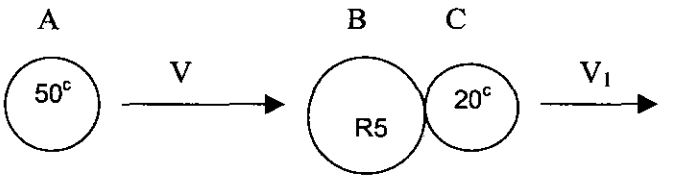


Diagram 5.1. A 50^c coin A approaching at velocity V from the left hits a stationary R5 coin B, resulting in the movement of C a 20^c coin away from B. (The collisions are linear and B is pressed firmly downwards on the table by a learner).

After the prediction phase the experiment was performed, observations were made and learners were asked to explain their observations. Explanations of the demonstrations were given by small groups and class discussions were held.

Immediately after this phase personal interviews between the researcher and the subjects were held. The outcomes of the interviews are given in the next chapter (chapter 6).

Six weeks after the demonstration a post-test was administered to the same groups of learners to determine if there was any change in achievement and conceptual development in the syllabus section on momentum due to the intervention. The time allocated for the two tests (pre- and post-) was two hours each with the researcher supervising. The setting for the tests was of a formal class arrangement where learners worked individually.

5.3.4. Data analysis

Data for this study were processed by means of statistical software available at the North West University, Potchefstroom campus (Ellis & Steyn, 1999).

5.3.5. Instruments

Measurement instruments provide a basis on which the entire research effort rests. A requirement is thus that the instrument used must be valid and reliable (Leedy & Ormrod, 2001: 98 and Wiersma, 1995: 20).

The next two paragraphs reflect on the validity and reliability of the questionnaires.

5.3.5.1. Validity of the instrument

The validity of a measurement instrument refers to the extent to which the instrument measures what it is supposed to measure (Leedy & Ormrod, 2001: 98). For the purpose of this study content validity was considered to be appropriate as the questionnaires focused on sections of mechanics. The instruments assessed whether lecture demonstrations enhance conceptual development in this section of mechanics to concur with the hypothesis and in the objectives stated in section 1.2.2.

5.3.5.2. Reliability of the instrument

The reliability of a measuring instrument is the extent to which it yields consistent results when the characteristic being measured has not changed (Leedy & Ormrod, 2001: 98). The reliability of the instrument in this study was tested by means of matched items in educators' and learners' questionnaires. The results are discussed in paragraph 6.6.1. – 6.6.6.

5.3.6. Questionnaires

When carefully constructed, questionnaires have a number of benefits to the researcher. Apart from being economical in terms of time and costs to both the researcher and respondents, questionnaires facilitate contact with the subjects participating in the study when they could otherwise not be reached (Schnetler *et al.* 1989: 50).

In this study a three point Likert-type scale (Schnetler *et al.* 1989: 50) was employed because of its flexibility and the wide range of constructs that the scale can measure. This range may vary from abstract to specific and has a number of categories of response. According to Schnetler *et al.* (1989: 68) the number of responses given on the scale, gives an indication of the degree of agreement or disagreement on measuring the following: Firstly the frequency at which lecture–demonstrations are conducted at the schools mentioned in section 5.3.1; secondly, how lecture–demonstrations are conducted at the said schools; thirdly, how the POE approach is carried out at the targeted schools and fourthly, to investigate whether or not conceptual development is enhanced by lecture-demonstrations.

In this study, the items of the questionnaire were arranged in such a way that they could be ranked such that, if a respondent reacts positively to a particular item, he will respond similarly to all other items with a lower rank. The scale used is cumulative in nature in that all respondents indicate the items with which they agree, as well as those with which they don't.

5.3.6.1. Questionnaire Items

The items in the questionnaires used in this study were constructed to cover the objectives (see section 1.5.2.) of the study. It focused on the general state of affairs with regard to strategies employed in the teaching and learning of grade 12 physics at schools. It also probed on how lecture demonstrations are conducted at the targeted schools of this study. Specific items in the questionnaire are discussed in detail in the next chapter (chapter 6).

5.4. CONCLUSION

In this chapter the research methodology employed was outlined. It reflected on the literature study, the population, data collection, analysis of the data and the measuring instruments used.

In the next chapter the results of the empirical survey are reported, analyzed and discussed.

CHAPTER 6

EMPIRICAL SURVEY AND RESULTS

6.1. INTRODUCTION

As mentioned in section 5.3 of this dissertation data for this study were collected by means of questionnaires administered to educators and learners as well as by means of pre- and post-tests (Appendix 1 - 4 and Appendix 5). The pre- and post-tests constituted a learning gain test as they were meant to measure learners' learning gains. The pre- and post-tests quantified conceptual development. The questionnaires were administered to both educators and learners involved in the teaching and learning of grade 12 physics at the three selected schools. This chapter presents a discussion of the empirical results obtained by means of the questionnaires and by means of the learning gain tests.

6.2. EDUCATORS' DEMOGRAPHIC INFORMATION

The demographic information of the educators who participated in this study is shown in Table 6.1

TABLE 6.1. EDUCATORS' DEMOGRAPHIC INFORMATION (N = 20)

MALES	FEMALES	TEACHING EXPERIENCE (IN YEARS)						ACADEMIC QUALIFICATIONS				PROFESSIONAL QUALIFICATIONS		
		<5	6	7	8	9	>10	M	M+3	M+4	M+5	M+3	M+4	M+5
10	10	11		1	3		5	20				15	4	1

6.3. LEARNERS' DEMOGRAPHIC INFORMATION

The demographic information of the learners who participated in the study is shown in Table 6.2.

TABLE 6.2. LEARNERS' DEMOGRAPHIC INFORMATION (N = 109)

Gender					Male **72**	Female **37**
Have you registered as a higher or standard grade candidate in natural science?					HG **12**	SG **97**
Years in grade **Number of learners**			1st **109**	2nd **0**	3rd **0**	>3 **0**
Age of learners (in years) **Number of learners**			16 **1**	17 **10**	18 **29**	> 19 **69**
Your last examination mark for Physical Science (June 2004) **Number of learners**	A 100-80	B 79-70 **3**	C 69-60 **14**	D 59-50 **24**	E 49-40 **36**	F < 40 **32**

6.4. RESULTS OF EDUCATORS' QUESTIONNAIRE

The educators' questionnaire was subdivided into three subsections: Firstly it covered the situation analysis at the schools where the research was conducted with regard to the availability of apparatus and its condition. Secondly the questionnaire probed into their teaching and practices employed in the learning of science and thirdly, it attempted to reveal how demonstrations are conducted at the schools selected for this study.

The next paragraph gives the item by item responses of educators.

6.4.1. Results of educators' questionnaires

The completed questionnaires received from the 20 educators who were involved in the survey were processed by hand. The results are given in table 6.3. (For the exact formulation of the items in the questionnaire see Appendix 4).

TABLE 6.3. RESULTS OF EDUCATORS' RESPONSES (N = 20)

ITEM	AGREE		DISAGREE		AGREE WITH RESERVATIONS	
	n	(%)	n	(%)	n	(%)
1. I Incorporate lecture demonstrations in my teaching	13	65	1	5	6	30
2. I remove distracters	18	90	1	5	1	5
3. I start demonstrations with a problem question	12	60	4	20	4	20
4. lecture demonstrations are easy to conduct	13	65	1	5	6	30
5. I reach intended outcomes	8	40	6	30	6	30
6. Outcomes are clearly stated	10	50	5	25	5	25
7. I discuss learning outcomes with learners	10	50	2	10	8	40
8. Learners' concentration span lapses during demonstrations	5	25	11	55	4	20
9. I ask thought provoking questions	15	75	2	10	3	15

10. I remain silent during demonstrations	**15**	**75**	**2**	**10**	**3**	**15**
11. I don't have difficulty in demonstrations	**1**	**5**	**15**	**75**	**4**	**20**
12. I test apparatus beforehand	**19**	**95**	**0**	**0**	**1**	**5**
13. I control my tempo	**15**	**75**	**0**	**0**	**5**	**25**
14. Voice clarity is essential in demos.	**20**	**100**	**0**	**0**	**0**	**0**
15. I improvise	**14**	**70**	**3**	**15**	**3**	**15**
16. School buys apparatus	**2**	**10**	**14**	**70**	**4**	**20**
17. Education department supply resources once a year	**6**	**30**	**12**	**60**	**2**	**10**
18. I use POE approach in demos	**13**	**65**	**1**	**5**	**6**	**30**
19. Learners are engaged in demos	**19**	**95**	**0**	**0**	**1**	**5**
20. Learners are actively involved in science demos	**14**	**70**	**1**	**5**	**5**	**25**
21. Learners come to class with alternative conceptions	**15**	**75**	**2**	**10**	**3**	**15**
22. I let learners formulate their learning objectives	**8**	**40**	**11**	**55**	**1**	**5**
23. Learners predict results before demos are conducted	**12**	**60**	**4**	**20**	**4**	**20**
24. Lecture demos are effective in combating alternative conceptions	**16**	**80**	**2**	**10**	**2**	**10**
25. In lecture demos, learners predict before	**10**	**50**	**4**	**20**	**6**	**30**

the actual demo is conducted.			

In the next paragraph the results are discussed item by item. Comparisons are made between educators' and learners' responses (Table 6.4.).

Item 1 (I incorporate lecture demonstrations in my presentation at least once per week during practical sessions in physical science)

Thirteen (65%) of the responding educators indicated that they incorporate lecture demonstrations during the practical sessions in their teaching in physical science. This seems to concur with what the learners revealed as 75% of them agreed that their educators do perform science demonstrations in class (see summary of the results of the learners' questionnaire – Appendix 2)

Item 2 (Before I start with demonstrations, I remove all possible distracters from the demonstration table)

Educators in response to this item revealed that it is essential to ensure clear visibility on the demonstration table as eighteen (90%) agreed that they remove distracters from the demonstration table. This is verified by 76% of the learners who agreed that during science demonstrations they are able to see the apparatus and proceedings of the demonstration quite well.

Item 3 (I always start demonstrations with a problem question)

Twelve (60%) of the educators agreed that they start science demonstrations with a problem question. This item is linked with *items 4, 15 and 19 of the learners' questionnaire.* 78% of the learners agreed that their educators do ask questions. Not only do the educators start with a problem question before demonstrations, but they, according

to 76% of learners, ask challenging questions. 82% of the learners further agreed that the educators ask questions that are related to the activity they are engaged on.

Item 4 (Lecture demonstrations are easy to conduct)

Conducting demonstrations seemed not to be a problem to most educators as thirteen (65%) of them agreed that they can easily conduct demonstrations.

Item 5 (I reach the intended learning outcomes with lecture demonstrations)

Eight (40%) of the educators indicated that they reach the intended learning outcomes with the aid of lecture demonstrations. This seemed to concur with the learners as 47% said that the learning outcomes intended by the demonstrations conducted by their educators are achieved.

Item 6 (The outcomes are clearly stated before demonstrations)

According to Roberts (1996: 2) a learning instruction should be defined in terms of outcomes to be achieved, yet ten (50%) of the educators agreed that they do state the learning outcomes before the actual demonstrations were conducted. 53% of the learners also agree that their educators state the learning outcomes intended by the demonstrations.

Item 7 (I discuss the learning outcomes with my learners)

It is essential to discuss the learning outcomes with learners as that will guide both the learners and educator to stay focused on the intended activity. Educators in this item seemed to concur as ten (50%) indicated that they discuss the learning outcomes of the demonstrations with their learners prior to the demonstrations.

Item 8 (Learners' concentration span lapses during demonstrations)

When demonstrations are presented in a traditional approach, where an educator is a sole participant, there is a likelihood that learners' concentration will fade and that they will ultimately lose interest. In this item eleven (55%) of the educators disagreed that learners' concentration span lapses during demonstrations. On the other hand 44% of the learners indicated that their concentration span can stand the time allocated for demonstrations.

Item 9 (I ask thought provoking questions during demonstrations)

Learners must always be challenged with thought provoking questions so as to gather how much they know about a particular concept in physical science so that the educator can teach accordingly. In this item fifteen (75%) of the educators indicated that they ask thought provoking questions. This is in line with what the learners said about their educators as 76% of them agreed that the educators ask challenging questions.

Item 10 (I sometimes remain silent during demonstrations)

Displaying excitement and making demonstrations come alive is one of the recipes for a successful science demonstration lesson. However it is also crucial to know when to remain silent where sound effects are expected to surface during demonstrations. In this item fifteen (75%) of the educators agreed that they sometimes remain silent during the demonstrations.

Item 11 (I don't experience difficulty in conducting demonstrations due to the availability of apparatus)

In this item fifteen (75%) of the educators agreed that they have to face difficulties in conducting demonstrations due to the lack of or unavailability of apparatus. These indicated the willingness of the educators to conduct science demonstrations but they are discouraged by the lack of apparatus.

Item 12 (I test the apparatus that I will use before the actual demonstrations in class)

It is good practice to test apparatus before the actual demonstrations are carried out in class. This helps with time and the success of the intended demonstrations. In this item nineteen (95%) of the educators agreed that they test the apparatus ahead of the actual demonstrations in class.

Item 13 (I control my tempo when conducting demonstrations)

Fifteen (75%) of the educators indicated that they control their tempo when conducting demonstrations. This is in accordance with Trowbridge and Bybee's (1990: 233) guidelines that it is essential to control ones' tempo to keep learners interested and attentive.

Item 14 (Voice clarity is essential in lecture demonstrations)

The response by educators in this item concurred with what Trowbridge and Bybee (1990: 233) advised on voice control. All twenty (100%) educators agreed that voice clarity is essential in lecture demonstrations. An educator should speak loud enough to be heard at the back of the classroom. The tone and volume should be modulated to avoid monotonous delivery.

