

**ASSESSING THE IMPACT SCIENCE CENTRES HAVE ON  
THE *HOLISTIC DEVELOPMENT* OF SCIENCE LEARNERS**

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## ABSTRACT

The turn of the 21<sup>st</sup> century dawned with an increasing number of interactive science centres worldwide. South Africa is no exception as the number of science centres are also on the increase in the country. The science centre movement see interactive science centres as a dimension and context in which the hands-on and minds-on learning approach will be enhanced to the fullest.

In this context the research question addressed in the study was: do science centres contribute to the cognitive, affective and psychomotoric (*holistic*) development of learners?

The study was conducted at the Potchefstroom Science Centre. This centre is developed to include hands-on activities that focus on the New Curriculum Statements for Physical Sciences. Two groups of learners were involved: a control group of 375 learners who had no previous exposure to a science centre and an experimental group of 375 learners who visited the Science Centre quarterly. Learners in the Further Education and Training Band were selected. From each of the five schools in both control and experimental groups 25 Physical Sciences learners from each of the grades 10, 11 and 12 were selected on random basis. Information was obtained by pre-and post-tests, questionnaires to the learners and to their educators. The written information was supplemented by videos taken of learners during visits to the science centre and by interviews.

The outcome of the study indicates that Physical Sciences learners develop holistically through exposure to a science centre.

## SUMMARY

The study orientates the reader about the current situation on the *holistic* development or lack of it, of the Physical Science learners in terms of the cognitive, affective and the psychomotor skills in science education. Therefore the study intends to probe into the prevailing situation and position the science centre as a core context of learning, a learning context perceived to be conducive for learning that enhances and advocates for the holistic approach in learner development. The problem statement to that effect and the motivation to the study are outlined in *chapter 1*.

Because the acquisition of the three skills envisaged requires a certain level of knowledge and a specific knowledge type, *chapter 2* outlines what scientific knowledge is. The chapter further outlines how scientific knowledge is acquired and gives a broader view of types of knowledge types. This is done so as to unpack the type of knowledge required for the acquisition of each skill in the process of developing Physical Science learners in a holistic manner.

As stated in the preceding paragraph, the acquisition of knowledge is a process. This process starts with the interaction of the event and the observer. The interaction involves a mental process. It is for that reason that memory and its function is discussed in *chapter 3*. The chapter further outlines the role played by memory in knowledge acquisition. The chapter depicts the pivotal role played by memory elements in encoding, retaining and retrieving the acquired knowledge.

*Chapter 4* extends the process of knowledge acquisition by presenting the how, what and how much knowledge is stored for learning purpose. This chapter seeks to define what learning is by looking at various learning theories and extract one that is more relevant to the perceived nature of science and possibly suitable for application in the science centre environment.

In this chapter (*chapter 5*) the concept of a science centre will be outlined. The chapter will also look at how science centres are classified, their roles in society and their objectives as spelt out by the Department of Science and Technology. The science centre forms the central part of the study as it is regarded as the context through which the objectives of the study will be achieved.

Details of how science centres may be assessed in terms of the three levels of learning are outlined in *chapter 6*. This is done in order to sustain the development of the science centres.

The process through which the gathering of data is collected is outlined in *chapter 7*. The gathered data is then processed and analysed and the procedure thereof is unfolded in *chapter 8*.

The conclusion remarks and recommendations of the study are outlined in *chapter 9* of this study.

## OPSOMMING

Die studie oriënteer die leser tot die huidige situasie van leerders in Natuurwetenskap t.o.v. die kognitiewe, affektiewe en psigomotoriese vermoëns in Wetenskap-onderrig, het sy 'n holistiese benadering al dan nie. Die studie beoog dus om die heersende situasie en die rol van die wetenskapsentrum as fundamenteel vir die leerproses, te ondersoek. 'n Verstaanbare leer omgewing wat bevorderlik is vir leer en wat in die leerder se ontwikkeling 'n holistiese benadering aanmoedig en ondersteun. Die probleem stelling en motivering vir die studie word in *hoofstuk 1* bespreek.

Om die aanleer van die drie vermoëns onder die loep te neem/voor oë te stel, vereis 'n sekere vlak van kennis en 'n spesifieke soort kennis, daarom word daar in *hoofstuk 2* 'n beskrywing gegee van wat die kennis van wetenskap is. Verder bespreek die hoofstuk ook hoe die kennis van wetenskap behou kan word en gee dit ook 'n wyer blik oor verskillende soorte van kennis. In *hoofstuk 2* word daar dus ten doel gestel om die tipe kennis wat nodig is vir aanleer van elke vaardigheid tydens die holistiese ontwikkelingsproses van leerder in Natuurwetenskappe, te ontleed.

Soos in die voorafgaande paragraaf genoem, is die aanleer van kennis 'n proses. Hierdie proses begin met interaksie tussen die waarnemer en die gebeurtenis. 'n Verstandelike proses vorm deel van hierdie interaksie en daarom word daar in *hoofstuk 3*, geheue en die rol van geheue bespreek. Hierdie hoofstuk bespreek dan ook die rol wat geheue speel in die implementering van kennis. Die vernaamste rol wat die elemente van geheue speel in die behou en herroep van verlangde kennis, word dus hier beskryf.

*Hoofstuk 4* gee meer breedvoerig aandag aan die proses vir die aanleer van kennis. Hoe kennis bekom word en watter en hoeveel kennis nodig is wanneer leer ten doel gestel word, word hier bespreek. Die klem word hier gelê op die mees relevante aspek vir die aard van Wetenskap en waarskynlik dus ook die toepassing wat die geskikste is vir die klimaat in die wetenskapsentrum as omgewing waar kennis bekom word.

In *hoofstuk 5* word die konsep-ideë van 'n wetenskapsentrum in hooftrekke bespreek. Hierdie hoofstuk kyk ook na die klassifikasie van wetenskapsentrums, die rol van wetenskapsentrums in die samelewing, asook die uitkomste soos deur die Departement van Wetenskap en Tegnologie voorgeskryf word vir wetenskapsentrums. Die wetenskapsentrums staan sentraal in hierdie studie omdat die wetenskapsentrum gereken word as die belangrikste konteks om die doel van die studie te bereik.

Hoe die wetenskapsentrum geassesseer moet word in terme van die drie vlakke van leer, word in *hoofstuk 6* in meer besonderhede bespreek en steun so die ontwikkeling van wetenskapsentrums.

Die proses wat gebruik is om data te versamel word in *hoofstuk 7* uiteengesit. Die prosedure waarvolgens versamelde data verwerk en ontleed is, word *hoofstuk 8* verduidelik.

Gevolgtrekkings en aanbevelings van die studie word in hoofstuk 9 uiteengesit.

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# CHAPTER 1

## INTRODUCTION

*All men by nature desire knowledge (Aristotle)*

### 1.1. PROBLEM STATEMENT AND LITERATURE REVIEW

In a quest to promote public awareness and understanding of science and technology, the Department of Science and Technology (DST) tasked science centres to implement national science weeks and provide continued support programmes. The Department sees this as part of the solution to curb the cycle of mediocrity in academic performance in science, mathematics and technology (NSMSTE, 2005: 5). According to the DST (2005) the problem could be solved by instilling an *interest* in science in learners; improving their *scientific knowledge* base and by *stimulating the production* of new resources. However the DST reports (1996, 1999) and the National Research and Development Strategy (2002) have revealed that *most science centres lack capacity to fulfil these roles*. In addition none of the centres *had any form of external evaluation* (DST, 2004: 2, Nursall, 2003: 381).

The roles and goals of science centres as specified in the Norms and Standards document (2004: 4) and the education policy document (DoE, 2003: 13) cut across the three learning domains as described by Bloom, namely, the *cognitive, affective* and *psychomotoric* learning domains (Bloom *et al.*, 1964: 12, Krathwohl *et al.*, 1964: 11, Furst, 1994: 28, Madaus & Kreitzer, 1994: 64). These goals include inter alia:

- ❖ Promoting science literacy among the youth and the population in general.
- ❖ Enhancing learner participation and performance.
- ❖ Providing career education among the youth.

This study investigated the influence science centres have on the *cognitive, affective* and the *psychomotoric* learning domains, referred to as the *holistic development* on science learning. The goals of science centres listed above are in line with learner outcomes (for the Physical Sciences learner) envisaged by the National Curriculum Statement (DoE, 2003: 5). In brief it states that a learner emerging from the Further Education and Training band must:

- ❖ Have access to, and succeeds in, lifelong education and training of good quality.
- ❖ Demonstrates an ability to think logically and analytically, as well as *holistically*.
- ❖ Be able to transfer skills from familiar to unfamiliar situations.

According to the DoE (2003: 13 – 14) such a learner will accomplish these goals if or when he/she demonstrates mastery of the three learning outcomes in Physical Sciences:

- ❖ Learning outcome 1: Practical scientific inquiry and problem-solving skills.
- ❖ Learning outcome 2: Constructing and applying scientific knowledge.
- ❖ Learning outcome 3: Understanding the nature of science and its relationships to technology, society and the environment.

Bloom (1994: 6) argues that it is the responsibility of a school to ensure that the educational process of a learner is increasingly concerned with the fullest (*holistic*) development of the learner. In achieving this, the school has to seek *conducive learning conditions* which will enable each learner to reach the highest level of learning possible, thereby developing the learner in a holistic manner (cognitive, affective and psychomotoric development).

The Department of Science and Technology (DST) in the white paper on science and technology (DST, 1996) and the National Research and Development Strategy (2002) identified science centres as important infrastructures (*conducive learning conditions*) required for achieving the science goals mentioned above. Hence the empirical study of this thesis was conducted in a science centre as a context which is conducive to learning. Learning that probably has as outcome the development of science learners in a holistic manner.

The following section highlights the aim and objectives of this study.

## **1.2. RESEARCH AIM AND OBJECTIVES**

### **1.2.1. Research Aim**

This study was aimed at investigating the impact science centres have on the learning of physical science in a holistic manner. The study was limited to Physical Sciences learners (grades 10 – 12).

### **1.2.2. Research Objectives**

The research aim was achieved by pursuing the following objectives:

- (a) The extent was determined to which science centres contribute to the
  - (i) Cognitive;
  - (ii) Affective and
  - (iii) The psycho-motoric development of Physical Sciences in learners.
- (b) Problems associated with the learning of Physical Sciences by learners in a holistic manner were identified, within the context of science centres.

(c) Practical ways were proposed to empower science centres to be more effective in the development of a learner's physical science knowledge, with regard to the cognitive, affective and the psycho-motoric domains.

### **1.3. RESEARCH HYPOTHESIS**

The hypothesis of this study is: *Science centres impact positively on learners' holistic development in the physical sciences.*

### **1.4. DESCRIPTION OF TERMS**

The terms which are key to this study and forms essential part to the formulation of the research topic are briefly described in the following subsections.

#### **1.4.1. Science Centres**

O'Hare (2000) quoted by Murphy (2002: 7) defines a science centre as a *place where one can see science happen – and even more importantly, experience science by doing.* O'Hare (2000) emphasizes that interactivity is the key word in successful science centres.

Reville (2001) quoted by Murphy (2002: 7) perceives a modern science centre as a place that *has exhibits designed to attract, excite and educate people*, with the main idea being to educate through entertaining.

The Department of Science and Technology found that the definitions provided for science centres were narrow and limiting as they could not address the key challenges facing schools in South Africa with regard to the quality of performance in science and mathematics. As a result, a more inclusive and broader concept of what a science centre should be was introduced. A science centre is considered to be: *a permanently established education facility that provides an interactive educational experience through the use of interactive science, technology, engineering and mathematics exhibits, displays and programmes* (DST, 2004: 5).

In this study a science centre will be considered as a facility described by the latter definition of DST.

#### **1.4.2. Holistic development**

Holistic development in educational context as described by Bloom (Anderson *et al.*, 2001: 27, Bloom, 1994: 6, Krathwohl *et al.*, 1964: 6) refers to the development in three learning domains, the *cognitive*, the *psychomotoric* and the *affective* domains.

The three domains of the Taxonomy will be discussed in detail in Chapter 4 of this study.

#### **1.4.3. Assessment**

Assessment in educational context is defined as a systematic collection of information about learners' learning and about other variables associated particularly with learning experience (Tamir, 1998: 765). The definition implies that learners are engaged in a cognitive process that involves a description of knowledge in at least two points, which are the points prior to the learning experience and upon completion of the learning task. In this definition, learners' prior knowledge is taken into consideration, a fact that is essential in the constructivist learning theory (Novodvorsky, 1997: 242).

A learner may be assessed in a group or as an individual under partly controlled physical and social conditions, to assess whether or not he/she can solve a variety of lifelike problems (Payne, 2003: 5).

According to Cronbach (1960) quoted by Payne (2003: 5), there are three principal characteristics of assessment, which are:

- ❖ The use of a variety of techniques (*cognitive and psychomotoric domain*).

- ❖ Reliance on observation in structured and unstructured situations, and (*cognitive and affective domain*).
  