Item 15 (In the absence of relevant resources, I improvise to verify the concept dealt with in specific sections)

This item was included so as to elicit educators' creativity with regard to improvising science demonstrations. A relative high percentage (70%) of the educators indicated that they do improvise in case the relevant apparatus are unavailable.

Item 16 (Our school buys apparatus to augment shortages)

Fourteen (70%) educators disagreed with the statement indicating that the schools do not buy apparatus in case there is a shortage. This item revealed that it is not normal practise for schools to buy apparatus from school funds. It could be that science apparatus are not budgeted for by schools and that buying remains the prerogative of the education department.

Item 17 (I acquire new resources from the department once every year)

This item was included so that it should consolidate item 16 above. From the response it is clear that the conclusion above is valid because a similar percentage twelve (60%) of the educators indicated that they do not acquire new resources from the department annually.

Item 18 (I use the POE approach in presenting demonstrations)

The item revealed that a fairly good percentage (65%) of the educators involved in this investigation use the POE approach in presenting science demonstrations.

Item 19 (Learners are engaged in lecture demonstrations)

Nineteen (95%) of the educators indicated that they engage learners in their lecture demonstrations. Educators believe that by asking learners to perform certain duties during demonstrations help stimulate their thinking. For instance, an educator asks a learner to hold a test tube during a demonstration.

Item 20 (I find learners to be actively involved in lecture demonstrations)

In this item fourteen (70%) agreed that learners are actively involved in lecture demonstrations. In *items 16* and *20* of the learners' questionnaire, 82% stated that their

educators ask questions during demonstrations and 41% indicated that they are given the opportunity to respond to the questions asked by their peers.

Item 21 (I frequently find out that learners come to class with alternative conceptions)

The educators seemed to agree that knowledge is constructed in the mind of the learner and that learners learn from the environment, as fifteen (75%) indicated that learners come to class with alternative conceptions.

Item 22 (I let learners formulate their learning outcomes for the particular lesson)

In this item eleven (55%) of the educators indicated that they do not let learners formulate their own learning outcomes for the lesson.

Item 23 (My learners predict the results of the demonstration to be carried out)

This item revealed that twelve (60%) of the educators allowed learners to predict the results of the demonstration to be carried out.

Item 24 (I find lecture demonstrations to be effective in combating learners' alternative conceptions)

Sixteen (80%) agreed that lecture demonstrations are an effective means in combating learners' alternative conceptions when conducted properly.

Item25 (In lecture demonstrations, learners predict before the actual demonstration is carried out)

This item was included to confirm whether or not educators are consistent and understand the nature of the POE approach. In item 23 60 % of the educators agreed that they

allowed their learners to predict the outcome of the demonstration. In this item, ten (50%) of the educators indicated that in lecture demonstrations learners predict before the actual demonstration is carried out.

The next paragraph gives the items in the learners' questionnaire, the learners' responses to the items and an analysis of the responses.

6.5. RESULTS OF LEARNERS' QUESTIONNAIRE

The learners' questionnaire was compiled to probe the situation with regard to, firstly, the frequency at which their educators conduct lecture demonstrations, secondly how their educators conduct lecture demonstrations, and thirdly, how do they (learners) perceive lecture demonstrations.

6.5.1. Results of learners' responses.

The completed questionnaires from the 109 learners who were involved in this survey were processed by hand. The results are given in table 6.4. (The items in the questionnaire are stated in abbreviated form. For complete statements refer to Appendix 2).

TABLE 6.4. RUSULTS OF LEARNERS' QUESTIONNAIRE (N = 109)

ITEM	AGREE		DISAGREE		AGREE WITH RESERVATIONS		$\sum$ n
	n	(%)	n	(%)	n	(%)	
1. My educator performs science demos	81	74	15	14	12	12	109
2. I can see all apparatus during	82	75	23	22	3	03	109

demos						
3. Educator establishes prior knowledge	55	51	34	31	19	18	109
4. Educator asks questions during demos	86	79	11	10	11	11	109
5. Outcomes are clearly stated	58	54	25	23	25	23	109
6. Apparatus are available at school	69	63	17	16	22	21	109
7. Science demos stimulate thinking	61	56	20	19	27	25	109
8. Science demos are easy to understand	62	58	21	19	25	23	109
9. Science demos improve my understanding	82	76	13	12	12	12	109
10. Science demos help to prepare for tests	81	74	13	13	13	13	109
11. I have difficulties in understanding principles in demos	65	60	28	26	15	14	109
12. My concentration span can stand time in science demos	47	44	20	19	40	37	109
13. Science demos are thought provoking	36	33	34	32	38	35	109
14. Science demos are convincing after an argument	80	74	7	07	20	19	109
15. I am challenged	83	76	12	12	13	12	109

by questions asked by my educator during demos						
16.I am encouraged to ask questions	**89**	**82**	**11**	**11**	**7**	**07**	**109**
17. Educator spends time to clarify uncertainties	**70**	**65**	**22**	**21**	**15**	**14**	**109**
18. Educator gives time for learners to think of answers	**70**	**64**	**27**	**25**	**11**	**11**	**109**
19. Questions asked are related to activity	**89**	**82**	**10**	**09**	**9**	**09**	**109**
20. Educator does not give answers to questions asked, learners do	**44**	**41**	**34**	**31**	**30**	**28**	**109**
21. Learning objectives are achieved	**50**	**47**	**24**	**22**	**33**	**31**	**109**
22. Educators demos are successful	**80**	**74**	**15**	**14**	**13**	**12**	**109**
23. Science demos are conducted once a week	**25**	**23**	**59**	**54**	**24**	**23**	**109**

In the next paragraph the results summarized in the questionnaire are discussed item by item. Comparisons are made with educators' responses (Table 6.3.).

Item 1 (my educator performs science demonstrations during practicals)

The results from the three schools revealed that in two of the schools the educators use demonstrations frequently. In the two schools 94% and 89% of the learners agreed that

their educators perform science demonstrations during practical lessons. Only 40% of learners at the third school agreed with the statement. In total 81% of the learners agreed with the statement.

Item 2 (during the demonstrations, I could see all the apparatus used)

From the learners' response it is evident that during lecture demonstrations educators do remove distracters from the demonstration table as 76% of the learners agreed that during demonstrations they can see the apparatus used.

Item 3 (my educator always establishes what we already know on the section before he carries out science demonstrations)

Half of the learners in this study revealed that educators do not establish the extent to which they (learners) know the concepts to be taught, because 51% of the learners revealed that their educators do not establish prior knowledge before they carry out demonstrations.

Item 4 (my educator asks questions during science demonstrations)

In all three schools there is a positive response to this item to such an extent that 79% of the learners indicated that the educators ask questions during science demonstrations.

Item 5 (the learning outcome(s) intended by the demonstrations conducted by my educator is/are clearly stated)

In one school, 45% of the respondents disagreed that the educator does not state learning outcomes. The response from the other two schools revealed that 85% and 60% of the learners agree with the statement. In total 53% of the learners agreed with the statement.

Item 6 (apparatus meant for grade 12 practical work are available)

From the responses it showed that 63% of the learners agreed that the schools do have apparatus suitable for grade twelve practical work.

Item 7 (science demonstrations stimulate my thinking)

A fairly good percentage of learners, 56%, indicated that science demonstrations stimulate their thinking. On the other hand 16% of the learners did not concur with the statement.

Item 8 (I find it easy to understand science demonstrations)

The responses on this item indicated that learners understand science demonstrations conducted by their educators with a relative degree of ease since 58% of the learners agreed that they find it easy to understand science demonstrations.

Item 9 (science demonstrations improve my understanding of the theory of science)

From the response one can gather that science demonstrations conducted by educators improve learners' understanding because 76% agreed that science demonstrations improve their understanding.

Item 10 (I can prepare better for tests and examinations with the help of science demonstrations lessons)

75% of the learners indicated that science demonstrations are helpful because they (demonstrations) serve as a means for efficient preparations. They help them (learners) to achieve better test and examination scores.

Item 11 (I sometimes have difficulties in understanding the principles involved in science demonstrations)

Sixty percent of the learners revealed that they have difficulties in understanding the principles involved in science demonstrations. This is due to the techniques employed by educators during demonstrations. The POE approach is not used effectively in the schools. Other factors could be the techniques employed by educators during demonstrations.

Item 12 (my concentration span can stand the time allocated for science demonstrations)

The response to this item indicated that 44% of the learners agreed that their concentration span can stand the time allocated or science demonstrations. This item was included to investigate the perception of both learners and educators about the formers' concentration span in demonstrations. 55% of the educators agreed that learners' concentration span can stand the time allocated for lecture demonstrations. This indicates that attention must be given to the time spent on a demonstration.

Item 13 (science demonstrations are thought provoking)

The responses to this item were evenly spread over the three options given in the questionnaire. An overall percentage of 33% learners agreed that science demonstrations are thought provoking, whereas 32% disagreed with the statement. 35% agreed with reservations that science demonstrations are thought provoking.

Item 14 (after an argument, I feel convinced when a relevant science demonstration is carried out for proof)

75% of the learners felt convinced when a relevant science demonstration is carried out for proof after an argument with either their peers or educator.

Item 15 (I am challenged by the questions my educator ask during science demonstrations)

A large percentage of learners (76%) indicated that that they are challenged by the questions their educators ask during science demonstrations.

Item 16 (my educator encourages learners to ask questions during science demonstrations)

The responses to the item revealed that learners and educators consider questioning as one of the essential aspects in conducting lectured demonstrations. In total 82% of the learners agreed that educators encourage them to ask questions during science demonstrations.

Item 17 (my educator spends time to clarify uncertainties)

According to the responses to this item 65% of the learners agreed that their educators spend time to clarify uncertainties during science demonstrations.

Item 18 (my educator gives us time to think before the answer to a question is given)

The responses to this item seemed to concur with Trowbridge and Bybee (1990: 533) recommended. They emphasised that it is essential to pause for a few seconds after a question has been posed to give learners an opportunity to think about the answer. 64% of the learners indicated that their educators allot them time to think of an answer before attention to the answer is given.

Item 19 (the questions asked during science demonstrations are directly related to the activity)

According to the responses to this item it can be concluded that learners and educators ask relevant questions pertaining to demonstrations. This is evident as 82% of the learners indicated that questions asked during demonstrations are directly related to the activity.

Item 20 (my educator does not give answers, the class does)

The item revealed that educators, to some extent, give learners a chance to respond to questions asked. This is indicated by the 41% of learners who affirmed the statement. The ideal situation should be that all learners agree with the statement.

Item 21 (the learning outcome(s) intended by the demonstrations conducted by my educator is/are achieved)

Less than half of the group of learners, 47%, indicated that their educators **do not** reach the intended outcomes of the lecture demonstrations.

Item 22 (science demonstrations conducted by my educator are successful)

Although 47% of learners agreed that their educators do not reach the intended outcomes in demonstrations, 74% indicated that demonstrations conducted by their educators are successful.

Item 23 (during science practicals, my educator performs science demonstrations once a week)

54% of the learners indicated that during practical periods educators do not perform science demonstrations once a week. The motivation given by the learners is that

educators perform demonstrations at a higher frequency. They indicated that educators conduct the demonstrations at least two times a week.

In section 6.6 the statistical analysis of items that addressed similar aspects in the educators' and learners' questionnaire is discussed.

6.6. Statistical Analysis of educators' and learners' questionnaires

It is important to know whether a relationship between two variables is statistically significant (Ellis & Steyn, 1999: 4). To determine the significance in this study, similar items in the educators and learners questionnaires were matched. The educators' responses on items 2; 5; 6; 8; 9 and 16 were respectively compared to learners' response on items 2; 21; 5; 12; 15 and 6. The items addressed similar aspects of demonstrations in the two questionnaires.

Relevant to this investigation is to know the Effect size. The effect size (Phi coefficient) is given by $w=\sqrt{\frac{X^2}{n}}$, where X^2 is the usual Chi-square statistic for the contingency table and n is the sample size (Steyn, 1999 and Steyn, 2002). Note that the effect size is again independent of sample size. Cohen (1988) gives the following guidelines for the interpretation of it in the current case:

(a) Small effect: $w=0.1$, (b) medium effect: $w=0.3$, (c) large effect: $w=0.5$.

Statistically a relationship with $w \geq 0.5$ is considered as practically significant. This means that if the calculated $w \geq 0.5$ for a matched pair of items, educators and learners differ significantly in opinion on the issue addressed by that item. The extent to which the two groups differ is large.

In paragraph 6.6.1 – 6.6.6 the effect sizes of the matching items are attended to. (The item number in the paragraph headings refers to the educators' questionnaires).

6.6.1. Analysis of Item 2

(Item 2 in the educators' questionnaire is selected to match item 2 in the learners' questionnaire)

With this item the researcher wanted to check if educators do make an effort to ensure clear visibility of the demonstration table during the actual science demonstrations and if the learners could see the demonstrations properly. The table below shows the frequency at which educators and learners responded positively to the item.

Table of group by Q2

group Q2

Frequency, Percent , Row Pct , Col Pct ,	1	2	3	Total
Educator	18	1	1	20
	13.95	0.78	0.78	15.50
	90.00	5.00	5.00	
	16.98	5.56	20.00	
Learners	88	17	4	109
	68.22	13.18	3.10	84.50
	80.73	15.60	3.67	
	83.02	94.44	80.00	
Total	106	18	5	129
	82.17	13.95	3.88	100.00

Statistics for Table of group by Q2

Statistic	DF	Value	Prob
Chi-Square	2	1.6136	0.4463
Likelihood Ratio Chi-Square	2	1.9759	0.3723
Mantel-Haenszel Chi-Square	1	0.4267	0.5136
Phi Coefficient		0.1118	
Contingency Coefficient		0.1111	
Cramer's V		0.1118	

Sample Size = 129

According to the statistical results, 90% of the educators agreed that they remove all possible distracters to ensure clear learner visibility. 81% of the learners concurred with their educators. The calculated phi coefficient of this item is 0, 11 and means that in practice learners confirm that educators are successful in their efforts to make demonstrations visible.

6.6.2. Analysis of Item 5

(Item 5 in the educators' questionnaire is selected to match item 21 in the learners' questionnaire)

The intention of this item was to establish if educators reach the intended outcomes using lecture demonstrations. The phi coefficient on this item is calculated as 0, 13 which mean that educators and learners agreed that the intended teaching and learning outcomes are reached with lecture demonstrations. The table below gives the breakdown of the results.

Table of group by Q5

group Q5

Frequency, Percent , Row Pct , Col Pct ,	1	2	3	Total
Educator	8	6	6	20
	6.20	4.65	4.65	15.50
	40.00	30.00	30.00	
	11.94	25.00	15.79	
Learners	59	18	32	109
	45.74	13.95	24.81	84.50
	54.13	16.51	29.36	
	88.06	75.00	84.21	
Total	67	24	38	129
	51.94	18.60	29.46	100.00

Statistics for Table of group by Q5

Statistic	DF	Value	Prob
Chi-Square	2	2.3039	0.3160
Likelihood Ratio Chi-Square	2	2.1397	0.3431
Mantel-Haenszel Chi-Square	1	0.4792	0.4888
Phi Coefficient		0.1336	
Contingency Coefficient		0.1325	
Cramer's V		0.1336	

Sample Size = 129

6.6.3. Analysis of Item 6

(Item 6 in the educators' questionnaire was selected to match item 5 in the learners' questionnaire).

The item probed into the clarity of the stated teaching and learning outcomes. The statistical results indicated that 50% and 60% of educators and learners respectively responded positively to the item. The phi coefficient has a value of 0, 07 which imply the two groups concur with each other. The table is shown below:

Table of group by Q6

group Q6

Frequency, Percent , Row Pct , Col Pct ,	1,	2,	3,	Total
Educator ,	10 ,	5 ,	5 ,	20
	7.75 ,	3.88 ,	3.88 ,	15.50
	50.00 ,	25.00 ,	25.00 ,	
	13.33 ,	18.52 ,	18.52 ,	
Learners ,	65 ,	22 ,	22 ,	109
	50.39 ,	17.05 ,	17.05 ,	84.50
	59.63 ,	20.18 ,	20.18 ,	
	86.67 ,	81.48 ,	81.48 ,	
Total	75	27	27	129
	58.14	20.93	20.93	100.00

Statistics for Table of group by Q6

Statistic	DF	Value	Prob
Chi-Square	2	0.6443	0.7246
Likelihood Ratio Chi-Square	2	0.6374	0.7271
Mantel-Haenszel Chi-Square	1	0.5368	0.4638
Phi Coefficient		0.0707	
Contingency Coefficient		0.0705	
Cramer's V		0.0707	

Sample Size = 129

6.6.4. Analysis of Item 8

(Item 8 in the educators' questionnaire was selected to match item 12 in the learners' questionnaire).

The item inquired about learners' concentration span during lecture demonstration. The results indicated that there is medium correspondence between the educators' and learners' responses as the calculated phi coefficient is 0, 29. The table below shows the analysis:

Table of group by Q8

group Q8

Frequency, Percent , Row Pct , Col Pct ,	1	2	3	Total
Educator	5	11	4	20
	3.88	8.53	3.10	15.50
	25.00	55.00	20.00	
	8.77	33.33	10.26	
Learners	52	22	35	109
	40.31	17.05	27.13	84.50
	47.71	20.18	32.11	
	91.23	66.67	89.74	
Total	57	33	39	129
	44.19	25.58	30.23	100.00

Statistics for Table of group by Q8

Statistic	DF	Value	Prob
Chi-Square	2	10.7994	0.0045
Likelihood Ratio Chi-Square	2	9.6013	0.0082
Mantel-Haenszel Chi-Square	1	0.2598	0.6103
Phi Coefficient		0.2893	
Contingency Coefficient		0.2779	
Cramer's V		0.2893	

Sample Size = 129

6.6.5. Analysis of Item 9

(Item 9 in educators' questionnaire was selected to match item 15 in the learners' questionnaire).

To investigate whether or not educators ask thought provoking questions during demonstrations a comparison between the two groups was done. The results revealed that educators do challenge learners with questions during demonstrations and learners confirm this because the phi coefficient showed no statistical significance (0, 05). The frequency table to the item is reported below:

Table of group by Q9

group Q9

Frequency, Percent , Row Pct , Col Pct ,	1,	2,	3,	Total
Educator,	15,	2,	3,	20
	11.63,	1.55,	2.33,	15.50
	75.00,	10.00,	15.00,	
	15.31,	12.50,	20.00,	
Learners,	83,	14,	12,	109
	64.34,	10.85,	9.30,	84.50
	76.15,	12.84,	11.01,	
	84.69,	87.50,	80.00,	
Total	98	16	15	129
	75.97	12.40	11.63	100.00

Statistics for Table of group by Q9

Statistic	DF	Value	Prob
Chi-Square	2	0.3446	0.8417
Likelihood Ratio Chi-Square	2	0.3352	0.8457
Mantel-Haenszel Chi-Square	1	0.0958	0.7569
Phi Coefficient		0.0517	
Contingency Coefficient		0.0516	
Cramer's V		0.0517	

Sample Size = 129

6.6.6. Analysis of Item 16

(Item 16 in the educators' questionnaire was selected to match item 6 in the learners' questionnaire).

To get a picture of the availability of apparatus suitable for lecture demonstrations at the respective schools educators were asked if schools do buy apparatus or not. From the results it came out that the response is significant in that educators and learners differ drastically in opinion. The phi coefficient on this item is calculated as 0, 52. This stems from the fact that 10% of educators agreed to the item compared to 69% of learners. The table below gives the breakdown of the calculated results:

Table of group by Q16

group Q16

Frequency, Percent , Row Pct , Col Pct ,	1,	2,	3,	Total
Educator ,	2 ,	14 ,	4 ,	20
	1.55 ,	10.85 ,	3.10 ,	15.50
	10.00 ,	70.00 ,	20.00 ,	
	2.60 ,	50.00 ,	16.67 ,	
Learners ,	75 ,	14 ,	20 ,	109
	58.14 ,	10.85 ,	15.50 ,	84.50
	68.81 ,	12.84 ,	18.35 ,	
	97.40 ,	50.00 ,	83.33 ,	
Total	77	28	24	129
	59.69	21.71	18.60	100.00

Statistics for Table of group by Q16

Statistic	DF	Value	Prob
Chi-Square	2	35.2502	<.0001
Likelihood Ratio Chi-Square	2	32.2951	<.0001
Mantel-Haenszel Chi-Square	1	9.9801	0.0016
Phi Coefficient	0.5227		
Contingency Coefficient	0.4633		
Cramer's V	0.5227		

Sample Size = 129

The table below presents a summary for the sets of matched items and the corresponding Phi Coefficients per matched item.

TABLE 6.5. SUMMARY OF MATCHED ITEMS

Item: Educators	Learners	Phi Coefficient
2	2	0, 11
5	21	0, 13
6	5	0, 07
8	12	0, 29
9	15	0, 05
16	6	0, 52

In section 6.7 comprehensive conclusions are drawn from the results of the learners and educators' questionnaires.

6.7. Conclusion from educators' and learners' questionnaires

The empirical results drawn from the responses of both educators and learners revealed that educators are fairly acquainted with lecture demonstrations and apply the approach in their respective science classrooms. This is verified by 76% of the learners in item 9 of the learners' questionnaire agreed that lecture demonstrations improve their understanding in the theory of science.

As identified in the literature (section 4.15.2) in order to execute lecture demonstrations effectively educators should be skilled. The results of this survey showed that educators are relatively skilled in conducting demonstrations. This is supported by the responses in items 19, 20, 23 and 24 of the educators' questionnaire. These items encompass the learners' involvement in lecture demonstrations and their involvement in the techniques of applying the POE approach. The same results are revealed by learners about their educators as they agreed that the educators' skills in demonstrations yield positive results and lead to conceptual development.

mental activities of interpreting and drawing conclusions on the occurrences. In this study data were collected by means of observations, questionnaires and personal interviews (Appendix 2).

The questionnaires developed and utilized in this study were administered to a group of learners in the three schools described in section 5.3.1. A separate questionnaire was administered to a group of educators in the areas described in section 5.3.1 (appendices 2 & 4). Learners were allocated forty five (45) minutes and educators thirty (30) minutes to complete the questionnaire. The time allocated to complete the questionnaires seemed to be reasonable as both groups managed to complete it before the allocated time elapsed. The researcher supervised the completion of the questionnaire at the respective schools to ensure that the subjects of the study (learners and educators) do not encounter difficulties and that the conditions under which the questionnaires were completed were similar. As is stated before the pre– post-test method was used to measure the learning gains obtained by the lecture demonstration method.

During and prior to the pre-test there were no science demonstrations relevant to the physics sections included in this study (refer to section 5.3.2.).

After the pre–test learners were exposed to lecture demonstrations conducted by their educators. As it was stated earlier the learners' involvement was considered to be the critical aspect of the activity. Educators used the Predict-Observe-Explain (POE) approach in executing the demonstrations. In this approach learners are encouraged to predict the outcome of the demonstration before it is conducted. At this prediction stage the educators attempted to retrieve learners' pre-constructed knowledge regarding the phenomenon in question. For instance, different coins were placed on the demonstration table as shown in the diagram (Diagram 5.1.). Learners were then asked to predict what would happen if A (a 50c coin) collides with B (a R5 coin) held firmly down by the thumb of a learner. They were also asked to compare the velocity V of coin A before collision with that of coin C (V_1) (a 20c coin) after collision. This demonstration was conducted to probe understanding of the concept momentum conservation and

momentum as being the product of the mass and velocity of an object. An example of the demonstrations conducted is given below (extracted from Appendix 5). In total 8 demonstrations were conducted.

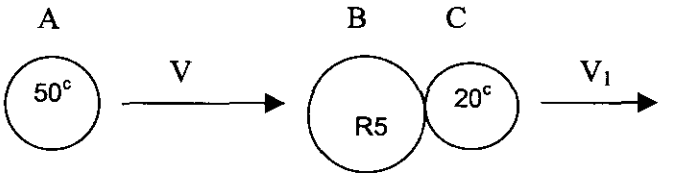


Diagram 5.1. A 50^c coin A approaching at velocity V from the left hits a stationary R5 coin B, resulting in the movement of C a 20^c coin away from B. (The collisions are linear and B is pressed firmly downwards on the table by a learner).

After the prediction phase the experiment was performed, observations were made and learners were asked to explain their observations. Explanations of the demonstrations were given by small groups and class discussions were held.

Immediately after this phase personal interviews between the researcher and the subjects were held. The outcomes of the interviews are given in the next chapter (chapter 6).

Six weeks after the demonstration a post-test was administered to the same groups of learners to determine if there was any change in achievement and conceptual development in the syllabus section on momentum due to the intervention. The time allocated for the two tests (pre- and post-) was two hours each with the researcher supervising. The setting for the tests was of a formal class arrangement where learners worked individually.

5.3.4. Data analysis

Data for this study were processed by means of statistical software available at the North West University, Potchefstroom campus (Ellis & Steyn, 1999).

5.3.5. Instruments

Measurement instruments provide a basis on which the entire research effort rests. A requirement is thus that the instrument used must be valid and reliable (Leedy & Ormrod, 2001: 98 and Wiersma, 1995: 20).

The next two paragraphs reflect on the validity and reliability of the questionnaires.

5.3.5.1. Validity of the instrument

The validity of a measurement instrument refers to the extent to which the instrument measures what it is supposed to measure (Leedy & Ormrod, 2001: 98). For the purpose of this study content validity was considered to be appropriate as the questionnaires focused on sections of mechanics. The instruments assessed whether lecture demonstrations enhance conceptual development in this section of mechanics to concur with the hypothesis and in the objectives stated in section 1.2.2.

5.3.5.2. Reliability of the instrument

The reliability of a measuring instrument is the extent to which it yields consistent results when the characteristic being measured has not changed (Leedy & Ormrod, 2001: 98). The reliability of the instrument in this study was tested by means of matched items in educators' and learners' questionnaires. The results are discussed in paragraph 6.6.1. – 6.6.6.

5.3.6. Questionnaires

When carefully constructed, questionnaires have a number of benefits to the researcher. Apart from being economical in terms of time and costs to both the researcher and respondents, questionnaires facilitate contact with the subjects participating in the study when they could otherwise not be reached (Schnetler *et al.* 1989: 50).

In this study a three point Likert-type scale (Schnetler *et al.* 1989: 50) was employed because of its flexibility and the wide range of constructs that the scale can measure. This range may vary from abstract to specific and has a number of categories of response. According to Schnetler *et al.* (1989: 68) the number of responses given on the scale, gives an indication of the degree of agreement or disagreement on measuring the following: Firstly the frequency at which lecture–demonstrations are conducted at the schools mentioned in section 5.3.1; secondly, how lecture–demonstrations are conducted at the said schools; thirdly, how the POE approach is carried out at the targeted schools and fourthly, to investigate whether or not conceptual development is enhanced by lecture-demonstrations.