- ❖ Integration of information (*cognitive domain*).

The definition and the characteristics of assessment cited above are in line with the context of assessment concerned with the totality of an individual – the cognitive, affective and the psychomotoric domain of the taxonomy of learning. According to Tamir (1998: 765) the most widely utilized framework for learner assessment and evaluation is the taxonomy of educational objectives in the cognitive domain (Bloom, 1956), the psychomotoric and the affective domains (Krathwohl *et al.*, 1964).

For the purpose of this study learners' assessment will be based on the three domains of the taxonomy of learning as described in Section 1.2.2 above.

#### **1.4.4. Physical Sciences**

According to the National Curriculum Statement (DoE, 2003: 9) the subject Physical Sciences focuses on physical and chemical phenomena and the associated laws, principles and theories. For the purpose of this study Physical Sciences will refer to the structural discipline as outlined in the National Curriculum Statements (DoE, 2003: 9) for grades 10 – 12.

#### **1.4.5. Learners**

In the context of this study, “learners” refer to physical science learners who are in grades 10 – 12.

#### **1.4.6. Interactivity**

In the Norms and Standard document (DST, 2004: 5) the term interactivity refers to exhibits and displays that can be handled and require response. The response is supposed to be *manual, emotional, mental* and social. Therefore it means that interactive exhibits and displays would be used in science centres to excite and entertain as well as linking educational experience to learning outcomes. This will be done by fulfilling and enhancing learners' psychomotoric skills (*manual*), affective aspects (*emotional*) and their cognitive skills (*mental*). The achievement of this in this study is seen as the development of science learners in a holistic manner.

### **1.5. METHOD OF RESEARCH**

#### **1.5.1. Literature Study**

The literature about this study was obtained by means of an intensive electronic search on publications on the subject in scientific and educational journals and from the internet. The following key words were used in the search: *science centres, assessment, holistic development and science*.

#### **1.5.2. Empirical Study**

Data in this study were acquired by means of questionnaires developed by the researcher, a pre-test and post-test (also developed by the author of this thesis) constituted by items based on the cognitive, affective and psycho-motoric domains of learning. Video recordings of the learners' interaction in the Potchefstroom Science Centre as well as personal interviews were conducted. This method of acquiring data was employed so as to achieve objectives (a), (b) and (c) stated in Section 1.2.2 above.

#### **Outlining objectives**

For the objectives (a) – (c) respectively:

- (a) A survey of the literature, the empirical study and the researcher's observations on the subjects of this study was made.
- (b) A literature study was conducted. The results of the empirical study were furthermore used to achieve this objective.
- (c) This objective was achieved through the empirical and literature study.

#### **1.5.2.1. Population**

The study focused on science learners who were enrolled in grades 10 – 12 with their respective schools in Potchefstroom, North-West province. A sample of learners (N = 375) who were in grades 10 - 12 and were Physical Sciences candidates from the five secondary schools (Tlokwe, Botoka, Resolofetse, Boitshoko and Seiphemelo) was considered. The sample comprised of twenty five learners per grade per school with, as far as possible, equal numbers of males and females. Learners were given the opportunity to visit the Potchefstroom Science Centre (located at the North West University) on a quarterly basis.

#### **1.5.2.2. Statistical Analysis**

The Statistical Support Services of the North-West University (Potchefstroom campus) were consulted to assist in the statistical analysis of the data. The specific statistical analysis used is outlined in Chapter 7 of this study.

### **1.6. OUTLINE OF THIS STUDY**

In Chapter 1 the motivation for a study of the impact that science centres have on the holistic development of Physical Sciences learners, the research aim and objectives, description of terms and the method of research is outlined.

Chapter 2, which constitutes the first part of the literature review, gives as an outline of how knowledge, and more specifically scientific knowledge, is acquired in learning. The structure of knowledge is also outlined. The process of acquiring knowledge in physical science is crucial in learning as it not only determines the quality of the knowledge retained, but also specifies the level of complexity of the retained knowledge (Anderson *et al.*, 2001: 38; Roth *et al.*, 1993: 27). This chapter addresses objectives (a) (i) and (b) of the study.

Since knowledge is the essential component of the development of memory, Chapter 3 explores the elements of memory and the memory process. The memory elements impacts on the type of knowledge and the period of storage of a particular knowledge. This chapter forms the second part of the literature study and relates to objective (a) of the study.

Since the contents of memory largely determines what is likely to be learned, Chapter 4, defines what learning is by looking at various learning theories and by extracting one that is more relevant to the perceived nature of science. Bloom's Taxonomy with regard to the cognitive, affective and psychomotoric domains is outlined. The chapter relates to the objectives (a); (b) and (c) of the study and constitutes the third part of the literature study.

In Chapter 5, the fourth part of the literature study, the science centre is defined as a concept of educational context. Its role in the development of science learners is explored. The chapter also seeks to classify science centres according to their categories. This chapter mainly addresses objective (c) of the study, but also attends to objectives (a) and (b).

The last chapter of the literature study, Chapter 6, looks at the assessment of science centres as described by literature. This chapter gives an assessment of a science centre in terms of the three learning domains (objectives) defined by Bloom, that is, in terms of the

cognitive, the affective and the psychomotoric development of the learner in Physical Sciences. The chapter relates to objectives (a) and (c) of the study.

Chapter 7 outlines the research methodology of this study. The discussions explain how the literature survey was performed and how the empirical survey was conducted. The questionnaires were administered to learners so as to address objectives (a), (b) and (c) respectively. An appropriate research scale was used to gather information about the subjects' opinions, feelings and convictions about items related to the objectives of the study.

In Chapter 8 the discussion of the empirical results, which focuses on the items of the questionnaire and the subjects' performance, is presented. This chapter relates to objectives (a), (b) and (c) of the study.

The analysis of results is followed by the conclusions and recommendations in Chapter 9. This chapter rounds-off the objectives that are stated in Section 1.2.2 of this study.

## **1.7.SUMMARY**

Science learners are primarily engaged in routine lower order thinking in their classrooms. In most science classrooms, the affective component of the learning domains is not considered. Focus is on the cognitive learning domain. The exclusion of the affective learning domain is detrimental as it is learners' attitudes that determine whether or not they will attend to their learning of science. Therefore this study was executed to make a contribution to the assessment of science centres in South Africa in terms of Bloom's Taxonomy of learning domains, which covers the cognitive, affective and the psychomotoric skills of learners, referred to as the *holistic* development of the learner. This was done to determine the impact of science centres on the holistic development of grades 10 – 12 science learners.

It is expected that the recommendations based on the results of this study will contribute towards the improvement of the effectiveness of science centres.

## CHAPTER 2

### THE STRUCTURE OF SCIENTIFIC KNOWLEDGE

*The learning and knowledge that we have is at the most, but little compared with that of which we are ignorant (Plato)*

#### 2.1. INTRODUCTION

Current dynamics and conceptions of physical science learning, focus on the active, *cognitive* and constructive processes involved in meaningful learning (Anderson *et al.*, 2001: 38; Yager, 1991: 44). In this learning approach, learners are assumed to be active agents in their own learning, they select the information to which they will attend and construct their own meaning from this selected information (Anderson *et al.*, 2001: 38; Haney & Lumpe, 2003: 366; Cobb, 1999: 15).

In instructional settings, learners come to class with a wide array of self constructed knowledge based on their prior experience (Driver, 1983: 6; Driver *et al.*, 1985: 4; White, 1988: 77 & Anderson *et al.*, 2001: 38). It is therefore essential, in the researcher's viewpoint that not only the concept *knowledge* should be defined, but that the process of acquisition of knowledge in physical science teaching and learning context should also be explored.

This chapter intends to define the concept *knowledge* within the realm of physical science and the way in which it is acquired. Types of knowledge will be identified and their impact on learning discussed.

#### 2.2. DEFINING SCIENTIFIC KNOWLEDGE

Epistemologically knowledge is defined as a belief that is justified as true to an absolute certainty (Pollock, 1986: 36; Carr & O'Connor, 1982: 64). Levi (1980: 1) seems to

support this notion in that he contends that for a belief to qualify as knowledge, it must be true and justified.

Malhotra (1994: 4) asserts that there are two conceptions of science which embody two different valuations of scientific life and of the purpose of scientific enquiry. According to the first conception science is an imaginative and exploratory activity in which a person taking part engages in a great deal of intellectual adventure. In this conception truth manifests itself in the mind of the observer; therefore it is the observer's imaginative understanding of what might be true. According to the second conception, truth resides in nature and is to be investigated through the evidence of the senses. The role of a science learner or scientist in this conception is essentially that of discernment. It follows therefore that science arrives at truth by logical inferences from empirical observations (Ziman, 1968: 5).

However it is important to note that knowledge does not arise from the object nor from the subject, but from their interactions, that is, between the subject and the perceived object (Malhotra, 1994: 4; Smock, 1981: 53; Ziman, 1968: 5; White, 1988: 121; Chadwick *et al.*, 1984: 4). To know objects, the subject must act upon and transform them. These transformations consist of actions that connect, displace, combine, take apart and reassemble. Therefore to know an object or reality means to construct systems of transformations that can be carried out with objects (Piaget, 1971), as quoted by Smock (1981: 53).

In defining scientific knowledge one has to firstly establish what science (physics/chemistry) is. The word *science* (Malhotra, 1994: 3) has its origin in the Latin verb *scire*, meaning "to know". Therefore *scientia*, meaning knowledge refers to a system of acquiring knowledge based on experimentation, experience and methodological naturalism aimed at finding the truth about nature. In science, the basic unit of knowledge is the theory which is a hypothesis that is predictable (Malhotra, 1994: 3). The term science also refers to the organized body of knowledge humans have gained by interacting with nature or by research (Malhotra, 1994: 3).

According to Taylor (1940: 1) quoted by Rapule (2005: 12) physical 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.

Scientific knowledge is distinguished from other intellectual artefacts of human society in that its contents are reached on consensus basis. This implies that each fact should not be so ambiguous that the next person is unable to give his/her consent or give an objection based on his/her findings (Ziman, 1968: 9; Malhotra, 1994: 5).

Scientific knowledge therefore would be *knowledge* (facts; concepts; laws; principles; theories and models) accumulated by systematic and scientific inquiry and investigation. This *knowledge* is a well tested sequence of events extracted from nature by cognitive observations (Barnes *et al.*, 1996: 2; White, 1988: 117; Monk & Dillon, 1995: 118; Hodson, 1998: 11). Because the acquisition and the interpretation of observational data can only take place within a theoretical framework, it follows that prior knowledge determines the quality of the observations that scientists and science learners can make and the meaning they ascribe to them (Hodson, 1998: 11; Desautels & Larochelle, 1998: 120).

### **2.2.1. Conclusion**

From the literature reviewed in section 2.2 above it follows that scientific knowledge must fulfil the following criteria:

- ❖ It should be theoretical in nature.
- ❖ It must form a systematic and consistent body of knowledge.
- ❖ It must be repeatable and reproducible.

- ❖ It must use objective scientific methods.
- ❖ It must be open to criticism when confronted with a new body of knowledge.

According to Beilin (1971: 98) it is crucial for teachers, learners and other stakeholders (curriculum developers) to note the following about the nature of scientific knowledge:

- ❖ Scientific knowledge is constructed. It is neither a copy of reality nor an interpretation of reality. It is constructed from experience and data.
- ❖ Knowledge (scientific) is constructed in the mind of an individual by means of a self-regulated mental mechanism.
- ❖ The constructive nature of knowledge implies that an individual plays an active rather than a passive role in creating knowledge.
- ❖ Development of the capacity to construct knowledge is a long process.

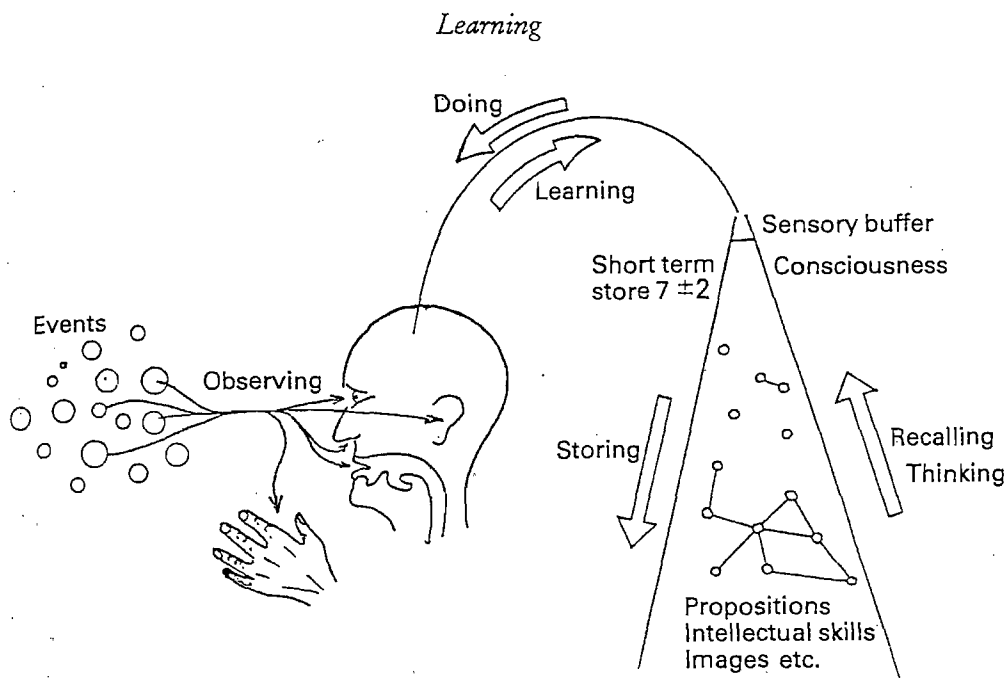
Since the acquisition of scientific knowledge depends on the observation of a body of structured *knowledge* and prior knowledge, the subsequent section attempts to reveal how this *knowledge* is acquired.

### **2.3. ACQUISITION OF SCIENTIFIC KNOWLEDGE**

Central to the South African policy document on education as reflected on the Physical Sciences National Curriculum Statement (DoE, 2003: 12 – 13), is the construction and application of scientific knowledge. This knowledge is, according to the constructivist theory, constructed in the mind of the learner during interaction with nature (Novodvorsky, 1997: 242). This self constructed knowledge is then brought to a learning context and is related to the relevant learning experience, be it scientifically correct or not

(Gunstone, 1991: 67; Hewson, 1981: 33 Novodvorsky, 1997: 242) quoted by Rapule (2005: 78).

In acquiring scientific knowledge White (1988: 117) argues that the process starts with the learner surrounded by events. The learner's body contains specialized receptors which are sensitive to five sorts of physical consequences of events, which are experienced as a sense of sight; touch; smell; taste and hearing. According to White (1988: 117) stimuli must be above a certain threshold intensity before the nervous system is triggered and a sensation is experienced.



**Figure 2.1. Representation of an information-processing model of learning (White, 1988: 119)**

White states that the selection of a series of events by a learner is affected by three factors, which are: the attributes of events; attributes of a learner as an observer and the interaction between events and observer (1988: 119). White (1988: 119) contends that the determinants of the attributes of events are objective properties. This means that the

greater degree of energy involved in the stimuli, the more likely the event is to be noticed. With regard to the attributes of the observer, the determining factor is the level of alertness of the learner/observer. If a learner is cognitively alert, then he/she will be at a better state of making connections to the learning material and hence will acquire knowledge.

By adopting scientific knowledge an individual goes through a process of conceptual change and replaces structures that emerged from everyday experience with scientific conceptions (Kempa, 1988: 22) quoted by Rapule (2005: 78). These knowledge structures incorporate a large body of routines that allow an agent to overcome limitations of his/her cognitive capacities (Hewson *et al.*, 1998: 201; Posner *et al.*, 1982: 212; Smock, 1981: 53).

The next section deals with knowledge change and also looks at factors influencing knowledge change.

## **2.4. KNOWLEDGE CHANGE**

Chinn and Brewer (1998: 98) contend that knowledge acquisition may proceed in two different stages, which they refer to as *global* and *local knowledge changes*. Global knowledge change is concerned with how whole systems of new knowledge are related to systems of old knowledge. The next section outlines how the global knowledge change occurs.

### **2.4.1. Global knowledge change**

#### **2.4.1.1. No knowledge to structured knowledge**

This knowledge structure has its roots from the *tabula rasa* learning theory which is based on the premise that the human mind (at birth) begins with no innate behaviours or knowledge at all. The human mental condition at birth is appropriately figured by white

paper, void of all characters or, wax to be moulded and fashioned as one pleases (Adams, 1922: 6; Locke, 1910: 9).

According to this theory the human mind acquires knowledge through the use of the five senses. The scholars of the theory do admit however that a child is born with a mechanism of human consciousness, but with no knowledge of content (Locke, 1910: 9). Knowledge of content is acquired through the interaction of the learner with nature through his/her senses. In the process the learner shifts from a state of not having knowledge at all to a state of acquiring structured knowledge (Chinn & Brewer, 1998: 98).

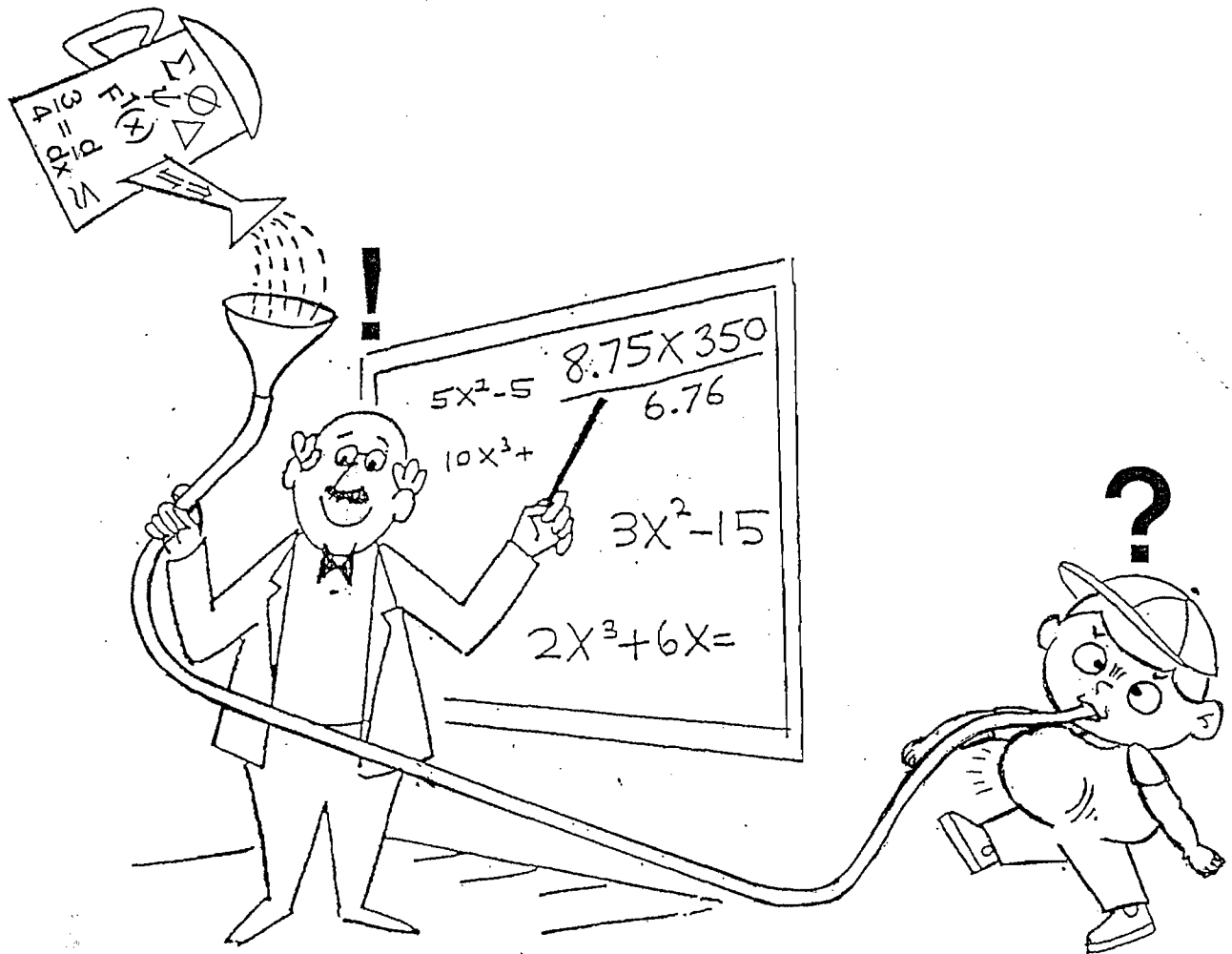


Figure 2.2. Representation of the tabula rasa learning theory (Skinner: 1989)

#### **2.4.1.2. Fragmented knowledge to structured knowledge**

The historic problem of the South African education system among other problems was the fact that the content of a subject was perceived as a linear input or output process. The syllabus therefore was rigid and non-negotiable (Olivier, 2002: 99). This led to learners acquiring knowledge which is fragmented. Because of the fragmented knowledge, naïve learners in the physics domain start out with a multiple of intuitions about the physical world. However, as they learn their fragmented knowledge is gradually refined into a structured whole (Chinn & Brewer, 1998: 98).

#### **2.4.1.3. Simple core knowledge**

From the discussion of scientific knowledge in Section 2.2 it follows that physics must consist of specialized knowledge. The idea is supported by Spelke (1991) quoted by Chinn and Brewer (1998: 98) in that he (Spelke), argues that in the absence of special instruction in physics, knowledge about the physical world is simply an elaboration but not necessarily a change in conception. This statement holds because through the interaction between events and the observer, the observer forms concepts and hence knowledge of states of matter. These conceptions remain at the core of later physics knowledge, which extends and adds to the core conceptions without changing them (White, 1988: 119; Chinn & Brewer, 1998: 98).

#### **2.4.1.4. Structured knowledge to conceptually-based structured knowledge**

The shift from structured to conceptually structured knowledge does not occur rapidly. This is because learners might have, through their interaction with the physical world, believed that when heated objects become thinner and longer. But when confronted with contrary evidence they change their minds and say heated objects become thicker and longer. This change according to Chinn and Brewer (1998: 99) does not seem to involve any changes in explanatory concepts.

#### **2.4.1.5. Structured knowledge to conceptually incommensurate structured knowledge**

There comes a time when in the knowledge structure of a discipline, like in physics or chemistry, a particular theory is under siege. In such instances where a conflict between science and its paradigms arises, due to either insufficient or inconsistent explanation on a phenomenon, a paradigm shift occurs (Kuhn, 1962). It is during such a knowledge change that structured knowledge changes to conceptually incommensurate structured knowledge. For instance, when learners learn about weight and mass there is a fundamental change in conceptions, such that the conceptual system completely changes (Chinn & Brewer, 1998: 99).

#### **Conclusion**

The nature of knowledge change has brought diverse teaching dimensions. Depending on the teacher's view-point, the lesson will be prepared and presented accordingly. For instance, a teacher who holds a view that learning about chemical reactions is a matter of elaborating core concepts will definitely present his/her lesson differently from the one who believes that learning about reactions involves a shift from one system of thought to an incommensurable one. Therefore the knowledge shift in learners is influenced by the learners' existing knowledge structures. A teacher would then, as in the constructivist theory, establish what learners know and adapt the teaching accordingly (Ausubel, 1968: 201).

In the next subsection the second stage of knowledge acquisition, *local knowledge changes*, is discussed.

## **2.4.2. Local knowledge changes**

The local knowledge changes are characterized into several types, which are: generalization; specialization; addition and deletion (Chinn & Brewer, 1998: 100). A brief outline of each is discussed hereunder.

### **2.4.2.1. Generalization**

Generalization consists of inducing an abstract principle by instances or applying a principle to a greater range of instances. In this process a learner will use logical reasoning based on general principles to arrive at a particular case. If the principle holds for that particular case then a learner will *generally* apply the logic or the deduced principle in similar cases (Chinn & Brewer, 1998: 100).

### **2.4.2.2. Specialization**

As stated in Section 2.2, science is an organized body of knowledge concerning the physical world, both animate and inanimate. The definition provided by Malhotra (1994: 3) in Section 2.2 includes the attitudes and methods through which this body of knowledge is formed. This body of knowledge may be divided into three main sections, which are physical sciences, earth sciences and the life sciences. The physical sciences include physics; chemistry and astronomy. Each of these sub-sections can also be subdivided into branches such as mechanics, electricity and magnetism, in the case of physics. The subdivision of physics as a subject signifies the fact that it comprises of a large body of knowledge. This knowledge could be factual, conceptual, procedural and/or metacognitive in nature (Anderson *et al.*, 20001: 45, Livingston, 1997: 1).

It is for this reason that one has to acquire specialized knowledge in a branch of physics so as to enhance the knowledge base in the particular area of study. As Chinn and Brewer (1998: 100) put it, when a learner has specialized knowledge, he/she will be able to create two principles or conceptions where only one existed before. This process helps

learners to form a better concept of principles and will be able to construct a network on concept mapping.

#### **2.4.2.3. Addition**

Addition occurs when new knowledge is added to the existing knowledge structures. Prior knowledge forms the bedrock that learners use to inform inferences based on later experiences. Thus, in any science classroom, it can be expected that learners will have had experiences that helped them develop stable and functional constructs of the world. These constructs or ideas will influence interpretations made of explorations in science. When a learner encounters further developments of a particular knowledge structure that is consistent with the existing knowledge he/she will add that knowledge to the existing knowledge structure (Wandersee *et al.*, 1994: 178, Chinn & Brewer, 1998: 99, Thagard, 1992: 252).