In this study, the items of the questionnaire were arranged in such a way that they could be ranked such that, if a respondent reacts positively to a particular item, he will respond similarly to all other items with a lower rank. The scale used is cumulative in nature in that all respondents indicate the items with which they agree, as well as those with which they don't.

5.3.6.1. Questionnaire Items

The items in the questionnaires used in this study were constructed to cover the objectives (see section 1.5.2.) of the study. It focused on the general state of affairs with regard to strategies employed in the teaching and learning of grade 12 physics at schools. It also probed on how lecture demonstrations are conducted at the targeted schools of this study. Specific items in the questionnaire are discussed in detail in the next chapter (chapter 6).

5.4. CONCLUSION

In this chapter the research methodology employed was outlined. It reflected on the literature study, the population, data collection, analysis of the data and the measuring instruments used.

In the next chapter the results of the empirical survey are reported, analyzed and discussed.

CHAPTER 6

EMPIRICAL SURVEY AND RESULTS

6.1. INTRODUCTION

As mentioned in section 5.3 of this dissertation data for this study were collected by means of questionnaires administered to educators and learners as well as by means of pre- and post-tests (Appendix 1 - 4 and Appendix 5). The pre- and post-tests constituted a learning gain test as they were meant to measure learners' learning gains. The pre- and post-tests quantified conceptual development. The questionnaires were administered to both educators and learners involved in the teaching and learning of grade 12 physics at the three selected schools. This chapter presents a discussion of the empirical results obtained by means of the questionnaires and by means of the learning gain tests.

6.2. EDUCATORS' DEMOGRAPHIC INFORMATION

The demographic information of the educators who participated in this study is shown in Table 6.1

TABLE 6.1. EDUCATORS' DEMOGRAPHIC INFORMATION (N = 20)

MALES	FEMALES	TEACHING EXPERIENCE (IN YEARS)						ACADEMIC QUALIFICATIONS				PROFESSIONAL QUALIFICATIONS		
		<5	6	7	8	9	>10	M	M+3	M+4	M+5	M+3	M+4	M+5
10	10	11		1	3		5	20				15	4	1

6.3. LEARNERS' DEMOGRAPHIC INFORMATION

The demographic information of the learners who participated in the study is shown in Table 6.2.

TABLE 6.2. LEARNERS' DEMOGRAPHIC INFORMATION (N = 109)

Gender					Male **72**	Female **37**
Have you registered as a higher or standard grade candidate in natural science?					HG **12**	SG **97**
Years in grade **Number of learners**			1st **109**	2nd **0**	3rd **0**	>3 **0**
Age of learners (in years) **Number of learners**			16 **1**	17 **10**	18 **29**	> 19 **69**
Your last examination mark for Physical Science (June 2004) **Number of learners**	A 100-80	B 79-70 **3**	C 69-60 **14**	D 59-50 **24**	E 49-40 **36**	F < 40 **32**

6.4. RESULTS OF EDUCATORS' QUESTIONNAIRE

The educators' questionnaire was subdivided into three subsections: Firstly it covered the situation analysis at the schools where the research was conducted with regard to the availability of apparatus and its condition. Secondly the questionnaire probed into their teaching and practices employed in the learning of science and thirdly, it attempted to reveal how demonstrations are conducted at the schools selected for this study.

The next paragraph gives the item by item responses of educators.

6.4.1. Results of educators' questionnaires

The completed questionnaires received from the 20 educators who were involved in the survey were processed by hand. The results are given in table 6.3. (For the exact formulation of the items in the questionnaire see Appendix 4).

TABLE 6.3. RESULTS OF EDUCATORS' RESPONSES (N = 20)

ITEM	AGREE		DISAGREE		AGREE WITH RESERVATIONS	
	n	(%)	n	(%)	n	(%)
1. I Incorporate lecture demonstrations in my teaching	13	65	1	5	6	30
2. I remove distracters	18	90	1	5	1	5
3. I start demonstrations with a problem question	12	60	4	20	4	20
4. lecture demonstrations are easy to conduct	13	65	1	5	6	30
5. I reach intended outcomes	8	40	6	30	6	30
6. Outcomes are clearly stated	10	50	5	25	5	25
7. I discuss learning outcomes with learners	10	50	2	10	8	40
8. Learners' concentration span lapses during demonstrations	5	25	11	55	4	20
9. I ask thought provoking questions	15	75	2	10	3	15

10. I remain silent during demonstrations	**15**	**75**	**2**	**10**	**3**	**15**
11. I don't have difficulty in demonstrations	**1**	**5**	**15**	**75**	**4**	**20**
12. I test apparatus beforehand	**19**	**95**	**0**	**0**	**1**	**5**
13. I control my tempo	**15**	**75**	**0**	**0**	**5**	**25**
14. Voice clarity is essential in demos.	**20**	**100**	**0**	**0**	**0**	**0**
15. I improvise	**14**	**70**	**3**	**15**	**3**	**15**
16. School buys apparatus	**2**	**10**	**14**	**70**	**4**	**20**
17. Education department supply resources once a year	**6**	**30**	**12**	**60**	**2**	**10**
18. I use POE approach in demos	**13**	**65**	**1**	**5**	**6**	**30**
19. Learners are engaged in demos	**19**	**95**	**0**	**0**	**1**	**5**
20. Learners are actively involved in science demos	**14**	**70**	**1**	**5**	**5**	**25**
21. Learners come to class with alternative conceptions	**15**	**75**	**2**	**10**	**3**	**15**
22. I let learners formulate their learning objectives	**8**	**40**	**11**	**55**	**1**	**5**
23. Learners predict results before demos are conducted	**12**	**60**	**4**	**20**	**4**	**20**
24. Lecture demos are effective in combating alternative conceptions	**16**	**80**	**2**	**10**	**2**	**10**
25. In lecture demos, learners predict before	**10**	**50**	**4**	**20**	**6**	**30**

the actual demo is conducted.			

In the next paragraph the results are discussed item by item. Comparisons are made between educators' and learners' responses (Table 6.4.).

Item 1 (I incorporate lecture demonstrations in my presentation at least once per week during practical sessions in physical science)

Thirteen (65%) of the responding educators indicated that they incorporate lecture demonstrations during the practical sessions in their teaching in physical science. This seems to concur with what the learners revealed as 75% of them agreed that their educators do perform science demonstrations in class (see summary of the results of the learners' questionnaire – Appendix 2)

Item 2 (Before I start with demonstrations, I remove all possible distracters from the demonstration table)

Educators in response to this item revealed that it is essential to ensure clear visibility on the demonstration table as eighteen (90%) agreed that they remove distracters from the demonstration table. This is verified by 76% of the learners who agreed that during science demonstrations they are able to see the apparatus and proceedings of the demonstration quite well.

Item 3 (I always start demonstrations with a problem question)

Twelve (60%) of the educators agreed that they start science demonstrations with a problem question. This item is linked with *items 4, 15 and 19 of the learners' questionnaire.* 78% of the learners agreed that their educators do ask questions. Not only do the educators start with a problem question before demonstrations, but they, according

to 76% of learners, ask challenging questions. 82% of the learners further agreed that the educators ask questions that are related to the activity they are engaged on.

Item 4 (Lecture demonstrations are easy to conduct)

Conducting demonstrations seemed not to be a problem to most educators as thirteen (65%) of them agreed that they can easily conduct demonstrations.

Item 5 (I reach the intended learning outcomes with lecture demonstrations)

Eight (40%) of the educators indicated that they reach the intended learning outcomes with the aid of lecture demonstrations. This seemed to concur with the learners as 47% said that the learning outcomes intended by the demonstrations conducted by their educators are achieved.

Item 6 (The outcomes are clearly stated before demonstrations)

According to Roberts (1996: 2) a learning instruction should be defined in terms of outcomes to be achieved, yet ten (50%) of the educators agreed that they do state the learning outcomes before the actual demonstrations were conducted. 53% of the learners also agree that their educators state the learning outcomes intended by the demonstrations.

Item 7 (I discuss the learning outcomes with my learners)

It is essential to discuss the learning outcomes with learners as that will guide both the learners and educator to stay focused on the intended activity. Educators in this item seemed to concur as ten (50%) indicated that they discuss the learning outcomes of the demonstrations with their learners prior to the demonstrations.

Item 8 (Learners' concentration span lapses during demonstrations)

When demonstrations are presented in a traditional approach, where an educator is a sole participant, there is a likelihood that learners' concentration will fade and that they will ultimately lose interest. In this item eleven (55%) of the educators disagreed that learners' concentration span lapses during demonstrations. On the other hand 44% of the learners indicated that their concentration span can stand the time allocated for demonstrations.

Item 9 (I ask thought provoking questions during demonstrations)

Learners must always be challenged with thought provoking questions so as to gather how much they know about a particular concept in physical science so that the educator can teach accordingly. In this item fifteen (75%) of the educators indicated that they ask thought provoking questions. This is in line with what the learners said about their educators as 76% of them agreed that the educators ask challenging questions.

Item 10 (I sometimes remain silent during demonstrations)

Displaying excitement and making demonstrations come alive is one of the recipes for a successful science demonstration lesson. However it is also crucial to know when to remain silent where sound effects are expected to surface during demonstrations. In this item fifteen (75%) of the educators agreed that they sometimes remain silent during the demonstrations.

Item 11 (I don't experience difficulty in conducting demonstrations due to the availability of apparatus)

In this item fifteen (75%) of the educators agreed that they have to face difficulties in conducting demonstrations due to the lack of or unavailability of apparatus. These indicated the willingness of the educators to conduct science demonstrations but they are discouraged by the lack of apparatus.

Item 12 (I test the apparatus that I will use before the actual demonstrations in class)

It is good practice to test apparatus before the actual demonstrations are carried out in class. This helps with time and the success of the intended demonstrations. In this item nineteen (95%) of the educators agreed that they test the apparatus ahead of the actual demonstrations in class.

Item 13 (I control my tempo when conducting demonstrations)

Fifteen (75%) of the educators indicated that they control their tempo when conducting demonstrations. This is in accordance with Trowbridge and Bybee's (1990: 233) guidelines that it is essential to control ones' tempo to keep learners interested and attentive.

Item 14 (Voice clarity is essential in lecture demonstrations)

The response by educators in this item concurred with what Trowbridge and Bybee (1990: 233) advised on voice control. All twenty (100%) educators agreed that voice clarity is essential in lecture demonstrations. An educator should speak loud enough to be heard at the back of the classroom. The tone and volume should be modulated to avoid monotonous delivery.

Item 15 (In the absence of relevant resources, I improvise to verify the concept dealt with in specific sections)

This item was included so as to elicit educators' creativity with regard to improvising science demonstrations. A relative high percentage (70%) of the educators indicated that they do improvise in case the relevant apparatus are unavailable.

Item 16 (Our school buys apparatus to augment shortages)

Fourteen (70%) educators disagreed with the statement indicating that the schools do not buy apparatus in case there is a shortage. This item revealed that it is not normal practise for schools to buy apparatus from school funds. It could be that science apparatus are not budgeted for by schools and that buying remains the prerogative of the education department.

Item 17 (I acquire new resources from the department once every year)

This item was included so that it should consolidate item 16 above. From the response it is clear that the conclusion above is valid because a similar percentage twelve (60%) of the educators indicated that they do not acquire new resources from the department annually.

Item 18 (I use the POE approach in presenting demonstrations)

The item revealed that a fairly good percentage (65%) of the educators involved in this investigation use the POE approach in presenting science demonstrations.

Item 19 (Learners are engaged in lecture demonstrations)

Nineteen (95%) of the educators indicated that they engage learners in their lecture demonstrations. Educators believe that by asking learners to perform certain duties during demonstrations help stimulate their thinking. For instance, an educator asks a learner to hold a test tube during a demonstration.

Item 20 (I find learners to be actively involved in lecture demonstrations)

In this item fourteen (70%) agreed that learners are actively involved in lecture demonstrations. In *items 16* and *20* of the learners' questionnaire, 82% stated that their

educators ask questions during demonstrations and 41% indicated that they are given the opportunity to respond to the questions asked by their peers.

Item 21 (I frequently find out that learners come to class with alternative conceptions)

The educators seemed to agree that knowledge is constructed in the mind of the learner and that learners learn from the environment, as fifteen (75%) indicated that learners come to class with alternative conceptions.

Item 22 (I let learners formulate their learning outcomes for the particular lesson)

In this item eleven (55%) of the educators indicated that they do not let learners formulate their own learning outcomes for the lesson.

Item 23 (My learners predict the results of the demonstration to be carried out)

This item revealed that twelve (60%) of the educators allowed learners to predict the results of the demonstration to be carried out.

Item 24 (I find lecture demonstrations to be effective in combating learners' alternative conceptions)

Sixteen (80%) agreed that lecture demonstrations are an effective means in combating learners' alternative conceptions when conducted properly.

Item25 (In lecture demonstrations, learners predict before the actual demonstration is carried out)

This item was included to confirm whether or not educators are consistent and understand the nature of the POE approach. In item 23 60 % of the educators agreed that they

allowed their learners to predict the outcome of the demonstration. In this item, ten (50%) of the educators indicated that in lecture demonstrations learners predict before the actual demonstration is carried out.

The next paragraph gives the items in the learners' questionnaire, the learners' responses to the items and an analysis of the responses.

6.5. RESULTS OF LEARNERS' QUESTIONNAIRE

The learners' questionnaire was compiled to probe the situation with regard to, firstly, the frequency at which their educators conduct lecture demonstrations, secondly how their educators conduct lecture demonstrations, and thirdly, how do they (learners) perceive lecture demonstrations.

6.5.1. Results of learners' responses.

The completed questionnaires from the 109 learners who were involved in this survey were processed by hand. The results are given in table 6.4. (The items in the questionnaire are stated in abbreviated form. For complete statements refer to Appendix 2).

TABLE 6.4. RUSULTS OF LEARNERS' QUESTIONNAIRE (N = 109)

ITEM	AGREE		DISAGREE		AGREE WITH RESERVATIONS		$\sum$ n
	n	(%)	n	(%)	n	(%)	
1. My educator performs science demos	**81**	**74**	**15**	**14**	**12**	**12**	**109**
2. I can see all apparatus during	**82**	**75**	**23**	**22**	**3**	**03**	**109**

demos						
3. Educator establishes prior knowledge	55	51	34	31	19	18	109
4. Educator asks questions during demos	86	79	11	10	11	11	109
5. Outcomes are clearly stated	58	54	25	23	25	23	109
6. Apparatus are available at school	69	63	17	16	22	21	109
7. Science demos stimulate thinking	61	56	20	19	27	25	109
8. Science demos are easy to understand	62	58	21	19	25	23	109
9. Science demos improve my understanding	82	76	13	12	12	12	109
10. Science demos help to prepare for tests	81	74	13	13	13	13	109
11. I have difficulties in understanding principles in demos	65	60	28	26	15	14	109
12. My concentration span can stand time in science demos	47	44	20	19	40	37	109
13. Science demos are thought provoking	36	33	34	32	38	35	109
14. Science demos are convincing after an argument	80	74	7	07	20	19	109
15. I am challenged	83	76	12	12	13	12	109

by questions asked by my educator during demos						
16.I am encouraged to ask questions	**89**	**82**	**11**	**11**	**7**	**07**	**109**
17. Educator spends time to clarify uncertainties	**70**	**65**	**22**	**21**	**15**	**14**	**109**
18. Educator gives time for learners to think of answers	**70**	**64**	**27**	**25**	**11**	**11**	**109**
19. Questions asked are related to activity	**89**	**82**	**10**	**09**	**9**	**09**	**109**
20. Educator does not give answers to questions asked, learners do	**44**	**41**	**34**	**31**	**30**	**28**	**109**
21. Learning objectives are achieved	**50**	**47**	**24**	**22**	**33**	**31**	**109**
22. Educators demos are successful	**80**	**74**	**15**	**14**	**13**	**12**	**109**
23. Science demos are conducted once a week	**25**	**23**	**59**	**54**	**24**	**23**	**109**

In the next paragraph the results summarized in the questionnaire are discussed item by item. Comparisons are made with educators' responses (Table 6.3.).

Item 1 (my educator performs science demonstrations during practicals)

The results from the three schools revealed that in two of the schools the educators use demonstrations frequently. In the two schools 94% and 89% of the learners agreed that

their educators perform science demonstrations during practical lessons. Only 40% of learners at the third school agreed with the statement. In total 81% of the learners agreed with the statement.

Item 2 (during the demonstrations, I could see all the apparatus used)

From the learners' response it is evident that during lecture demonstrations educators do remove distracters from the demonstration table as 76% of the learners agreed that during demonstrations they can see the apparatus used.

Item 3 (my educator always establishes what we already know on the section before he carries out science demonstrations)

Half of the learners in this study revealed that educators do not establish the extent to which they (learners) know the concepts to be taught, because 51% of the learners revealed that their educators do not establish prior knowledge before they carry out demonstrations.

Item 4 (my educator asks questions during science demonstrations)

In all three schools there is a positive response to this item to such an extent that 79% of the learners indicated that the educators ask questions during science demonstrations.

Item 5 (the learning outcome(s) intended by the demonstrations conducted by my educator is/are clearly stated)

In one school, 45% of the respondents disagreed that the educator does not state learning outcomes. The response from the other two schools revealed that 85% and 60% of the learners agree with the statement. In total 53% of the learners agreed with the statement.

Item 6 (apparatus meant for grade 12 practical work are available)

From the responses it showed that 63% of the learners agreed that the schools do have apparatus suitable for grade twelve practical work.

Item 7 (science demonstrations stimulate my thinking)

A fairly good percentage of learners, 56%, indicated that science demonstrations stimulate their thinking. On the other hand 16% of the learners did not concur with the statement.

Item 8 (I find it easy to understand science demonstrations)

The responses on this item indicated that learners understand science demonstrations conducted by their educators with a relative degree of ease since 58% of the learners agreed that they find it easy to understand science demonstrations.

Item 9 (science demonstrations improve my understanding of the theory of science)

From the response one can gather that science demonstrations conducted by educators improve learners' understanding because 76% agreed that science demonstrations improve their understanding.

Item 10 (I can prepare better for tests and examinations with the help of science demonstrations lessons)

75% of the learners indicated that science demonstrations are helpful because they (demonstrations) serve as a means for efficient preparations. They help them (learners) to achieve better test and examination scores.

Item 11 (I sometimes have difficulties in understanding the principles involved in science demonstrations)

Sixty percent of the learners revealed that they have difficulties in understanding the principles involved in science demonstrations. This is due to the techniques employed by educators during demonstrations. The POE approach is not used effectively in the schools. Other factors could be the techniques employed by educators during demonstrations.

Item 12 (my concentration span can stand the time allocated for science demonstrations)

The response to this item indicated that 44% of the learners agreed that their concentration span can stand the time allocated or science demonstrations. This item was included to investigate the perception of both learners and educators about the formers' concentration span in demonstrations. 55% of the educators agreed that learners' concentration span can stand the time allocated for lecture demonstrations. This indicates that attention must be given to the time spent on a demonstration.

Item 13 (science demonstrations are thought provoking)

The responses to this item were evenly spread over the three options given in the questionnaire. An overall percentage of 33% learners agreed that science demonstrations are thought provoking, whereas 32% disagreed with the statement. 35% agreed with reservations that science demonstrations are thought provoking.

Item 14 (after an argument, I feel convinced when a relevant science demonstration is carried out for proof)

75% of the learners felt convinced when a relevant science demonstration is carried out for proof after an argument with either their peers or educator.

Item 15 (I am challenged by the questions my educator ask during science demonstrations)

A large percentage of learners (76%) indicated that that they are challenged by the questions their educators ask during science demonstrations.

Item 16 (my educator encourages learners to ask questions during science demonstrations)

The responses to the item revealed that learners and educators consider questioning as one of the essential aspects in conducting lectured demonstrations. In total 82% of the learners agreed that educators encourage them to ask questions during science demonstrations.

Item 17 (my educator spends time to clarify uncertainties)

According to the responses to this item 65% of the learners agreed that their educators spend time to clarify uncertainties during science demonstrations.

Item 18 (my educator gives us time to think before the answer to a question is given)

The responses to this item seemed to concur with Trowbridge and Bybee (1990: 533) recommended. They emphasised that it is essential to pause for a few seconds after a question has been posed to give learners an opportunity to think about the answer. 64% of the learners indicated that their educators allot them time to think of an answer before attention to the answer is given.

Item 19 (the questions asked during science demonstrations are directly related to the activity)

According to the responses to this item it can be concluded that learners and educators ask relevant questions pertaining to demonstrations. This is evident as 82% of the learners indicated that questions asked during demonstrations are directly related to the activity.

Item 20 (my educator does not give answers, the class does)

The item revealed that educators, to some extent, give learners a chance to respond to questions asked. This is indicated by the 41% of learners who affirmed the statement. The ideal situation should be that all learners agree with the statement.

Item 21 (the learning outcome(s) intended by the demonstrations conducted by my educator is/are achieved)

Less than half of the group of learners, 47%, indicated that their educators **do not** reach the intended outcomes of the lecture demonstrations.

Item 22 (science demonstrations conducted by my educator are successful)

Although 47% of learners agreed that their educators do not reach the intended outcomes in demonstrations, 74% indicated that demonstrations conducted by their educators are successful.

Item 23 (during science practicals, my educator performs science demonstrations once a week)

54% of the learners indicated that during practical periods educators do not perform science demonstrations once a week. The motivation given by the learners is that

educators perform demonstrations at a higher frequency. They indicated that educators conduct the demonstrations at least two times a week.

In section 6.6 the statistical analysis of items that addressed similar aspects in the educators' and learners' questionnaire is discussed.

6.6. Statistical Analysis of educators' and learners' questionnaires

It is important to know whether a relationship between two variables is statistically significant (Ellis & Steyn, 1999: 4). To determine the significance in this study, similar items in the educators and learners questionnaires were matched. The educators' responses on items 2; 5; 6; 8; 9 and 16 were respectively compared to learners' response on items 2; 21; 5; 12; 15 and 6. The items addressed similar aspects of demonstrations in the two questionnaires.

Relevant to this investigation is to know the Effect size. The effect size (Phi coefficient) is given by $w=\sqrt{\frac{X^2}{n}}$, where X^2 is the usual Chi-square statistic for the contingency table and n is the sample size (Steyn, 1999 and Steyn, 2002). Note that the effect size is again independent of sample size. Cohen (1988) gives the following guidelines for the interpretation of it in the current case:

(a) Small effect: $w=0.1$, (b) medium effect: $w=0.3$, (c) large effect: $w=0.5$.

Statistically a relationship with $w \geq 0.5$ is considered as practically significant. This means that if the calculated $w \geq 0.5$ for a matched pair of items, educators and learners differ significantly in opinion on the issue addressed by that item. The extent to which the two groups differ is large.

In paragraph 6.6.1 – 6.6.6 the effect sizes of the matching items are attended to. (The item number in the paragraph headings refers to the educators' questionnaires).

6.6.1. Analysis of Item 2

(Item 2 in the educators' questionnaire is selected to match item 2 in the learners' questionnaire)

With this item the researcher wanted to check if educators do make an effort to ensure clear visibility of the demonstration table during the actual science demonstrations and if the learners could see the demonstrations properly. The table below shows the frequency at which educators and learners responded positively to the item.

Table of group by Q2

group Q2

Frequency, Percent, Row Pct, Col Pct	1	2	3	Total
Educator	18	1	1	20
	13.95	0.78	0.78	15.50
	90.00	5.00	5.00	
	16.98	5.56	20.00	
Learners	88	17	4	109
	68.22	13.18	3.10	84.50
	80.73	15.60	3.67	
	83.02	94.44	80.00	
Total	106	18	5	129
	82.17	13.95	3.88	100.00

Statistics for Table of group by Q2

Statistic	DF	Value	Prob
Chi-Square	2	1.6136	0.4463
Likelihood Ratio Chi-Square	2	1.9759	0.3723
Mantel-Haenszel Chi-Square	1	0.4267	0.5136
Phi Coefficient		0.1118	
Contingency Coefficient		0.1111	
Cramer's V		0.1118	

Sample Size = 129

According to the statistical results, 90% of the educators agreed that they remove all possible distracters to ensure clear learner visibility. 81% of the learners concurred with their educators. The calculated phi coefficient of this item is 0, 11 and means that in practice learners confirm that educators are successful in their efforts to make demonstrations visible.

6.6.2. Analysis of Item 5

(Item 5 in the educators' questionnaire is selected to match item 21 in the learners' questionnaire)

The intention of this item was to establish if educators reach the intended outcomes using lecture demonstrations. The phi coefficient on this item is calculated as 0, 13 which mean that educators and learners agreed that the intended teaching and learning outcomes are reached with lecture demonstrations. The table below gives the breakdown of the results.

Table of group by Q5

group Q5

Frequency, Percent , Row Pct , Col Pct ,	1,	2,	3,	Total
Educator ,	8 ,	6 ,	6 ,	20
	6.20 ,	4.65 ,	4.65 ,	15.50
	40.00 ,	30.00 ,	30.00 ,	
	11.94 ,	25.00 ,	15.79 ,	
Learners ,	59 ,	18 ,	32 ,	109
	45.74 ,	13.95 ,	24.81 ,	84.50
	54.13 ,	16.51 ,	29.36 ,	
	88.06 ,	75.00 ,	84.21 ,	
Total	67	24	38	129
	51.94	18.60	29.46	100.00

Statistics for Table of group by Q5

Statistic	DF	Value	Prob
Chi-Square	2	2.3039	0.3160
Likelihood Ratio Chi-Square	2	2.1397	0.3431
Mantel-Haenszel Chi-Square	1	0.4792	0.4888
Phi Coefficient		0.1336	
Contingency Coefficient		0.1325	
Cramer's V		0.1336	

Sample Size = 129

6.6.3. Analysis of Item 6

(Item 6 in the educators' questionnaire was selected to match item 5 in the learners' questionnaire).

The item probed into the clarity of the stated teaching and learning outcomes. The statistical results indicated that 50% and 60% of educators and learners respectively responded positively to the item. The phi coefficient has a value of 0, 07 which imply the two groups concur with each other. The table is shown below:

Table of group by Q6

group Q6

Frequency,
Percent ,
Row Pct ,
Col Pct , 1, 2, 3, Total

Educator	10	5	5	20
	7.75	3.88	3.88	15.50
	50.00	25.00	25.00	
	13.33	18.52	18.52	
Learners	65	22	22	109
	50.39	17.05	17.05	84.50
	59.63	20.18	20.18	
	86.67	81.48	81.48	
Total	75	27	27	129
	58.14	20.93	20.93	100.00

Statistics for Table of group by Q6

Statistic	DF	Value	Prob
Chi-Square	2	0.6443	0.7246
Likelihood Ratio Chi-Square	2	0.6374	0.7271
Mantel-Haenszel Chi-Square	1	0.5368	0.4638
Phi Coefficient		0.0707	
Contingency Coefficient		0.0705	
Cramer's V		0.0707	

Sample Size = 129

6.6.4. Analysis of Item 8

(Item 8 in the educators' questionnaire was selected to match item 12 in the learners' questionnaire).