#### **2.4.2.4. Deletion**

Deletion is a process in which old/existing knowledge is either deleted or suppressed. Learners are unlikely to make major changes to their knowledge structures unless they believe that less radical changes will not work. When learners become dissatisfied with existing ideas and recognize new ideas as intelligible, plausible and fruitful, they seem to suppress or delete the existing knowledge (Chinn & Brewer, 1998: 99, Hodson, 1998: 52, Posner *et al.*, 1982: 214, Thagard, 1992: 252).

### **Conclusion**

As indicated in Section 2.3, when acquiring scientific knowledge an individual goes through a process of conceptual change and replaces structures that emerged from experience. This shows that knowledge acquisition is a process. In order to enhance these processes science teachers should ensure that they:

- ❖ Create a discrepant event (conflict/phenomenon that cannot be explained by learners' current conceptions but can be explained by the concept that is the current topic of discussion).
- ❖ Create a context/atmosphere conducive to teaching/learning by allowing learners to freely discuss their alternative conceptions.
- ❖ Set learning and instructional outcomes.
- ❖ Constantly pose thought provoking questions.
- ❖ Have adequate knowledge on the content discussed.
- ❖ Create a concept conflict (Rapule, 2005: 90, Chinn & Brewer, 1998: 99, Chinn & Brewer, 1993: 15, Hodson, 1998: 39).

Conceptual change teaching strategies has three-fold benefits (cognitive, affective and psycho-motoric skills) as they tend to develop learners holistically. Niaz (2005: 5) asserts that conceptual change teaching strategies can promote learners' interest, curiosity and understanding.

It has been discovered that there are three basic factors that impede knowledge change, which are *prior knowledge*, *characteristics of input information* and *processing strategies*.

In the following subsection factors influencing knowledge change will be discussed.

## **2.5. FACTORS INFLUENCING KNOWLEDGE CHANGE**

### **2.5.1. Prior knowledge**

Constructivist theorists argue that all new learning builds on prior understanding or knowledge. Depending on the quality and the consistency of the knowledge gathered through experience with the world, prior knowledge can make it either difficult or easy to understand or learn new information. This is supported by the argument put forth by Roschelle (1997: 1) that learners' prior knowledge often confounds an educator's best efforts to deliver ideas accurately.

According to Roschelle (1997: 1); Thompson and Zamboanga (2003: 96) learning proceeds primarily from prior knowledge and only secondarily from presented materials. When prior knowledge is at odds with the *new* or presented knowledge, learners will distort that knowledge. However, neglecting prior knowledge is detrimental as it may result in learners learning something opposed to the teaching–learning outcome of the encounter. Therefore it is important to note that prior knowledge does not only influence learning, but it forces a theoretical shift to viewing learning as conceptual and knowledge change (Chinn & Brewer, 1998: 104; Thompson & Zamboanga, 2003: 96; Roschelle, 1997: 2).

### **2.5.2. Characteristics of input information**

Once an individual has a set of knowledge structures and a particular framework of prior knowledge, input of new information, be it in the form of rules; models or theories, depends on how the information is presented as well as on the nature of the information. Chinn and Brewer (1998: 105) contend that one group of learners learn best by discovering ideas by themselves through exploration, without being presented with the exposition, while another group may need to be guided and furnished with examples. There may also be a third group that learns best from analogies.

It is important to note that new knowledge does not replace prior knowledge but rather refines it and builds on it to form a meaningful whole. Thus learners are more likely to construct an interpretation that agrees with prior knowledge and consequently distort anything else. The effects of prior knowledge therefore, require a shift from the notion that learning is absorption of transmitted knowledge to the view that learning is a process of conceptual and hence knowledge change. Science teachers will then develop a good teaching strategy if they consider the extent and nature of prior knowledge that learners possess before their teaching–learning experience (Trowbridge & Bybee, 1990: 46; Chinn & Brewer, 1998: 105; Roschelle, 1997: 8).

### **2.5.3. Processing strategies**

A learner's role in knowledge acquisition is vital in that it (knowledge acquisition) depends on the learner's processing strategies. A strategic learner (a learner who is conscious of his learning abilities and potential) is capable of selecting a relevant learning strategy based on the goals he/she aims to achieve. Therefore it is critical for learners to be aware of the various learning strategies and to know which to apply when faced with a task in order to enhance knowledge change and hence knowledge acquisition (Chinn & Brewer, 1998: 106, Ertmer & Newby, 1996: 4).

The general perspective of this study on knowledge is based on the cognitive psychology on knowledge representation. There are many different types of knowledge but this study will focus on the main four, which are discussed hereunder. In the next chapter, Chapter 3, a diagram and discussion on how information, hence knowledge construction, flows from the stimuli (environment) through the memory system is discussed (see Section 3.2).

## 2.6. TYPES OF KNOWLEDGE

The opening part of this chapter (Section 2.2) defined the concepts *knowledge* and *scientific knowledge*. In an attempt to clarify the different levels of knowledge, consider the following scenario in four isolated physical science classes.

Teacher A's objective is to see his learners being able to list (systematically) the first twenty elements of the periodic table. Learners in teacher B's class shall have achieved the outcome when they are able to successfully classify different elements of the periodic table into their groups and periods. The learning outcome(s) in teacher C's class concerns the outlining of the experimental procedure to determine the rate of reaction of alkaline metals (group 1 elements) with oxygen and water. From the experimental observations learners in teacher D's class are expected to achieve the outcome if they can associate the relative reactivity of the alkali and alkaline earth metals with oxygen and water, with their position (groups and periods) on the periodic table of elements.

The scenario above depicts the four different types of knowledge within the same content. The importance of the teacher's role in handing out a task is evident in that he/she should consider learners' knowledge base or prior knowledge and the type of knowledge that learners have or should acquire (Anderson *et al.*, 2001: 40).

In the subsequent subsection, types of knowledge, *factual*; *conceptual*; *procedural* and *metacognitive* knowledge, are discussed.

### 2.6.1. Factual knowledge

According to Anderson *et al.*, (2001: 45) factual knowledge refers to knowledge of discrete, isolated content elements. This type of knowledge includes knowledge of terminology and that of specific details and elements. Even though factual knowledge exists at the lowest level of abstraction it encompasses a large body of basic elements that experts use in their academic discipline. Due to the enormous wealth of this body of

knowledge, it is almost inconceivable for learners to learn all of it, in this case scientific knowledge. Because of the rapid growth of scientific knowledge and the already extensive body of existing scientific knowledge learners and even scientists cannot keep up with all.

Anderson *et al.*, (2001: 45) propose two sub-types of factual knowledge, which are knowledge of terminology and knowledge of specific details. The next sub-sections distinguish between the two sub- types of knowledge.

#### **2.6.1.1. Knowledge of terminology**

Physical science as a subject consists of a large number of symbols that may be verbal or non-verbal such as symbols for elements of the periodic table; units of measurements; names of concepts or definitions and warning signs for safety measures in the laboratory. This knowledge constitutes what Anderson *et al.*, (2001: 45) refer to as knowledge of terminology. Knowledge of terminology forms the basic language of physical science such that it facilitates communication between experts in the field. Since knowledge of terminology is the underlying knowledge in a field, learners in that field must be cognizant of it so as to build on it as they develop new knowledge.

#### **2.6.1.2. Knowledge of specific details**

The science of physics and chemistry has developed out of efforts of men and women to explain why our physical world behaves as it does. These efforts have been so successful that the laws of physics and chemistry now encompass a remarkable variety of phenomena. For instance, rocket science and the development of space travel have their roots firmly planted in the physical laws of Galileo Galilei (1564 – 1642) and Isaac Newton (1642 – 1727). This kind of knowledge is about knowledge of events, locations, people, dates and sources of information (Cutnell & Johnson, 1998: 2, Anderson *et al.*, 2001: 47).

Knowledge of specific details requires science learners to have specific information about events in physical science so as to help a learner to acquire a basic knowledge of phenomena. Very often this type of knowledge is meant for enrichment (Cutnell & Johnson, 1998: 2, Anderson *et al.*, 2001: 47).

### **2.6.1.3. Acquisition of factual knowledge**

Evidence of the acquisition of factual knowledge will be seen when learners are able to answer questions related to the following action verbs (Anderson *et al.*, 2001: 48):

- ❖ *State* Newton's laws of motion in words.
- ❖ *Define* what an electric field is.
- ❖ *Name* scientists who contributed towards the development of the atomic model.
- ❖ *Write* down the mathematical relation of Newton's second law of motion.
- ❖ *Recall* the principle of conservation of charge.
- ❖ *Recognize* Boyle's law apparatus.
- ❖ *List* the different parts of Boyle's law apparatus.
- ❖ *Label* the parts of a Boyle's law apparatus.

### **2.6.2. Conceptual knowledge**

Unlike factual knowledge, conceptual knowledge is a more complex type of knowledge which does not only include knowledge of categories and classification, but also seek for the relationships between them. It is the type of knowledge that deals with schemas and

mental models in different cognitive psychological models. Conceptual knowledge is rich in relationships and understanding. It is a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information (Anderson *et al.*, 2001: 48). In science education concept maps are often used to display the relationships between concepts (White, 1988; White & Gunstone, 1993).

According to Shaw and Wilson (1976: 198) a basic characteristic of human intelligence is the ability to formulate conceptual knowledge about objects (apparatus) and events (procedure). Conceptual knowledge is therefore exemplified when learners can deal appropriately with novel instances of a concept, that is, when learners' knowledge goes beyond just the instances experienced. In other words, conceptual knowledge will be enhanced when learners use their prior knowledge to make sense of the new information and construct meaning out of the two. Learners should make sense of the experimental procedure that they carry out. The knowledge base should not just be limited to the physical interaction with the apparatus.

The three subtypes of conceptual knowledge are discussed below.

#### **2.6.2.1. Knowledge of classification and categories**

When learners are given a task, for example to state with reasons why the symbols of the elements hydrogen; lithium; sodium; potassium; rubidium; cesium and francium are placed on group 1 on the periodic table of elements, they will have to consider possible reasons for classifying and categorizing these elements. They will consider common features of the elements. With the aid of knowledge of how to classify and categorize objects, learners will discover that the electronic configuration of the said elements is such that each has one valence electron; hence they are all in the same group.

Knowledge of classification and categories is an essential aspect of developing expertise in an academic discipline. Anderson *et al.* (2001: 49) argue that proper classification and categorizing of information is a classic sign of learning and development. This subtype

of conceptual knowledge is of higher order as it requires learners to make connections among specific content elements of a complex system, that is, not only of terminology but of facts as well. Once a learner is able to classify and categorize objects of a complex system, a reflection of understanding and conceptual change will be evident.

#### **2.6.2.2. Knowledge of principles and generalizations**

Knowledge of principles and generalization includes knowledge of particular abstractions that summarize observations of phenomena. These abstractions have the greatest value in describing, predicting and explaining. For a learner to acquire knowledge of principles and generalization he/she must bring together a large number of underlying (basic) specific facts in physics and chemistry and be able to describe the processes and interrelationships among these specific details. It is crucial to note that in the process of gathering knowledge of principles and generalization, learners must be able to classify and categorize objects. Therefore, knowledge of principles and generalization enhances knowledge of classification and categorization (Anderson *et al.*, 2001: 51)

#### **2.6.2.3. Knowledge of theories, models and structures**

From the knowledge of basic underlying facts in the discipline (physics and/chemistry), theories are formulated. In this type of knowledge a great deal of network of interrelated concepts and propositions common to principles and generalizations are outlined so as to verify the consistency and validity of the outcome. In achieving this knowledge a successful learner will be able to give a simplified representation of an object, structure, event, model or the relationship thereof. Knowledge of theories, models and structures seek to reveal in learners the quality of relating ideas meaningfully and drawing relevant conclusion of events. In the event that scientific theories are inconsistent within the context of the existing scientific paradigm, a paradigm shift occurs. When a paradigm shift occurs, a scientist's world is qualitatively transformed and quantitatively enriched by fundamental novelties of fact and theory. This then calls for acquisition of new scientific

knowledge and formulation of new principles and theories (Hodson, 1998, 17, Anderson *et al.*, 2001: 52, Kuhn, 1970: 62).

### **2.6.3. Procedural knowledge**

Learning Outcome 1 of Physical Sciences focuses on practical inquiry and problem solving skills (DoE, 2003: 16). Teachers are now faced with the direct responsibility for assessing learners' scientific skills. Seemingly the position of skills and processes in science education will be a central issue for teachers. Skills and process development are essential to help learners acquire procedural knowledge so that they may develop a scientific approach and be able to make sense of, and fit into their future work environment (Jenkins, 1989: 41, Millar, 1989: 51).

According to Millar (1989: 52) a procedure is a naturally occurring, or designed sequence of operations that produce some outcome. It is the knowledge of how to *do* something. It includes the knowledge of skills, algorithms, techniques and methods, collectively known as procedure. Scientific processes are essential in science education as they enhance skills such as observing, classifying, inferring and hypothesizing. From the description it follows that when a learner has acquired procedural knowledge he/she would have mastered an essential skill for either following the preset sequence or for carrying out processes of inquiry (Millar, 1989: 52).