The item inquired about learners' concentration span during lecture demonstration. The results indicated that there is medium correspondence between the educators' and learners' responses as the calculated phi coefficient is 0, 29. The table below shows the analysis:

Table of group by Q8

group Q8

Frequency, Percent , Row Pct , Col Pct ,	1	2	3	Total
Educator	5	11	4	20
	3.88	8.53	3.10	15.50
	25.00	55.00	20.00	
	8.77	33.33	10.26	
Learners	52	22	35	109
	40.31	17.05	27.13	84.50
	47.71	20.18	32.11	
	91.23	66.67	89.74	
Total	57	33	39	129
	44.19	25.58	30.23	100.00

Statistics for Table of group by Q8

Statistic	DF	Value	Prob
Chi-Square	2	10.7994	0.0045
Likelihood Ratio Chi-Square	2	9.6013	0.0082
Mantel-Haenszel Chi-Square	1	0.2598	0.6103
Phi Coefficient		0.2893	
Contingency Coefficient		0.2779	
Cramer's V		0.2893	

Sample Size = 129

6.6.5. Analysis of Item 9

(Item 9 in educators' questionnaire was selected to match item 15 in the learners' questionnaire).

To investigate whether or not educators ask thought provoking questions during demonstrations a comparison between the two groups was done. The results revealed that educators do challenge learners with questions during demonstrations and learners confirm this because the phi coefficient showed no statistical significance (0, 05). The frequency table to the item is reported below:

Table of group by Q9

group Q9

Frequency, Percent , Row Pct , Col Pct ,	1	2	3	Total
Educator	15	2	3	20
	11.63	1.55	2.33	15.50
	75.00	10.00	15.00	
	15.31	12.50	20.00	
Learners	83	14	12	109
	64.34	10.85	9.30	84.50
	76.15	12.84	11.01	
	84.69	87.50	80.00	
Total	98	16	15	129
	75.97	12.40	11.63	100.00

Statistics for Table of group by Q9

Statistic	DF	Value	Prob
Chi-Square	2	0.3446	0.8417
Likelihood Ratio Chi-Square	2	0.3352	0.8457
Mantel-Haenszel Chi-Square	1	0.0958	0.7569
Phi Coefficient		0.0517	
Contingency Coefficient		0.0516	
Cramer's V		0.0517	

Sample Size = 129

6.6.6. Analysis of Item 16

(Item 16 in the educators' questionnaire was selected to match item 6 in the learners' questionnaire).

To get a picture of the availability of apparatus suitable for lecture demonstrations at the respective schools educators were asked if schools do buy apparatus or not. From the results it came out that the response is significant in that educators and learners differ drastically in opinion. The phi coefficient on this item is calculated as 0, 52. This stems from the fact that 10% of educators agreed to the item compared to 69% of learners. The table below gives the breakdown of the calculated results:

Table of group by Q16

group Q16

Frequency,				
Percent ,				
Row Pct ,				
Col Pct ,	1,	2,	3,	Total
Educator ,	2 ,	14 ,	4 ,	20
	1.55 ,	10.85 ,	3.10 ,	15.50
	10.00 ,	70.00 ,	20.00 ,	
	2.60 ,	50.00 ,	16.67 ,	
Learners ,	75 ,	14 ,	20 ,	109
	58.14 ,	10.85 ,	15.50 ,	84.50
	68.81 ,	12.84 ,	18.35 ,	
	97.40 ,	50.00 ,	83.33 ,	
Total	77	28	24	129
	59.69	21.71	18.60	100.00

Statistics for Table of group by Q16

Statistic	DF	Value	Prob
Chi-Square	2	35.2502	<.0001
Likelihood Ratio Chi-Square	2	32.2951	<.0001
Mantel-Haenszel Chi-Square	1	9.9801	0.0016
Phi Coefficient		0.5227	
Contingency Coefficient		0.4633	
Cramer's V		0.5227	

Sample Size = 129

The table below presents a summary for the sets of matched items and the corresponding Phi Coefficients per matched item.

TABLE 6.5. SUMMARY OF MATCHED ITEMS

Item: Educators	Learners	Phi Coefficient
2	2	0, 11
5	21	0, 13
6	5	0, 07
8	12	0, 29
9	15	0, 05
16	6	0, 52

In section 6.7 comprehensive conclusions are drawn from the results of the learners and educators' questionnaires.

6.7. Conclusion from educators' and learners' questionnaires

The empirical results drawn from the responses of both educators and learners revealed that educators are fairly acquainted with lecture demonstrations and apply the approach in their respective science classrooms. This is verified by 76% of the learners in item 9 of the learners' questionnaire agreed that lecture demonstrations improve their understanding in the theory of science.

As identified in the literature (section 4.15.2) in order to execute lecture demonstrations effectively educators should be skilled. The results of this survey showed that educators are relatively skilled in conducting demonstrations. This is supported by the responses in items 19, 20, 23 and 24 of the educators' questionnaire. These items encompass the learners' involvement in lecture demonstrations and their involvement in the techniques of applying the POE approach. The same results are revealed by learners about their educators as they agreed that the educators' skills in demonstrations yield positive results and lead to conceptual development.

Although educators are relatively skilled in conducting lecture demonstrations, there is room for improvement on all aspects of the demonstrations. This is illustrated by the percentage of educators who employ the POE approach in the science classes and the fact that only 65% agreed that they find lecture demonstrations easy to conduct.

In section 6.8 the pre- and post-tests results are displayed.

6.8. Pre- and post-test results.

The results of the pre- and post-test are displayed in Table 6.5. below. The results are derived from a test which is based on momentum at grade twelve level (Appendix 5). The post-test was written six weeks after the pre-test. The pre-test was administered immediately before the lecture demonstrations were conducted. The last column shows the difference in percentage between post- and pre-tests and the improvement. The improvement is the difference between the post- and the pre-test scores.

TABLE 6.6. TEST SCORES (N = 109)

LEARNER NUMBER	PRE-TEST SCORE (%)	POST-TEST SCORE (%)	IMPROVEMENT (%)
1	44.4	51.3	6.9
2	43.0	69.4	26.4
3	38.8	58.3	19.5
4	27.7	55.5	27.8
5	36.1	36.1	0
6	77.7	88.8	11.1
7	31.9	45.8	13.9
8	29.1	34.7	5.6
9	45.8	50.0	4.2
10	33.3	62.5	29.2
11	38.8	69.4	30.6
12	19.4	29.1	9.7
13	22.2	58.3	36.1
14	16.6	50.0	33.4
15	13.8	20.8	7.0
16	26.3	34.7	8.4
17	13.8	62.5	48.7
18	19.4	22.2	2.8
19	5.5	16.6	11.1
20	11.1	36.1	25.0
21	23.6	56.9	33.3

22	8.3	31.9	23.6
23	25.0	38.8	13.8
24	25.0	36.1	11.1
25	29.1	34.7	5.6
26	19.4	23.6	4.2
27	13.8	30.5	16.7
28	31.9	62.5	30.6
29	45.8	54.1	8.3
30	62.5	66.6	4.1
31	34.7	56.9	22.2
32	23.6	34.7	11.1
33	16.6	37.5	20.9
34	15.2	30.5	15.3
35	22.2	31.9	9.7
36	25.0	37.5	12.5
37	20.8	25.0	4.2
38	13.8	52.7	38.9
39	20.8	25.0	4.2
40	13.8	22.2	8.4
41	18.0	34.7	16.7
42	19.4	27.7	8.3
43	23.6	31.9	8.3
44	15.2	31.9	16.7
45	12.5	20.8	8.3
46	31.9	48.6	16.7
47	23.6	31.9	8.3
48	13.6	25.0	11.4
49	27.7	37.5	9.8
50	20.8	29.1	8.3
51	38.8	45.8	7.0
52	20.8	29.1	8.3
53	29.1	38.8	9.7
54	30.5	43.0	12.5
55	11.1	12.5	1.4
56	13.8	45.8	32.0
57	13.8	31.9	18.1
58	23.6	41.6	18.0
59	16.6	47.2	30.6
60	19.4	38.8	19.4
61	19.4	45.8	26.4
62	31.9	50.0	18.2
63	15.3	22.2	6.9
64	22.2	36.1	13.9
65	15.3	23.6	8.3
66	15.3	30.5	15.2
67	48.6	62.5	13.9
68	12.5	31.9	19.4
69	15.3	20.8	5.5
70	09.7	15.2	5.5
71	22.2	31.9	9.7
72	22.2	43.0	20.8
73	11.1	16.6	5.5
74	15.3	36.1	20.8

75	22.2	31.9	9.7
76	25.0	61.1	36.1
77	13.8	31.9	18.1
78	34.7	51.3	16.6
79	65.3	56.6	- 8.7
80	22.2	29.1	6.9
81	23.6	31.9	8.3
82	11.1	34.7	23.6
83	13.8	25.0	11.2
84	23.6	34.7	11.1
85	29.2	29.1	- 0.1
86	20.8	29.1	8.3
87	43.1	59.7	16.6
88	12.5	41.6	29.1
89	29.2	50.0	20.8
90	12.5	34.7	22.2
91	08.3	22.2	13.9
92	34.7	66.6	31.9
93	31.9	56.6	24.7
94	13.8	33.3	19.5
95	09.7	16.6	6.9
96	16.6	51.3	34.7
97	23.6	29.1	5.5
98	41.6	52.7	11.1
99	25.0	34.7	9.7
100	16.6	30.5	13.9
101	30.5	34.7	4.2
102	16.6	31.9	15.3
103	20.8	36.1	15.3
104	15.3	26.3	11.0
105	19.4	23.6	4.2
106	22.2	37.5	15.3
107	25.0	38.8	13.8
108	36.1	50.0	13.9
109	11.1	20.8	9.7
AVERAGE	23. 92	38. 78	14. 86

From the results in Table 6.5 the average normalized gain was calculated (Hake, 2002: 3)

6.9. Average Normalized Gain

According to Hake (2002: 3) the average normalized gain affords a consistent analysis of pre- or post tests data over diverse student populations. According to Hake the average normalized gain can be calculated from the relationship:

$$\text{Average Normalized Gain} = \frac{\text{Actual percentage gain}}{\text{Maximum possible gain}}$$

The difference of the pre- and post-test scores gives the actual learning gain. The maximum possible gain is given by the difference of the actual gain from the maximum possible gain (100%). Dividing the actual gain by the maximum possible gain gives the average normalized gain.

An illustration of how the average normalized gain (Gain) is calculated is described by means of an example extracted from table 6.6 above. The pre- and post-tests percentages in section A 1.1 of table 6.6 above are used as an example.

$$\begin{aligned}\text{Actual percentage gain} &= \text{Post test score} - \text{Pre-test score} \\ &= 50 - 23.6 \\ &= 26.4\end{aligned}$$

$$\begin{aligned}\text{Maximum possible gain} &= \text{Total possible gain} - \text{Actual gain} \\ &= 100 - 23.6 \\ &= 76.4\end{aligned}$$

$$\begin{aligned}\text{Average Normalized Gain} &= \frac{\text{Actual percentage gain}}{\text{Maximum possible gain}} \\ &= \frac{26.4}{76.4} \\ &= 0.34 \text{ or } 34\%\end{aligned}$$

To understand the significance of the Average normalized gain effect sizes were determined by calculating d-values. A natural way to comment on practical significance is to use the standardized difference between the means of populations, that is, the difference between the two means divided by the estimate for standard deviation (Ellis &

Steyn, 1999: 2). The d-values were obtained by means of the statistical software available at the North-West University, Potchefstroom campus.

The formula to determine the d-values is given below.

$$d = \frac{|\bar{x}_1 - \bar{x}_2|}{s_{max}},$$

where $|\bar{x}_1 - \bar{x}_2|$ is the difference between $\bar{x}_1$ and $\bar{x}_2$ without taking the sign into consideration.

The following table gives the guidelines for the interpretations of the effect sizes in this study:

Table 6.7. Effect sizes guidelines

Small effect	Medium effect	Large effect
$d = 0,2$	$d = 0,5$	$d = 0,8$

The d-value which is greater or equals 0, 8 is considered to be practically significant, since it is the result of a difference having a large effect. In practice, relevant to this study, a calculated value that is equal to or larger than 0, 8 would mean that lecture demonstrations enhance conceptual development and hence prove the hypothesis of this study to be true (section 1.2.2)

The learning gain scores per item are displayed in Table 6.6. below

TABLE 6.8. LEARNING GAIN SCORES (pre- and post-tests)

ITEM	PRE-TEST (%)	POST-TEST (%)	AVERAGE NORMAL GAIN	EFFECTIVE SIZE (d value)
SECTION A				
1.1	23.6	50.0	0. 34	0. 717391304
1.2	68.8	98.3	0. 94	0. 353081987
1.3	34.8	75.0	0. 61	0. 732240437
1.4	34.8	65.0	0. 52	0. 605210421
1.5	82.5	93.3	0. 51	0. 122866894
1.6	14.6	56.6	0. 49	1. 179775281
1.7	9.1	16.6	0. 08	0. 583657588
SECTION B.				
1.	36.6	61.6	0. 39	0. 509164969
2.	13.7	25.5	0. 13	0. 602040816
3.	23.8	16.6	- 0. 09	-0. 356435644
4.	37.6	23.3	- 0. 22	-0. 469622332
5.1.	37.6	56.6	0. 30	0. 403397028
5.2.	4.5	26.6	0. 23	1. 421221865
6.1.	29.3	33.3	0. 05	0. 127795527
6.2.	9.1	8.3	- 0. 09	-0. 091954023
6.3.	1.8	3.3	0. 01	0. 588235294
7.a.	23.8	75.0	0. 67	1. 036437247
7.b.	3.6	7.5	0. 74	0. 702702703
8.1.	18.3	51.6	0. 40	0. 9527897
8.2.	34.8	48.3	0. 20	0. 324909747
8.3.	27.5	45.1	0. 24	0. 484848485
8.4.	20.1	46.6	0. 33	0. 794602699
8.5.	39.4	36.6	- 0. 04	-0. 073684211

8.6.	27.5	41.6	0. 19	0. 408104197
9.	52.2	51.6	- 0. 01	-0. 011560694
10.	69.7	65.0	-0. 15	-0. 069784707
11.	20.1	51.6	0. 39	0. 878661088
12.	72.4	75.0	0. 81	0. 035278155
13.1.	0	18.3	0. 18	2
13.2.	0	30.0	0. 30	2
AVERAGE	**29. 05**	**47. 37**	**0. 27**	**0. 549712402**

In section 6.9.1 the statistical analysis of the effect sizes is discussed.

6.9.1. Conclusion from Statistical Analysis (Effect sizes)

The normalized average gain (Hake, 2002: 3) for the items as indicated in table 6.8 is 0.27 or 27%. This means that a practical significant improvement in marks had occurred. The effect size (d-value) calculated as shown in section 6.9 is 1, 51 which means that a practical significant improvement of marks had occurred since the calculated d-value is larger than 0, 8 (see Table 6.7). These figures suggest that the learners performed better in a test after being exposed to the POE approach in lecture demonstrations. The fourth objective of this study (stated in section 1.2.2. d) is: *to describe the effect of demonstrations on the conceptual development on the grade 12 physical science learners,* is related to the researches hypothesis: *lecture demonstrations in natural science enhances conceptual development in grade 12 physical science learners* (stated in section 1.3). The findings of this study prove the research hypothesis and objectives in that the statistical results proved that the practical significant due to lecture-demonstrations has occurred.

Section 6.10 presents the interviews that were conducted between the researcher and the educators and learners who participated in this study. Interviews were held to probe into educators' and learners' perceptions with regard to the role lecture demonstrations play in science.

6.10. Interviews

The following section outlines the interviews conducted between the researcher (interviewer) and educators (interviewee 1) as well as learners (interviewee 2) who took part in this study. Two separate interviews were held with educators and learners (one for each group) about an hour after the post-test.

The interview was about the perception of both educators and learners with regard to lecture demonstrations and questions asked in the pre- and post-tests. Three educators and five learners were interviewed. They were selected on grounds of the discussions on specific items of the questionnaires. Educators' and learners' responses were recorded on a separate sheet of paper by the researcher.

Interviewer: What is your view on the role of lecture demonstrations with regard to learners' alternative conceptions? Do you think lecture demonstrations, if applied correctly can combat learners alternative conceptions?

Interviewee 1: From what I have observed it looks like it (the POE approach) can help a great deal since it encourages learner involvement to the fullest. Learners are kept on their toes with relevant questions. It shows that when planning to conduct lecture demonstrations one must be thoroughly prepared, and not only consider the intended outcome of the demonstration/experiment.

Interviewer: What do you think are the problems associated with allowing learners to formulate their own objectives in lecture-demonstrations?

Interviewee 1: Learners will only focus on the said objective(s) and discard other occurrences.

Interviewer: What, in your opinion, can be done to effectively employ lecture demonstrations in science classrooms?

Interviewee 1: Let educators undergo a rigorous training in conducting demonstrations effectively. Some of the schools do have resources but educators do not use them profitably due to a lack of training and exposure to apparatus. Some of the educators in our schools are not really qualified to teach physical science at secondary schools, therefore they need to be trained to equip themselves to the required level of competency.

Interviewee 2: If only educators can involve us more in their demonstrations, our concentration span will improve. Sometimes our educator just continues to explain without asking questions and we feel ignored and bored by proceedings. However, the method introduced, POE, seems to be interesting. We will see how far it goes from here.

6.11. Conclusion from interviews

The conclusion drawn from the interviews suggest that a lot has still to be done if we want to see any kind of strategic teaching in our science classrooms. Educators still perceive that science demonstrations are conducted solely for the verification of a particular concept. This perception of science lecture demonstrations has to change as it nullifies the statement of Novodvorsky (1997: 242) that learners are capable of constructing knowledge on their own. Most importantly, as indicated by learners during the interview, it does not accord them the opportunity to explore and feel challenged by their educators. It does not help them think critically of possible answers to questions.

6.12. Summary

This chapter presented an analysis of the data collected, educators' and learners' questionnaires; learning gain test and the interviews between the researcher and the subjects of the study. Conclusions from the data analysis and interviews were also presented.

In the next chapter comprehensive conclusions drawn from the questionnaires completed by educators and learners, and the pre- and post-test and interviews are reported. The

conclusions take the relevant literature in account. Based on these conclusions recommendations on how to improve the lecture-demonstration teaching strategy are made.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

7.1. INTRODUCTION

This chapter aims to present the concluding remarks and recommendations of the study. The conclusion as well as the recommendations based on this study focus on the research hypothesis and objectives of the study. The chapter will firstly summarise recommendations on the empirical survey conducted on the study reported on in chapter 6. This chapter finally makes recommendations for further research which stems from this study.

7.2. CONCLUSIONS BASED ON EMPIRICAL STUDY

7.2.1. Educators

From the observations made by the researcher during lecture-demonstrations and personal interviews (see section 6.7) held between the researcher and the participants before the introduction of the POE approach, it became evident that science educators encounter difficulties in conducting science demonstrations. One of the study's objectives was to observe the present state of affairs with regard to the techniques educators employ in lecture demonstrations for physical science grade 12 (see section 1.5.2.). Most of the educators use demonstrations as a follow-up of the "accumulated theory" learnt in previous lessons. In this approach educators use demonstrations only to prove the assertions based on scientific principles.

The literature survey of this study revealed the essential guidelines for effective lecture demonstrations that will enhance conceptual development and understanding (see section 4.15.). The objectives (c) and (d) of this study are: *to investigate the effective ways of*

implementing demonstration work in the classroom **and** *to determine the effect of demonstrations on conceptual development on the grade 12 physical science learners* respectively. The literature examined in this study achieved the objectives (c) and (d) relating to the effective ways of implementing lecture demonstrations in science classes.

The empirical part of this survey proved the hypothesis stated in section 1.3. (*lecture-demonstrations in natural science enhances conceptual development in grade 12 physical science learners*) to be true. The statistical analysis of the pre- and post-tests results indicate a significant improvement of the results after lecture demonstrations were conducted to grade 12 physical science learners.

The POE instructional approach embeds the principles of constructivism. Therefore it is essential that learners, from knowledge constructed in their own minds, should critically think about the phenomena demonstrated by the educator. They should not be made to accept intended assertions.

Most researchers (Chinn & Brewer, 1998: 104, Toh, 1991: 89; and Thijs & Van den Berg (1995: 318) contend that the quality of prior knowledge is perceived to have powerful effects on the teaching and learning process in science. It is argued that if educators can probe into learners' prior knowledge, they can identify learners' alternative conceptions. This will also set the scene for the need to learn and to teach according to what learners already know. This is within the context of constructivist theory. According to Chinn and Brewer (1998: 104), the quality of prior knowledge determines the quality of the conception of *new knowledge.*

In the three schools where the study was conducted it became evident from the response in *items 15* and *16* of learners' questionnaire that during science lecture demonstrations learners are not asked thought provoking questions. They are generally not mentally challenged by their educators. In this regard educators do not get to identify learners' alternative concepts. If educators could value the learners' alternative conceptions they would be able to improve their demonstrations practises.

7.2.2. Learners

During the pre-test session on the learning gain, the researcher observed that from each of the three groups of learners from three different schools, on average, twelve to fifteen took out coins to perform experiments so as to respond to the questions based on the collision of the coins. Based on the observations made by the researcher during the pre-test session on learners, it can be said that demonstrations are an essential part of science learning and comprehension.

In the researcher's opinion this gave a striking illustration of the impact science demonstrations have on learners' concept formation. Scientific concepts are mastered better when preceded by demonstrations. This crucial observation made by the researcher describes the effect of lecture demonstrations on the conceptual development of learners because the learners, prior to the demonstration, could not understand the essence of the question. The findings are found to be in line with objective (d) of the study mentioned in section 1.5.2 (*to describe the effect of demonstrations on conceptual development on the grade 12 physical science learners*). This objective describes the effect of lecture demonstrations on the learners' conceptual development.

7.3. RECOMMENDATION FOR FURTHER RESEARCH

Based on the results of the empirical study it is worth mentioning that further research needs to be done. The following are the fields that are recommended to be researched:

7.3.1. Learning and the learner

There is a need to understand how learners learn. This should include the methods learners employ in learning physics concepts. When asked where scientific knowledge comes from, learners mentioned a number of sources like text-books and other tangible hard copies. More often learners cannot simply discover scientific knowledge for themselves because scientific knowledge is more than a description of how the world

operates. Learning science involves being introduced to, and coming to accept and understand, some of the norms, the ways of thinking and the ways of explaining used by the scientific community (see chapter 2).

It is also true that learners live within a community in schools that has its own ways of talking and thinking about events and phenomena which are of interest to scientists. These ways of thinking and talking lead to alternative conceptions that learners grow up with. Educators face the challenge of introducing learners to the scientific ways of interpreting and explaining phenomena.

From the results obtained it is evident that demonstrations have a definite place in science classrooms. The following recommendations will, in the opinion of the researcher, if implemented contribute towards improving the situation:

7.3.1.1. Establishing science centres

Science centres seem to be the immediate response to the existing problems of educators, learners and education authorities. Educators indicated during the survey and interviews that there is an alarming shortage of apparatus in schools (*items 11, 15 and 16 of the educators' questionnaire*). The other problem associated with availability of apparatus in schools is the lack of funds to buy these apparatus. As a means to eradicate the cited problems above, science centres could have the following advantages:

- Educators and learners will be invited to the science centres and be exposed to a variety of demonstrations and they will be challenged to a maximum (cognitively).

- The centres will relieve schools from exorbitant expenditures for the buying of apparatus.

- The science centres will immensely relieve the provincial education departments financially in that instead of budgeting for all schools, the resources can be directed to the centres.

- Science centres are relatively cheap and efficient to maintain.

- Science centres *do not* in any way replace educators but serve as a continuous workshop to educators as they can be re-skilled through theses centres.

7.3.1.2. Mobile Science units (MSU)

An alternative to the science centres is mobile science units where skilled facilitator(s) travel around to schools to perform demonstrations that educators experience difficulties with. The mobile science units have the same benefits of science centres but have shortcomings. The most important are:

- One cannot transport all apparatus to schools. Some apparatus are fixed, too large or too fragile to be moved around.

- The long distances to be travelled are time consuming.

7.3.1.3. Science demonstration workshops

The response gathered from educators' interviews and questionnaires indicated that there is an urgent need for educators' workshops on aspects (techniques) of demonstrations in science classes. This follows from the 65% of educators that indicated that they experience difficulties in conducting lecture demonstrations (*item 4 of educators' questionnaire*). This workshop can be attended to with the aid of the science centres recommended in paragraph 7.3.1.1.

The above mentioned conclusions and recommendations based on the conclusions are in line with the study's objectives, hypothesis and aim. The study's objective was to first, give a brief discussion of the teaching techniques employed in natural science, with particular focus on physical science. This objective was achieved by means of the literature study in chapter 4. The second objective was to investigate how educators conduct demonstrations in their classes (*to investigate how educators conduct demonstrations*). The third objective was *to investigate the effective ways of implementing demonstration work in the classroom*). An extensive literature study was done to investigate these effective ways. To complement the extensive literature study done on the descriptive effect of demonstrations on conceptual development, the pre- and post-test method was employed to achieve the fourth objective (*to determine the effect of demonstration on conceptual development on the grade 12 physical science learners*). In reaching these objectives the hypothesis of the study was proved to be true.

Learning in science classes is conducted in a passive mode. This view is strongly criticized by constructivists who believe that learning is and should be an activity between an educator and a learner or amongst learners (Leach & Scott, 2000: 42). The aim of this study as mentioned in section 1.2.1 was *to identify the role that demonstrations play in the teaching and learning of physical science.* The results obtained from the study itself (literature and empirical survey) proved that demonstrations play a critical role in the teaching and learning of physical science. This is verified by firstly, the observation made by the researcher during the pre-test session where learners performed demonstrations before they responded to questions asked in the test. Secondly the positive shift in the learning gain scores after demonstrations indicated that learners benefited from the intervention.

According to Hodson (1998: 39) conceptual change, hence conceptual development is made possible when learners understand the limitations of their current views and recognize the need to replace them. Lecture demonstrations (POE approach) as executed in this study provided learners with the opportunity to promote the conflict between

existing understanding (through prediction) and the *new* observation (observation then explanation).

7.3.2. Constructivism and teaching

Previous work done on constructivism is based on personal constructivism in that it focused on identifying patterns in the learners existing alternative conceptions about particular phenomena (Posner *et al.* 1982).

Based on the findings of the study there is a need to explore the impact of interaction between the educator and the learner and how this influences learning, especially during practical work in science. Lecture demonstrations within the context of the POE approach, has to be taught in a holistic way and not just to prove the underlying theory or scientific principle.