Anderson *et al.* (2001: 54) proposes the three subtypes of procedural knowledge which are discussed hereunder.

#### **2.6.3.1. Knowledge of subject-specific skills and algorithms**

To distinguish this subtype of procedural knowledge from others consider the following scenario. The learning outcome of the teaching/learning encounter of a grade 12 class is based on the experimental observation of the magnitude of the applied force ( $F$ ) and the acceleration ( $a$ ) of a given object of mass ( $m$ ). In finding the relationship between the

applied force and the acceleration, learners will have to follow a particular sequence of events. The experiment yields the results in that in applying a larger magnitude of force, the magnitude of the acceleration of an object of mass ( $m$ ) increases, hence a direct proportionality between the magnitude of the applied force ( $F$ ) and the magnitude of acceleration ( $a$ ) or  $F \propto a$ .

In achieving the outcome learners will carry out the experiment in a precise manner and follow preset sequences since the end result is predictable. In the process learners will acquire procedural knowledge (knowledge of following the sequence) and also acquire factual knowledge (that of the relationship between the magnitude of the force applied and acceleration of the object of a given mass). However, throughout the investigation learners acquire essential skills of observing and hypothesizing (Anderson *et al.*, 2001: 53, Millar, 1989: 52).

#### **2.6.3.2. Knowledge of subject-specific techniques and methods**

Contrary to how the knowledge of subject-specific content and algorithms is acquired, the acquisition of knowledge of subject-specific techniques and methods does not follow a preset sequence. It is knowledge that is largely the result of the consensus and agreement. It reflects on how scientists think and seek to address existing social and economic problems by way of a scientific approach (Anderson *et al.*, 2001: 54).

This knowledge helps learners to be creative and sharpen their problem solving skills. It is also fundamental in assisting them to view problems holistically, be they social, economic or scientific.

#### **2.6.3.3. Knowledge of criteria for determining when to use appropriate procedures**

It is not sufficient for learners to follow a particular sequence to solve a problem or design a meaningful procedure to attack an existing social problem. It is crucial to first understand the nature and the cause(s) of the problem before the plan can be executed.

Secondly it is equally important to have the knowledge of when and where to execute the plan. Acquisition of this knowledge will be helpful in informing learners what procedures to follow under certain circumstances and also when to apply a particular procedure (Anderson *et al.*, 2001: 55).

#### **2.6.4. Metacognitive knowledge**

Metacognitive knowledge is knowledge about cognition (action or process of acquiring knowledge, by reasoning or by intuition or through senses) as well as awareness of and knowledge about one's own cognition. Stated briefly, metacognitive knowledge refers to acquired knowledge about cognitive processes (Anderson *et al.*, 2001: 55, Brown, 1987: 66) (Flavell, (1979) quoted by Livingston (1997: 1).

According to Livingston (1997: 2) knowledge is considered metacognitive if it is actively used in a strategic manner to ensure that a goal/outcome (learning) is met. It includes knowledge and regulation of cognition consisting of (1) a person's variables, or knowledge about the thinking of one self and of others, (2) task variables or knowledge that different types of tasks exert different types of cognitive demands and (3) strategy variables or knowledge about cognitive and metacognitive strategies for enhancing learning and performance (Flavell, 1979: 908, Weinstein & Meyer, 1994: 3336, Zimmerman, 1990: 5, Ertmer & Newby, 1996: 1).

It follows therefore that a learner who has acquired metacognitive knowledge has knowledge of strategy variables which include knowledge about how an individual learns and processes information. This learner will be aware of his/her own learning processes. Metacognition includes strategic knowledge; knowledge about cognitive tasks and knowledge about self which are discussed hereunder.

### 2.6.4.1. Strategic knowledge

Strategic knowledge is knowledge of the general strategies for learning, thinking and problem solving (Mayer, 1987: 10, Livingston, 1997: 1, Anderson *et al.*, 2001: 56). The acquisition of this knowledge leads to learners being aware of a number of strategies concerning their learning, for instance:

- ❖ At what time of the day am I most productive for studying Physical Sciences?
- ❖ Am I likely to understand more efficiently if I study in a quiet place like a library or in a park or even at home?
- ❖ What learning strategies will I use to memorize the first twenty elements of the periodic table?
- ❖ When/how do I plan to finish the assignment on the project given?
- ❖ Where will I get the resources for the project to be submitted in a month's time from now?

The examples of strategies listed above are evidence that in acquiring strategic knowledge, learners can have essential knowledge of various metacognitive strategies that are useful in planning, monitoring and regulating their cognition. In addition to these general strategies, learners also acquire a number of learning strategies such as rehearsal, elaboration and organization (Mayer, 1987: 12, Livingston, 1997: 2, Anderson *et al.*, 2001: 56).

Rehearsal learning strategy is essential in helping learners to recall facts by repetition of the words or phrases. Elaboration strategy comes in handy when learners have to devise a strategy to learn the sequence of the rainbow colours or of the elements of the periodic table. In this case learners may use mnemonics devices to remember the order of the

sequence of the colours of the rainbow (e.g. ROYGBIV). Organizational strategy involves forms of outlining, or the drawing of concept maps. This strategy foster deeper processing of the content and result in better comprehension and learning compared to the first two strategies (Mayer, 1987: 15, Anderson *et al.*, 2001: 57).

#### **2.6.4.2. Knowledge about cognitive tasks, including contextual and conditional knowledge**

Imagine that a task at hand requires of learners to provide solutions to the contaminated water in a dam in their area, that is considered a health hazard to both humans and to the community's livestock. In the process learners will have to hypothesize about the problem and get to understand the nature of the problem. There has to be extensive consultation of experts, collecting of samples for testing, verification and educational programmes on the issue. In doing this learners must have appropriate strategies to effectively attack the problem. Essentially, they must know which strategy to use under particular conditions. Therefore learners must possess conditional knowledge (knowledge of the situation in which learners may use metacognitive knowledge) (Anderson *et al.*, 2001: 58).

Physical Sciences as a discipline/subject cover a broad perspective in learning. It instils in learners problem solving skills and scientific knowledge. It enables learners to understand its nature and relationships to other disciplines (DoE, 2003). In acquiring knowledge about cognitive tasks and conditional knowledge, learners are assured of effective strategies in carrying out tasks (Paris *et al.*, 1983: 302, Anderson *et al.*, 2001: 58).

#### **2.6.4.3. Self-knowledge**

A learner with self-knowledge will have knowledge of his/her own strengths and weaknesses in relation to cognition and learning. That learner will have personal beliefs about his/her capabilities to organize and implement the actions necessary to attain

designated learning and performance outcomes (Schunk, 1994: 84, Anderson *et al.*, 2001: 59).

In being cognitively aware of his/her strengths and weaknesses a learner will use appropriate strategies to perform given tasks. He/she will also reflect inwardly to choose a strategy based on the context of the task or problem.

## **2.7. CONCLUSION**

It is important to note that knowledge is not acquired in discrete processes. The purpose of the discussion in the preceding sections was to highlight the different types of knowledge, how they are acquired and the importance for learners to acquire it. It is evident that a learner may acquire all four types of knowledge in one comprehensive activity. Acquisition of these types of knowledge helps build a learner in totality (holistically) as the knowledge types cut across the *cognitive* (factual; conceptual; metacognitive and procedural knowledge), *affective* (procedural knowledge) and *psycho-motoric* (procedural) development of a learner.

One of the objectives of this study as stated in Section 1.2.2 is *to investigate the effective ways for learners to acquire scientific knowledge*. This objective is in line with the Physical Sciences learning outcome stated in the National Curriculum Statement about the construction and application of scientific knowledge (DoE, 2003). From the literature it follows however that, for acquiring scientific knowledge effectively, the following factors should be borne in mind:

### **2.7.1. Prior knowledge**

- ❖ The nature of learners' prior knowledge on the related topic should be considered essential and must be attended to with a broader mind.
  
- ❖ The characteristics of the input information must be considered.

- ❖ Learners' processing strategies must be taken into account.

**2.7.2.** The **type of knowledge** that learners have on various activities/ topics will be necessary information to teachers to determine the adjustments required for knowledge acquisition

**2.7.3.** The **factors which may impede possible knowledge change** should be identified and treated.

Chi (1987: 262) asserts that knowledge is an essential component of memory development. That is if for instance, cognitive structures (knowledge structure of a learner, see Section 2.6) are developed then those structures will enhance the memory of the learner.

It is important to note that scientific knowledge can be acquired through scientific procedures. McComas (1998: 64) supports this statement as he states that experiments are the principal route to scientific knowledge acquisition. It is the primary objective of this study to find out whether experiments bring about cognitive enhancement in science learners.

In the next chapter the processing, storing and retrieving of the acquired knowledge by the human memory will be explored.

## CHAPTER 3

### MEMORY: ITS FUNCTION AND ROLE IN KNOWLEDGE CONSTRUCTION AND LEARNING

*The mind is not a vessel to be filled but a fire to be ignited (Plutarch)*

#### 3.1. INTRODUCTION

The acquisition of scientific knowledge or knowledge in general as discussed in the previous chapter should be seen as a process. It is a process that starts with learners observing events that surround them (White, 1988: 117). The term “process” suggests that learners are not merely looking at events or at the world, but rather that they are mentally acting on the information that they are extracting from the occurrences (interaction between them and the world) and in the process, attaching meaning to the information gathered (Bjorklund, 2005, 119, Hamilton & Ghatala, 1994: 81).

Now that scientific knowledge is acquired, how is it *processed (encoded), retained (stored)* and *retrieved* when required? This chapter seeks to outline the process thereof. Although there is a plethora of approaches and theories on cognitive development of information processing, this study will limit itself to the approach that people do *process information* in a systematic manner referred to as a memory system.

#### 3.2. THE PROCESSING OF ACQUIRED KNOWLEDGE (Information)

When learners or observers interact with the external world they do so with the aid of their senses (White, 1988: 117). Such information from the external world is recorded in sensory registers. According to Bjorklund (2005: 120), Adams (1976: 242) Hamilton and Ghatala (1994: 80) each sense modality has its own sensory register which can hold an enormous amount of information for a short while. When a learner is looking at a

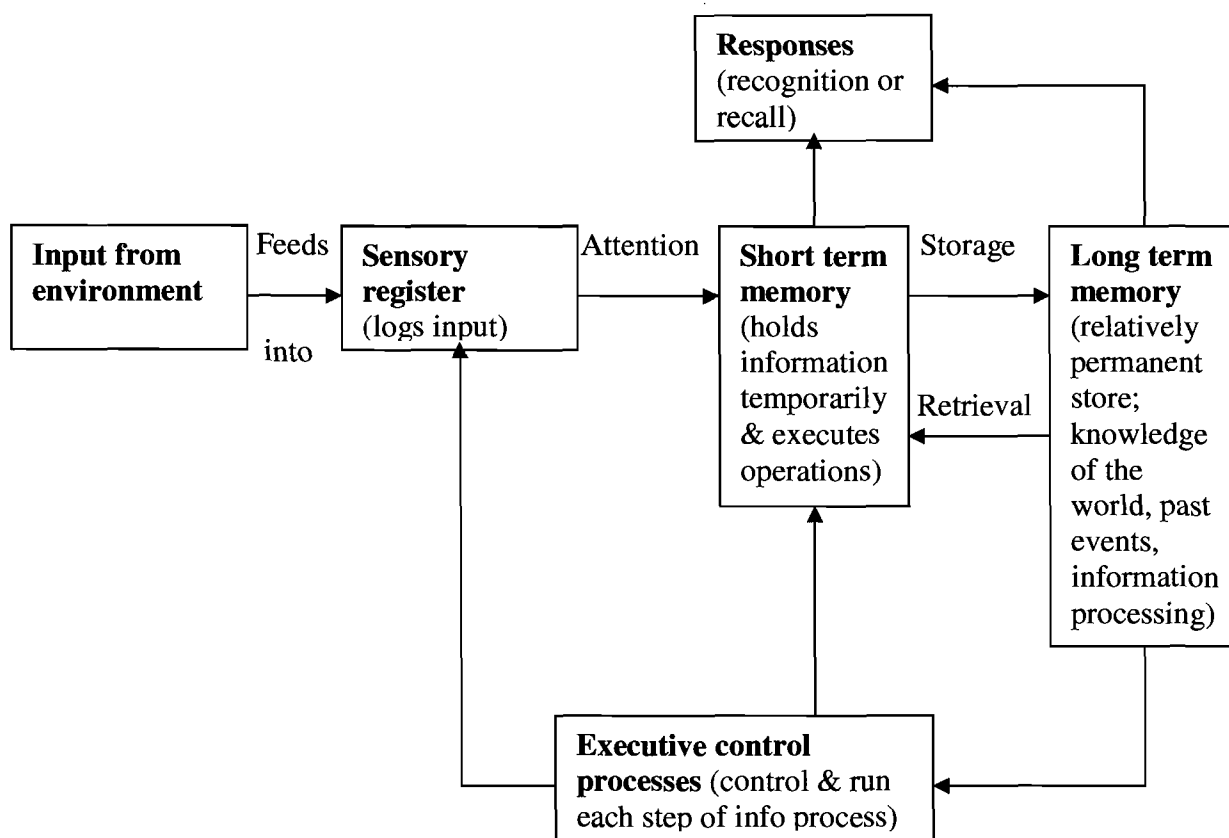
periscope in his hand, the sensory registers of the sense of vision and touch (examples of sense modality) will hold information about the periscope for a very short while (a time span of milliseconds). Depending on the learner's prior knowledge about the periscope, knowledge may be stored in the specific *compartment* of the memory.

However the most crucial step to take before any information can be processed is paying attention. The physical world provides much more information than the learner's memory can process. Thus the learner must make choices regarding the stimuli to which he/she will attend. Once the learner is attending to the phenomenon, then that information must be encoded to be remembered. Encoding refers to the translating of incoming information into a mental representation that can be stored in memory. The encoding of information to be stored may occur in different patterns. It may be encoded according to its acoustic code (sound) or according to its visual code (what it looks like) or even according to its semantic code (what it means) (Bjorklund, 2005: 121, Spear, 1978: 2).

From the initial registration of information through the senses, information is then passed on to the short term memory or working memory. Compared to the sensory memory, the capacity of the short term memory is small but the representations are more durable and last longer. In this compartment information is evaluated, strategies are applied to solve problems and the process of remembering is also taken care of, hence it is called the working memory. However if nothing is done (cognitively) to the information in the short term memory, it will be lost (Bjorklund, 2005: 121).

If cognitive operations on the short term memory are performed, the information will then be stored in the long term memory, where according to (Hamilton & Ghatala, 1994: 80, Bjorklund, 2005: 120, Higbee, 1977: 12) it will be stored indefinitely.

The diagram hereunder shows the flow of information through the memory system as described by Bjorklund (2005: 121) and Hamilton and Ghatala (1994: 81).



**Fig 3.1. Flow of information** (Bjorklund, 2005: 121; Hamilton & Ghatala, 1994: 81).

From this illustration it can be concluded that the acquisition and retention of memory can be classified according to (i) the duration of memory retention, (ii) the capacity of the memory compartment, (iii) the type of information, and (iv) the temporal direction. These therefore identify three distinct types of memory: *sensory memory*, *short term memory* (or working memory) and *long term memory*. A brief discussion of each follows after the tabular representation of the memory types hereunder.

<b>Memory type</b>	<b>Memory sub-type</b>	<b>Duration</b>	<b>Information type</b>	<b>Capacity</b>
<b>Sensory</b>	Iconic	0,5 seconds	Responds to stimuli	Between 5 and 8 items
	Echoic	0 – 5 seconds		More than 8 items
	Haptic	5 – 20 seconds		A large number of items
<b>Short term (Working memory)</b>		30 – 45 seconds	Select information to be stored	Up to 7 items at a given time
<b>Long term</b>	Declarative	Life time	Retain selected information for later use	Unlimited
	Non-declarative			

**Figure 3.2. Table showing the classification of memory** (Bjorklund, 2005: 121; Hamilton & Ghatala, 1994: 81).

### **3.3. TYPES OF MEMORY**

#### **3.3.1. Sensory memory**

Sensory memory refers to the human ability to retain impressions of sensory information after the original stimulus is ceased. Consider the scenario of the learner with the periscope mentioned in the preceding section. If the learner does not have a recollection of such or similar instruments in his/her sensory register, the information will be lost at the end of the time of interaction with the instrument. That is, if the stimulus (periscope) is removed the impression will either be ceased or retained depending on the learner's prior knowledge. However if a learner has a recollection of similar instruments in his/her

sensory register, the information will be passed through to the short term memory (STM) or working memory (Bjorklund, 2005: 120, Hamilton & Ghatala, 1994: 80).

Sensory memory has five basic sensory registers which acts like buffers to stimuli. These sensory registers are classified as a smell sensory memory, a taste sensory memory, a visual sensory memory (or **iconic memory**), an auditory sensory memory (or **echoic memory**) and a touch sensory memory (or **haptic memory**) (Bjorklund, 2005: 120, Hamilton & Ghatala, 1994, 80, Adams, 1976: 242). The last three are prevalent in the learning of physics and are discussed briefly in the subsequent sections.

### **3.3.1.1. Iconic memory**

The ability to hold visual images in the short term memory occurs in or is termed iconic memory. Sperling (1960) quoted by Adams (1976: 243) and Eysenck and Keane (1995: 125) discovered that the iconic memory operates upon stimuli of short duration. The iconic memory has a capacity of about 5 – 8 items and the impression lasts for only half a second. The perceiving of the impression occurs in mental pictures. Since impressions in the iconic memory occur in mental pictures, stimuli can be distinguished on the basis of physical properties (as in the colour or the size of a letter or apparatus) but not properties of the meaning of words or consonants.

The collection of all memory elements which include propositions, strings, images, episodes and intellectual skills seems to be enhanced by visual pictures (White, 1988: 32, Alesandrini, 1989: 358). This then is in agreement with the way information is acquired and hence concepts formed in one's knowledge structures. Alesandrini (1989: 358) aligns himself with this line of reasoning in that he argues that, pictorial learning strategies indicate that learning is improved when pictures supplement verbal materials. If we agree that the interaction (visualizing and interrogating the resources) between learners and the resources used is but one of the strategies that can be used to acquire knowledge, and the resources used refer to the "pictures" mentioned by Alesandrini, then it is not

difficult to see the connection between the cognitive development and the context in which the stimuli are presented (science centre in the case of this study).

Alesandrini (1989: 358) argues that, when learners are given a chance to draw their own pictures while studying and when they are asked to generate mental pictures while reading or studying, they will memorize and conceptualize easily. This supports the fact that when learners are engaged in science learning, where they see, touch and manipulate the "pictures", (which are resources or apparatus in our case), the learners should memorize and conceptualize successfully and meaningfully.

Smith & Jones (1989: 8), support the argument put forth by Alesandrini when they state that the images of physics and chemical reactions that learners acquire in their physical science courses affect how they feel about these courses and how well they learn it. Lectures, books and laboratory work have been students' primary sources of images, even of chemicals and of chemical reactions. This has deprived learners of the opportunity to memorize and conceptualize because the closest they come to see or touch resources for practical work, are when they hear speeches and see drawings on the chalkboard.

Since the iconic memory holds visual images for a short while, it can be concluded that the iconic memory may be enhanced by exposing learners continuously to the scientific resources so that they can see (for a longer period of time) and in the process consolidate the knowledge base.

### **3.3.1.2. Echoic memory**

Echoic memory refers to the ability to hold sounds in the short term memory. Adams (1976: 249), Travers (1982: 42) and Eysenck and Keane (1995: 126) assert that the basic difference between the iconic and the echoic memory lies in the persistence of items in either memory. As indicated in the discussion of iconic memory, items are retained for half a second in this memory but in the echoic memory lasts for much longer.

### **3.3.1.3. Haptic memory**

Haptic memory refers to the ability to hold information from the physical world through interaction with the material in the short term memory. The encoding of this memory is also momentarily, but has a relatively lasting impression compared to the iconic and the echoic memory. This is due to the fact that when a learner has a thermometer (for instance), he/she will interact with it and this interaction engages a number of sensory registers, thereby forcing the memory to focus on the instrument for a considerable amount of time (Adams, 1976: 256).

Since concrete-operational students reason in terms of direct experience, making attributes of abstract concepts more directly perceptible could improve comprehension. Illustrations, diagrams, and models have been used for just such purposes for years. However, the relative value of such materials for concrete-operational and formal-operational students has not been thoroughly explored, (Cantu & Herron, 1978: 136).

This discussion illustrates that exposing learners to environments where they can interact with resources by touching them will certainly play a vital role in learners to memorize and comprehend better and eventually to conceptualize. It also follows that, concrete-operational learners will be able to see, touch and manipulate resources and give meaning to their learning since they can perform the work practically (Cantu & Herron, 1978: 136).

When the sensory register has recorded the stimuli it is transferred to the short term memory where, depending on the prior knowledge and whether the information will be required immediately or for later use, it may be encoded.

### **3.3.2. Short term memory (Working memory)**

This memory type is called short term due to the fact that it decays rapidly. The concept of working memory seems to be appropriate as it describes the active role of this

memory. It refers to a set of processes or structures that enables temporary storage of the intermediate products of cognition and supports transformation of those products, hence the term “working” (Andrade, 2001: 5).

For the purpose of this study the two terms will be used interchangeably, labelling the same concept. The short term memory or working memory acts as a scratch pad that enables the brain to evaluate the input information or incoming stimuli. In the process the short term memory selects what is to be retained and memorized and what is to be rejected. In other words, the short term memory is responsible for enabling us to recall (temporarily) any information which is currently under process (Adams, 1976: 226, Hamilton & Ghatala, 1994: 80, Bjorklund, 2005: 120, Eysenck & Keane, 1995: 127, Higbee, 1977: 15). Once a stimulus is attended to and perceived, the input is transferred to the working memory. Incoming or new information is stored for a short time and is worked on by being rehearsed or related to prior knowledge stored in the long term memory (Schunk, 2000: 139).

The short term memory has a limited capacity and as a result decays rapidly, that is, it loses information after a short time. However if cognitive operations are performed on the information in the short term memory, that information will be stored in the long term memory (.Adams, 1976: 226, Hamilton & Ghatala, 1994: 80, Bjorklund, 2005: 120, Baddeley, 1996: 7, Martin & Lesch, 1996, Andrade, 2001: 8, Eysenck & Keane, 1995: 127, Higbee, 1977: 15).

The capacity of the working memory may be increased by a process called chunking. Chunking is a principle that applies to the effective communication of information between human beings (Johnstone, 1997: 262). According to Miller (1950) quoted by Higbee (1977: 15) chunking is all about presenting information in small digestible units. A digestible unit contains no more than nine separate items of information.

The next section explores the working of the long term memory.

### **3.3.3. Long term memory**

The long term memory forms the largest part of the memory model (see Figure 3.1). It has therefore the largest capacity and can hold information indefinitely (Adams, 1976: 226, Hamilton & Ghatala, 1994: 80, Bjorklund, 2005: 120, Baddeley, 1996: 7, Martin & Lesch, 1996, Andrade, 2001: 8, Eysenck & Keane, 1995: 127). Cognitive psychologists have classified different types of knowledge contained in the long term memory. Tulving (1985) quoted by Bjorklund (2005: 120) proposed that information in the long term memory can be represented in one of two general ways: declarative (explicit) and non-declarative (implicit) memory.

In the next section the two ways of representation of the long term memory will be discussed.

#### **3.3.3.1. Declarative memory (or explicit memory)**

According to Bjorklund (2005: 121) and Hamilton and Ghatala (1994: 81) declarative memory refers to facts and events. These facts and events may be represented either episodically or semantically. It is important to note that the storage of the episodes and semantics is not done separately in memory; the separation is done only for the purpose of memory analysis (White, 1988: 31). It is important to consider the distinction between the episodic and semantic memories in the learning of Physical Sciences as the two have a bearing on it. This phenomenon will be discussed in subsequent sections.

#### **Episodic memory**

The episodic memory refers to the information stored in the long term memory about personally experienced events which are an intricate part of one's life. This memory does not only reflect on a collection of one's events but also on the specifics of the occurrences in terms of time and place of the events. The most distinctive feature of the episodic memory is that one sees oneself as an actor in the event that one remembers.

This phenomenon is crucial as it impacts directly in the learning of science. When learners are surrounded with stimuli (such as a scientific exhibition or apparatus) in the science centre and interact with it, their episodic memories do not only memorize the events themselves but the entire context around them (White, 1988: 32, Hamilton & Ghatala, 1994: 80, Bjorklund, 2005: 120).

The quality of the events that are recalled by the episodic memory is directly related to the affectionate aspect of the events in that the emotions that learners experience at the time of the events (e.g. in the science centre) conditions the quality of their memorization process. Therefore it is crucial to take heed of the stimuli in the learning context as the episodic memory is mostly affected by different forms of amnesia. Taking careful consideration of the stimuli in the learning context will enhance the rate of the memory process and hence learning (White, 1988: 32, Hamilton & Ghatala, 1994: 80, Bjorklund, 2005: 120).

### **Semantic memory**

Semantic memory consists of memories of general concepts and principles and their relations. The knowledge that sulphur (flowers of sulphur/roll sulphur) is an element and is yellow in colour is of semantic nature. The organized knowledge, words and concepts and how all are connected are referred to as part of our semantic knowledge (Hamilton & Ghatala, 1994: 81).