The role of constructivism needs to be defined within the realm of lecture demonstrations. This is indicated by 65% of the educators who agreed that they employ the POE approach in demonstrations (*item 18: I use the POE approach in presenting demonstrations*). There is still a high percentage of educators who do not use this approach. Even though there is an indication that educators use lecture demonstrations in their classrooms, it remains a challenge to the techniques used when this method is employed. This is verified by the response to item 3 of the learners' questionnaire (*my educator always establishes what we already know on the section before he carries out science demonstrations*). In this item 51% of the learners indicated that educators do not establish what they (learners) know on the section to be treated before the actual demonstrations are conducted.

7.4. CONCLUSION

Translating knowledge about learning into strategies for more effective teaching is, as perceived by Asoko (2002: 153) not an easy task. Such knowledge could inform teaching

at different levels. The findings in this study support the idea stated by Asoko (2002: 154) that science teaching involves stimulating a process of change in the thinking of the learner, but conceptual change has to be viewed as a process of bewildering complexity.

In the past, as in the traditional school curriculum, description of science lecture demonstrations said two things about observation. First, nothing enters the mind of the scientist except by way of the senses, which is perceived by Hodson (1998: 10) as the *tabula rasa* on which the senses inscribe a true and faithful record of the world. Second, the validity and reliability of observation statements are independent of the opinions and expectations of the observer and can be readily confirmed by other observers. Contrary to the two statements, in reality we interpret the sensorial data that enter our consciousness in terms of our prior knowledge, beliefs, expectations and experiences. This is emphasized by Barley and Carre (1985) quoted by Hodson (1998: 10): *"we do not see things as they are, we see them as we are"*. As a result conceptual change will be made possible when learners understand the limitations of their current views and recognize the need to replace them.

7.5. SUMMARY

This study has proved that lecture-demonstrations improve grade 12 learners' conceptual development and understanding of the section dealing with mechanics. The study also identified weaknesses of educators and the school system that restricts lecture-demonstrations to be employed to its full potential. Recommendations for improvement and for further investigations are made in this chapter.

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APPENDIX 1

LEARNERS' DEMOGRAPHIC INFORMATION

GRADE 12

MARK THE APPROPRIATE SPACE WITH AN X

NAME OF SCHOOL:						
Gender					Male	Female
Have you registered as a higher or standard grade candidate in natural science					HG	SG
Number of years in grade			1st	2nd	3rd	>3
Age			16	17	18	> 19
Your last examination mark for Natural Science	A 100-80	B 79-70	C 69-60	D 59-50	E 49-40	F < 40

APPENDIX 2

LEARNERS' QUESTIONNAIRE

CAREFULLY READ THE FOLLOWING STATEMENTS AND RESPOND BY MARKING WITH AN (X) THE APPROPRIATE NUMBER THAT BEST DESCRIBES YOUR SITUATION.

KEY		
1	2	3
AGREE	DISAGREE	AGREE WITH RESERVATION

1.	My educator performs science demonstrations during practicals	1	2	3
2.	During the demonstrations, I could see all the apparatus used.	1	2	3
3.	My educator always establishes what we already know on the section before he carries out science demonstrations.	1	2	3
4.	My educator asks questions during science demonstrations	1	2	3

5.	The learning outcome(s) intended by the demonstrations conducted by my educator is/are clearly stated	1	2	3
6.	Apparatus meant for grade 12 practical work are available	1	2	3
7.	Science demonstrations stimulates my thinking	1	2	3
8.	I find it easy to understand science demonstrations	1	2	3
9.	Science demonstrations improves my understanding of the theory of science	1	2	3
10.	I can prepare better for tests and examinations with the help of science demonstration lessons	1	2	3
11.	I sometimes have difficulties in understanding the principles involved in science demonstrations	1	2	3
12.	My concentration span can stand the time allocated for science demonstrations	1	2	3
13.	Science demonstrations are thought provoking	1	2	3
14.	After an argument, I feel convinced when a relevant science demonstration is carried out for proof.	1	2	3

15.	I am challenged by the questions my educator ask during science demonstrations	1	2	3
16.	My educator encourages learners to ask questions during science demonstrations	1	2	3
17.	My educator spend time to clarify uncertainties	1	2	3
18.	My educator gives us time to think before the answer to a question is given	1	2	3
19.	The questions asked during science demonstrations are directly related to the activity	1	2	3
20.	My educator does not give the answers, the class does.	1	2	3
21.	The learning outcome(s) intended by the demonstrations conducted by my educator is/are achieved.	1	2	3
22.	Science demonstrations conducted by my educator are successful.	1	2	3

MOTIVATE: 22.

23.	During science practical my educator performs science demonstrations once a week	1	2	3

MOTIVATE: 23.

APPENDIX 3

EDUCATORS' INFORMATION

MARK WITH AN X IN APPROPRIATE SPACE

1. Gender					Male	Female
2. Experience (in years) of teaching Natural Science in grades 11 & 12	<5	6	7	8	9	>10
3. Highest academic qualifications in (Physics or Chemistry	M	M+3	M+4	M+5	M+6	OTHER
4. Professional qualifications	M+3	M+4	M+5	M+6	M+7	OTHER

APPENDIX 4

EDUCATORS' QUESTIONNAIRE

1. CAREFULLY READ THE FOLLOWING STATEMENTS AND RESPOND BY MARKING WITH AN (X) THE APPROPRIATE NUMBER THAT BEST DESCRIBES YOUR SITUATION.

KEY		
1	2	3
AGREE	DISAGREE	AGREE WITH RESERVATION

1.	I incorporate lecture demonstrations in my presentation at least once per week during practical sessions in physical science.	1	2	3
2.	Before I start with demonstrations, I remove all possible distracters from the demonstration table.	1	2	3
3.	I always start the demonstration with a problem question.	1	2	3
4.	Lecture demonstrations are easy to conduct.	1	2	3
5.	I reach the intended learning outcomes with lecture demonstrations.	1	2	3
6.	The outcomes are clearly stated before demonstrations.	1	2	3
7.	I discuss the learning outcomes with my learners	1	2	3

8.	Learners' concentration span lapses during demonstrations.	1	2	3
9.	I always ask thought provoking questions during demonstrations.	1	2	3
10.	I sometimes remain silent during demonstrations.	1	2	3
11.	I don't experience difficulty in conducting demonstrations due to the availability of resources/apparatus.	1	2	3
12.	I test the apparatus that I will use before the actual demonstrations in class.	1	2	3
13.	I always control my tempo when conducting demonstrations.	1	2	3
14.	Voice clarity is essential in lecture demonstrations.	1	2	3
15.	In the absence of relevant resources, I improvise to verify the concept dealt with in specific sections.	1	2	3
16.	Our school buy apparatus to augment shortages	1	2	3
17.	I acquire new resources from the department once every year.	1	2	3
18.	I use the POE (Predict – Observe – Explain) approach in Presenting demonstrations.	1	2	3

19.	Learners are engaged in my lecture demonstrations	1	2	3

19. MOTIVATE:

20.	I find learners to be actively involved in lecture demonstrations	1	2	3

20. MOTIVATE:

2. CONCEPT FORMATION

21.	I frequently find out that learners come to class with alternative conceptions (misconceptions).	1	2	3

21. MOTIVATE:

22.	I let learners formulate their learning outcomes for the particular lesson.	1	2	3

22. MOTIVATE:

23.	My learners predict the results of the demonstration to be carried out.	1	2	3

23. MOTIVATE:

24.	I find lecture demonstrations to be effective in combating learners' alternative conceptions.	1	2	3

24. MOTIVATE:

25	In lecture demonstrations, learners predict before the actual demonstration is carried out.	1	2	3

25. MOTIVATE:

APPENDIX 5

LEARNING GAIN TEST

INSTRUCTION: ATTEMPT ALL QUESTIONS

SECTION A: MULTIPLE CHOICE

1. The **condition** under which the total linear momentum of a system of objects is conserved, is

    A. The objects may not exert forces on each other
    B. No forces from outside the system may act on any of the bodies.
    C. For each body in the system, the resultant of the external forces acting on the body must be zero.

2. The momentum of a body is the product of the body's

    A. Mass and Velocity
    B. Mass and Force
    C. Energy and Acceleration
    D. Mass and Acceleration

3. A force F acts on a body for a short time Δt. The product F. Δt is known as the

    A. impulse of the force
    B. momentum of the body
    C. acceleration of the body
    D. work done by the force

4. The change in momentum of a body is equal to the

A. resultant force on the body
B. impulse of the resultant force
C. increase in mechanical energy of the body
D. acceleration of the body

5. The momentum of an object of mass 1, 5 kg moving at 2 $m.s^{-1}$ is

A. 1, 5 $kgm.s^{-1}$
B. 2, 0 $kgm.s^{-1}$
C. 3, 0 $kgm.s^{-1}$
D. 3, 75 $kgm.s^{-1}$

Question 6 and 7 refer to a ball of mass 0, 5 kg which is dropped, strikes the floor at a speed of 10 $m.s^{-1}$ and bounces back at 8 $m.s^{-1}$.

6. The change in momentum of the ball during the collision with the ground was

A. 1 $kg.m.s^{-1}$
B. 4 $kg.m.s^{-1}$
C. 5 $kg.m.s^{-1}$
D. 9 $kg.m.s^{-1}$

7. If the collision with the ground lasted for 0, 1 s, the average force which the floor exerted on the ball was

A. 10 N
B. 40 N
C. 50 N
D. 90 N

SECTION B

1. State the principle of conservation of momentum in words.

2. Explain what an isolated system is.

3. What happens to the momentum of an object if a resultant force acts on the object?

4. Can a rocket be propelled in vacuum (empty space)? Explain

5. A body of mass 7 kg is moving at 10 $m.s^{-1}$ and collides with a stationary body of mass 3 kg. The two bodies join together and carry on moving in the original direction.

5.1. Calculate the speed of the bodies after the collision.

5.2. Determine whether the collision was elastic or inelastic.

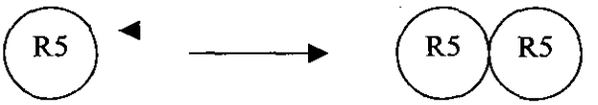
6. A sandbag of mass 0, 5 kg hangs from a string and a 2 kg trolley moves past under it at 5 $m.s^{-1}$. The instant that the trolley is directly under the sandbag, the string is cut so that the sandbag falls on the trolley.

6.1. Find the initial momentum of the trolley

6.2. Find the final momentum of the trolley.

6.3. Calculate the impulse which the trolley imparts to the sandbag

7. Take three large coins (R5 pieces). Press one coin against the table with your thumb and place a second one firmly in contact with the one under your thumb. Place the third coin in line with the other two about 40 mm from the coin under your thumb. Flick this (third) coin with a finger so that it moves and collides with the one under your thumb.

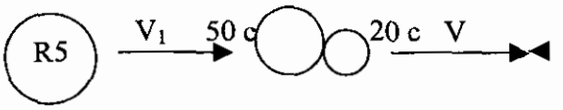


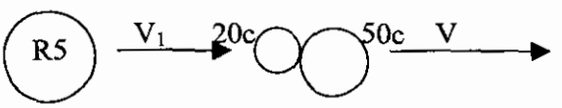
a. What do you think will happen?

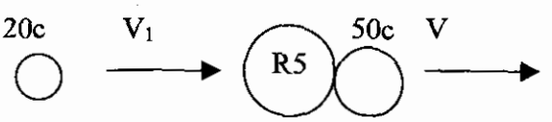
b. Explain your prediction for a situation where you press the middle one as hard as you can.

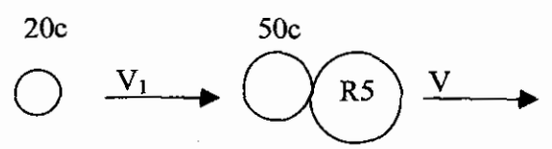
8. Consider the previous setting. If you now use different coins (50 cent, 20 cent and R5 coins) interchangeably, what observations will you make? Explain. In all cases (1 – 6) the velocity (V_1) at which the coin on the left strike the one in the middle is the same. In each case compare the magnitude of V_1 to that of V.

Mark with an X one of the three possibilities in the accompanying columns the relationship you think would hold (V_1 equals V, V_1 larger than V or V_1 smaller than V)

1. 

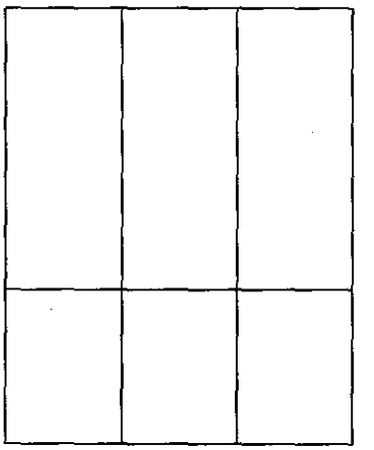
2. 

3. 

4. 

$V_1 = V$	$V_1 > V$	$V_1 < V$

5. 50c V_1 R5 c V



6. 50c V_1 20c R5 V

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For question 9 - 12 **circle** the most appropriate option.

9. What is needed to bring an object in motion?

A. Energy
B. Momentum
C. Velocity
D. Force

10. What always tends to oppose motion?

A. Energy
B. Friction
C. Momentum
D. Velocity

11. Which vector quantity is always in the direction of movement of a moving object?

A. Momentum
B. Force
C. Friction
D. Weight

12. If an object (eg. tin) is rolled across a horizontal smooth surface, like a floor, it will . . .

A. roll continuously
B. roll forward then stop
C. not roll at all

13.

An educator rolls an "**instructed tin**" from a position A across a horizontal floor. The tin rolls to position B where it stops momentarily, and then rolls back to A.

13.1. How would you explain the movement of the tin from B back to A?

13.2. What causes the tin to roll back?