Semantic memory is therefore a system that one uses to store one's knowledge of the world. This is the kind of knowledge that we all have and can easily access. Semantic memory includes memory of the rules and concepts that let us construct a mental representation of the world without any immediate perceptions. The contents of the semantic memory must therefore be abstract and related and it is also associated with the verbal symbols. Unlike episodic memory, semantic memory is independent of the spatial and temporal context in which it is acquired. That is if a learner recalls that sulphur is one of the elements and is yellow in colour, he/she does not necessarily see the context

where he/she has encountered that information. Whether the knowledge was acquired for the first time in the science centre or not, it has no bearing on the semantic memory (Hamilton & Ghatala, 1994: 80, Bjorklund, 2005: 120).

### **3.3.3.2. Non-declarative (or implicit memory)**

Non-declarative memory refers to knowledge of procedures that are unconscious. It is concerned with how to perform activities. Knowing how to perform an experiment procedurally requires implicit memory. The act of performing an experiment in science requires a detailed approach (scientific approach). The affectionate part of a human being is also involved in the experiment. Therefore skills and emotions are essential in carrying out the task. It can then be understood that the non-declarative memory is subdivided into two types, which are the procedural and the emotional aspects of the memory (Hamilton & Ghatala, 1994: 81).

The procedural aspect of the memory is responsible for the skills that learners may exhibit when interacting with the stimuli in the science centre. The emotional aspect of the non-declarative memory is responsible for the conditioning or the affective part of the skills possessed by learners when interacting with stimuli (Hamilton & Ghatala, 1994: 81). The two aspects will be dealt with in detail in the subsequent chapter.

## **3.4. THE RETENTION OF ACQUIRED KNOWLEDGE**

Memory retention is a process of representing events initially and thus establishing the memory for potential future references (Spear, 1978: 5). Howard (1995: 57) refers to memory retention as a system for holding and processing certain types of information. This definition indicates that the stored information is not only kept in memory but that something active such as processing, is done on the information.

Spear (1978: 6) argues that when a learner cognitively interacts with a certain stimulus, for instance a chaos pendulum, the extent to which he/she retains the nature of the image

depends on what he/she does with the images after interaction. The reference is to what happens after the learner has stopped active processing, that is, thinking of the episode. When the learner later sees a pendulum, he/she can reproduce the information about it (Spear, 1978: 6).

### **3.5. THE RETRIEVAL OF ACQUIRED KNOWLEDGE**

Memory retrieval refers to a process that takes the retained representations of events and manifests them in terms of behaviour, with the understanding that the behaviour might include further covert processing of the memory (Spear, 1978: 5). The memory storage is in terms of a collection of attributes corresponding to separate events that constitute an episode registered as a result of cognitive interaction with stimuli. Therefore for the memory item to be retrieved, a sufficient number or kind of the memory's attributes must be aroused contiguously (Spear, 1978: 50).

It means that when a learner notices a different kind of pendulum as an event, that attribute will arouse the original representation of the actual pendulum already stored. Attributes will also be aroused when the entire memory is retrieved. In this process information is temporarily copied from the long term memory into the working memory so that it can be used there. The more a memory has been encoded, elaborated, organized and structured, the easier it will be to retrieve (Spear, 1978: 51).

The retrieval of information encoded in the long term memory is traditionally divided into two categories, which are recall and recognition. Recall involves actively reconstructing the information, where as recognition only requires decision as to whether one thing among others has been encountered before. Recall is more demanding as it requires the activation of all neurons involved in the memory that is working at the time. In contrast, in recognition, even if a part of an object is seen that was initially part of the neural network concerned, that may suffice to activate the entire network (Spear, 1978: 50, Higbee, 1977: 18).

In the next section a summary of how the memory operates will be provided.

### **3.6. SUMMARY**

From the discussion in the Sections 3.2 – 3.5 it follows that one can ask three basic questions about the human memory. The first being how memories are formed or encoded, secondly how memories are retained and thirdly, how memories are retrieved. Based on the work done by Bjorklund (2005: 121), Higbee (1977: 12) Hamilton and Ghatala (1994: 81) and White (1988: 32) on the three questions the following can be arrived at:

#### **3.6.1. Encoding**

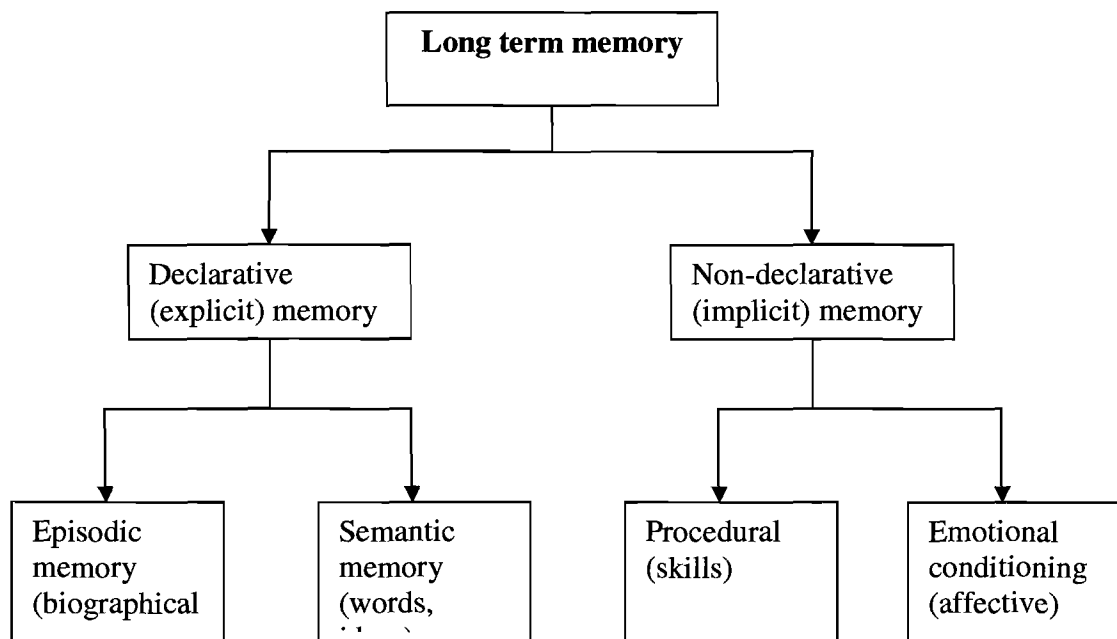
- ❖ Encoding is an active process.
- ❖ Selective attention is required to the material to be encoded.
- ❖ Memory is affected by the amount or type of attention devoted to the task of encoding the material.
- ❖ Visual imagery adds richness to the material to be remembered.
- ❖ Physical contact with the material enhances the memory retention.
- ❖ Elaboration strengthens association with other information.

#### **3.6.2. Storage**

- ❖ There are three memory stages, which are, sensory, short term (working memory) and long term memory.

- ❖ The sensory memory has three subtypes which are iconic, echoic and haptic memories.
- ❖ The sensory memory stores the sensory images for only a fraction of a second, that is, long enough to develop a perception.
- ❖ Short term memory lasts for a while longer, but is also relatively short. The information is said to last for about 20 – 30 seconds in the short term memory.
- ❖ Long term memory is suggested to be permanent.

The following diagram depicts the subdivision of the long term memory.



**Fig 3.3. The structure of the long term memory.** (Bjorklund, 2005: 121; Hamilton & Ghatala, 1994: 81).

### 3.6.3. Retrieval

- ❖ Retrieval from memory is not a random process.
- ❖ Memories are reconstructions supported by the schema theory.
- ❖ Retrieval process involves active mechanisms.

According to Hamilton and Ghatala (1994: 99) and Adams (1976: 242) before any information can be encoded a learner must pay attention to the stimuli around him/her. Therefore from the work done in Sections 3.2 – 3.6 the memory steps can therefore be condensed as follows:

**ATTENTION → ENCODING → STORAGE → RETRIEVAL**

According to Hamilton and Ghatala (1994: 99) attention is viewed as the person's allocation of cognitive resources to the tasks at hand. When we devote attention to a task, we put mental effort into it. In other words attention is used to refer to activities related to the taking in of information from some particular aspect of the environment in the case of this study, a science centre.

It is interesting to note that if a learner is not successful in any one of the four processes listed above, the information may not be encoded and thus be forgotten. However to remember a learner must be successful in all four processes (Higbee, 1977: 24).

The reasons why one forgets are discussed in the subsequent section below.

### 3.7. REASONS WHY HUMAN BEINGS FORGET

The retrieval of information from the memory is such a delicate process that if the information is not stored in an organized manner, it may be partly retrieved or it may not

be possible to be retrieved at all, hence it will be forgotten. This occurs as a result of failure or disturbance during one or all of the stages of knowledge acquisition (either failure to pay attention, or a disturbance during the encoding stage, or storage or retrieval stage) Higbee (1977: 24 – 25).

Higbee, (1977: 24, Spear, 1978: 38) contend that forgetting may occur because firstly, the memory is no longer present in the precise form it was at the original storage. Secondly it could be that, even if the memory is maintained in the storage with undiminished integrity since original learning, the memory cannot be retrieved. This means that the cause of forgetting is either that the memory is no longer stored in its original form, or if it is, it cannot be retrieved as readily as before.

The following are a few general suggestions of why human beings forget:

#### ❖ **Passive decay**

Passive decay is when memories cause some kind of a physical trace in the brain which gradually fades with time. This occurs due to the decline in learned performance as time passes since the learning encounter. The information becomes so passive that it eventually decays with time. This may be redressed by continuously exposing the subjects to the stimuli to unlock the memory (Higbee, 1977: 24, Spear, 1978: 118).

#### ❖ **Repression**

Repression occurs when unacceptable memories are intentionally forgotten. This phenomenon occurs because of the unpleasant nature of the memory that the subject deliberately chooses to forget. It could be an occurrence of a personal nature that has painful consequences so that it might be good to lose it (Higbee, 1977: 24).

### ❖ **Systematic distortion**

Systematic distortion is a situation where a learner's memories are affected by his/her values and interests. This suggests that a learner will change his/her memories to fit with what he/she wants to be or how he/she should feel. Systematic distortion is more of the emotional aspect of the memory. It is concerned with what or how a person feels. To remedy the situation teachers are advised to ask leading questions so that a learner will remember the extent or nature of the apparatus or experimental process.

### ❖ **Interference**

Much of the volume of forgetting is possibly due to interference by other learning (information to be stored). This statement does not however, refer to the capacity or lack of memory, where new information is supposed to be encoded. Learners' prior knowledge may interfere with their memory depending on the nature of the new knowledge.

Prior knowledge is perceived by most researchers to have powerful effects on the learning process and information acquisition (Chinn & Brewer, 1998: 104, Toh, 1991: 89; and Thijs & Van den Berg, 1995: 318, Ausubel *et al.*, 1968: 112). Chinn and Brewer (1998: 104) contend that the following aspects about learners' prior knowledge impede knowledge on memory and hence information acquisition in the teaching and learning of natural science. These aspects entrenchment of prior knowledge, quality of prior knowledge, naïve philosophy of science and the processing strategies, are crucial in enhancing the memory processes.

In the following section ways of improving memory retention and retrieval will be suggested so as to use the capacity of the working memory and the efficient storage of the long term memory, hence optimising remembering and retrieval from memory.

### **3.8. IMPROVING MEMORY**

Higbee (1977: 38) asserts that the factors that impede memory retention and retrieval may be improved upon such that the process of remembering is enhanced. The most important aspect of enhancing the process of retrieving information is by active learning. Active learning facilitates memory by helping learners to attend to and process information. Higbee (1977: 38) suggests that the following factors may improve the process of encoding, retention and the retrieval from one's memory:

#### **3.8.1. Familiarity**

Higbee (1977: 38) asserts that the more you know about a learning area like physical science, the easier it is to learn new information about it. The reason for this is that if a learner is familiar with graphs and equations of motion for instance, not only will the new information be more meaningful to him/her, but he/she will have something with which he/she can associate it, if exposed to similar apparatus, (like the two tracks shown in the learning gain test (see appendix 1). This, according to Higbee (1977: 38), helps learners to recall information quickly.

#### **3.8.2. Mnemonics and associations**

During the learning process, a person continuously makes associations. Some of the associations are between what we are learning and the context around where we are learning, or between the information and our mental states, or even between the information and our stream of thoughts. When information is associated in memory, thinking of one aspect of the information helps bring the other to mind. When learners are associating with the experiment on mirrors for instance (see appendix A), they can associate with the scenario in the science centre. They may even see themselves as role players in the process (White, 1988: 149, Spear, 1978: 71, Travers, 1982: 7, Gunter *et al.*, 1995: 263).

### **3.8.3. Visual memory (iconic memory)**

It is said that human beings remember information best when it is visually encoded. This could be because the capacity of the visual memory is unlimited. When information is visually encoded it is easily retrieved. One way of doing this is by mental associations. The consolidation of the picturesque is enhanced by elaborate exposure to the stimuli. That is, when learners are exposed for a considerable amount of time to the scientific resources then visual memory will be improved. If the visual memory is improved it directly relates to the encoding and retrieval process (Adams, 1976: 243, Smith & Jones, 1989: 8, Eysenck & Keane, 1995: 125).

### **3.8.4. Organized material**

The study conducted by Bousfield (1953: 33) reveals that when the material to be learnt is well structured and presented in an organized manner, it results in a situation where the information is encoded and retrieved more easily than in a haphazard way. The situation also yields what Bousfield terms free recall. The interpretation and analysis of material by learners in such a setting enhances systematic knowledge acquisition and hence memory retention and retrieval.

In the next section the implications of the memory process and other aspects of memory for teaching and learning is discussed.

## **3.9. IMPLICATION FOR TEACHING AND LEARNING**

Among the fundamental principles shaping learners' scientific knowledge and understanding are the conceptions they hold about science. Learners' conceptions of science influence their *thoughts*, *feelings* and *actions* associated with doing, understanding, teaching and the learning of science. This seems to be in line with the aim of the study as it intends to cover the cognitive (*thoughts*), affective (*feelings*) and the psychomotoric domains (*actions*) of the learners' holistic development (Hammerich,

1998: 127, Driver *et al.*, 1994: 8). It is for that reason that Ausubel *et al.* (1968: 112) conclude that the most important single factor influencing learning is what the learner already knows.

White (1988: 129) asserts that the best way of retrieving the retained knowledge is by a process called chunking. Chunking is a function of knowledge that refers to a situation of breaking large units of information into smaller, meaningful and manageable chunks. Size and therefore number of chunks perceived in a situation is one of the determinants between a knowledgeable person and a novice or ignorant person. According to White (1988: 129) an expert inhabits a simpler world than a beginner because the expert breaks the world into a smaller number of meaningful units.

Large amounts of meaningful units are organized by structures referred to as schemata by Schunk (2000: 145). According to Schunk (2000: 145) large meaningful units (schemata) are needed to organize propositions representing bits of information into a coherent whole. Schemata are said to assist the encoding process as it elaborate new learning material into a meaningful structure. This is achieved because using schema highlights important information.

It is crucial therefore that teachers should chunk the information to be exchanged with learners and also enable learners to do likewise. This will help learners because otherwise those who did not learn as much as the teacher on the related topic may fail to encode the intended information. The following situation will clarify the process. If a learner in a science centre cognitively interacts with an apparatus such as Newtons' cradle, then instead of seeing the equipment as a small number of chunks, the learner might perceive it as a greater number of chunks, thereby impeding conception and understanding (White, 1988: 131). In the memory process, this impacts on the short term memory as it can only hold a limited amount of information. Consequently the information is not encoded and the process of retaining information is disturbed. If the process is disturbed, information cannot be remembered as it is not stored (Adams, 1976: 242, Hamilton & Ghatala, 1994: 99, Higbee, 1977: 24).

### **3.9.1. Active learning**

Active learning, like attentiveness is often said to be the tool that engraves information into memory. Thus passiveness can radically reduce the memory performance. According to the constructivists' viewpoint in learning, learners come into the instructional setting with a broad array of knowledge, goals and prior experiences (Anderson *et al.*, 2001: 38, Driver, 1983: 6; Driver *et al.*, 1985: 4; White, 1988: 77). Learners then actively make sense of the information they encounter by means of various cognitive processes. The active participation of learners in interacting with the new knowledge impacts on the learners' memory processes, that is, paying attention to stimuli (information or experiment); encoding the new information; storage of the acquired information and the retrieval thereof (Hamilton & Ghatala, 1994: 99).

### **3.9.2. Visual memory (Iconic memory)**

Visual and auditory information have different features that influence how information is processed. The visual system can handle an immense amount of information in less than a hundredth of a second. In contrast, the auditory information has to enter the system piece by piece or word by word in case of language. This is because auditory information has to be processed in terms of large chunks. This calls for the entire part of the sentence to be stated before encoding proceeds. Therefore it is essential for learners to always see the resources they are working with instead of resources being described in words only.

This phenomenon, according to Travers (1982: 38), forms the sound base of information processing and hence knowledge acquisition. However Schunk (2000: 142) contends that dual coded knowledge may be remembered more efficiently. For instance an individual can encode information pictorially and be able to eloquently describe it (verbally). According to Schunk (2000: 142) this dual encoding process has an important implication on education as it confirms the general teaching principle of explaining or the cognitive

aspect of learning (verbal) and the practical work or the psycho-motoric effect (visual) part of learning.

### **3.9.3. Organized material**

Organizing material to be learnt makes the material more meaningful. Part of organizing includes chunking. If the material to be learnt is well organized, it facilitates the learning process because the material will be learned in parts and steps. This phenomenon has overwhelming impact on memory and learning (Bousfield, 1953: 35, Travers, 1982: 158).

With regard to this study, it means that the stimuli/apparatus/learning material or resources in the science centre should be arranged in a meaning and strategic manner so as to build upon one another. The apparatus related to the same concepts should be placed close by so as to reinforce the preceding or succeeding material. In this case the transfer of information from the short term memory system to the long term memory system takes place with the greatest efficiency because the information is organized (Travers, 1982: 273).

### **3.10. CONCLUSION**

The quest for knowledge that can be recalled for the solution of a great range of problems is a quest engaged in by every person. The search for skills, techniques, knowledge and principles that will always be successful in problem solving is a part of the human's way of conserving his resources. Knowledge that can be generalized to the solution of a whole range of problems should constitute the very core of education, namely *learning*.

In this section of the literature review the focus was on the acquisition of scientific knowledge (Chapter 2) and it explored the processing of acquired knowledge (information) by firstly dissecting the types of memory and the memory steps, viz from the attention to the retrieval stage. In the chapter the reasons were further considered why we forget and the ways to improve memory. All these were rounded off by

discussing the implications of memory towards teaching and learning. In the next chapter learning as a means of knowledge acquisition will be discussed.

## CHAPTER 4

### LEARNING: A MEANS TO KNOWLEDGE CONSTRUCTION

*He who learns, but does not think is lost (Chinese proverb)*

#### 4.1. INTRODUCTION

From the study of the acquisition of scientific knowledge in Section 2.3 of this study it follows that learning and the acquisition of knowledge are closely related. Although observational data forms the basis of the knowledge structure of the observer/learner, it is imperative that the observer should undergo a learning process so as to re-organize his/her knowledge framework, to enable him/her to construct his/her own knowledge.

Another fascinating fact about the acquired knowledge is that it is preserved by memory. As Howard (1995: 3) puts it, memory preserves acquired knowledge for immediate or later use. Therefore memory impacts on *how*, *what* and *how much* knowledge is stored. On the other hand, without memory, learning will have no purpose because the contents of memory largely determine what is likely to be learned. The contents of memory also inform how rapidly and how well learning will proceed. What is already known (prior knowledge) is a major determinant of what else can be acquired and it also limits what is to be acquired (Howard, 1995: 3, Kintsch, 1970: 136, Ausubel *et al.*, 1968: 112).

This chapter seeks to define what learning is by looking at various learning theories and extract one that is more relevant to the perceived nature of science and possibly suitable for application in the science centre environment. The nature of science as indicated by Wesi (2003: 12) and Wilson (1999: 1) quoted by Rapule (2005: 12) suggests that science is of cognitive nature and the person involved in it has to deal with a large volume of facts. This large volume of facts must be re-arranged in such a way that it fits in the

existing scientific knowledge structure. As this is a process, the mental framework is actively involved in sorting out the scientific framework.

It is at the heart of this research project to assess the impact science centres have on the development of science learners in a holistic manner. Therefore this chapter outlines Bloom's Learning Taxonomy (Krathwohl *et al.*,1964) with regard to the cognitive, affective and psychomotor domains of science learning and their impact on learners.

## **4.2. DEFINING LEARNING**

From the discussion in the previous chapter on memory processes (Sections 3.3 – 3.7) it follows that learning is a process that allows us to retain acquired information, the affective states and impressions. These affective states and impressions influence our behaviour and constructed knowledge. It is the main activity of the brain in which this organ (the brain), continue to formulate its own structure to improve the reflection on the experiences that we have had. Following this work, learning can be equated with encoding since, like encoding, it involves the acquisition, construction and modification of knowledge, skills, strategies, beliefs, attitudes and behaviours. It further involves cognitive, motor and affective skills of a learner. It is therefore the responsibility of a learner to actively reorganise, structure and construct the knowledge envisaged to be learnt (Schunk, 1991: 1, Ormrod, 1990: 6). This view of learning is held by the cognitive psychologists, hence the name constructivists.

It should be clear from an attempt to define learning that one has to take cognisance of the perspective from which learning can be viewed. For instance, behaviourists consider learning to be influenced by environmental factors such as context in which learning proceeds. Constructivists on the other extreme hold a view that learning is influenced by learners' constructing of their own knowledge.

This study intends to probe the three domains which are said to be involved in the learning of physics at school, namely the cognitive, affective and the psychomotor

domains. In the next section the types of learning will be extracted based on the different learning theories.

### **4.3. TYPES OF LEARNING**

Learning as a concept depends on one's perspective. For instance, if one's learning focuses on how learners' behaviours change over time and on the environmental conditions, one's view about learning will be of behavioural nature. However if one's point of view about learning focuses on the internal processes, (that is thinking), rather than behavioural change, one will be concerned with cognitive theory. Therefore types of learning will depend on a particular learning theory.

As one's concept of learning and knowledge is one of the most important variables that inform the process of instruction, it is important to develop a clear understanding of learning. It is imperative therefore to note that types of learning are entrenched in a particular learning theory. This fact calls for a closer look at different learning theories.

### **4.4. LEARNING THEORIES**

Science teachers are familiar with the concept *theory* from scientific theories like atomic theory, kinetic molecular theory and the theory of gravity. The knowledge may have become tacit to science teachers that a theory is a set of principles that together help us describe, explain and predict a particular set of natural events and phenomena. Theories may change as new information is gathered and often lead to a complete paradigm shift such as a scientific revolution described by Kuhn in 1962 (Kuhn, 1970).

A learning theory as defined by Bigge and Shermis (2004: 3) is a systematic and an integrated outlook about the nature of the process whereby people relate to their environments in such a way as to enhance their ability to use both themselves and their environments in the most effective way. The definition embraces two important aspects which are firstly, the social connotation of the learning theory and secondly the context

wherein the learning theory is executed. The definition suggests that there has to be interaction between the two aspects such that one has influence over the other.

A learning theory thus enables us to make sense out of facts about learning. When we theorize about learning, we are proposing which facts are most important for understanding how learners learn and what kind of relationships among the facts are most significant. As Hamilton and Ghatala (1994: 5) state, a learning theory is like a lens through which we can view situations such as the teacher and learner interaction or how an individual proceeds with his/her learning process.

A learning theory leads teachers and learners to attend to certain elements of a situation and see the selected elements in a particular pattern. Thus when a person adopts a particular theory, he/she takes on a set of beliefs concerning what questions about learning are valuable, what methods of studying these questions are relevant and most importantly what is the nature of learning (Hamilton & Ghatala, 1994: 6).

Current teaching and learning practices have their roots in two broad theoretical developments, that is behaviourism and cognitive psychology (refer to Section 4.4.5).

In the next subsections various learning theories are discussed and their implication on the learning of physics is outlined.

#### **4.4.1. Behavioural theories**

Behavioural theorists (Schunk, 1991: 30, Schultz & Schultz, 1996: 226) define learning as:

*Learning: a relatively permanent change in an individual's knowledge or behaviour that results from previous experience.*

The focal point in behaviourism is the environmental factors in learning. The behaviourists, although they acknowledge the existence of mental phenomena in learning, contend that such phenomena are not necessary to explain learning. The behavioural learning theory views learning as a change in the rate, frequency of occurrence, or form of behaviour or response which occurs primarily as a function of environmental factors (Schunk, 1991: 30, Schultz & Schultz, 1996: 226). This view is based on the premise that it is meaningless to theorise about the workings of the brain, since we can only study the behaviour of people responding to stimuli.

Based on this, the behavioural theory is underpinned by the following assumptions:

- ❖ People's behaviour is largely the result of their experience with environmental stimuli.
- ❖ Learning can be described in terms of the relationship among stimuli and response.
- ❖ Learning involves a behaviour change.
- ❖ Learning is most likely to take place when stimuli and response occur close together in time.
- ❖ Many species of animals, including humans, learn in a similar way.

#### **4.4.1.1. Implication on science learning**

The consequence of the premise and assumptions of the behaviourists is that the emphasis on learning strategies will be on memorization and repetition. These strategies will only encourage parrot learning as opposed to the higher order of cognitive processes. This emphasis is encouraged so as to exhibit the required behaviour in learners (Schultz & Schultz, 1992: 226).

Learning within the behavioural context will be reduced to reading and listening to teachers' presentations. This is done so as to drill the intended behaviour to be modelled by learners into them, and they will be influenced in this by the teacher. The outcome is therefore rote learning which does not enhance learning, or knowledge construction (Chinn & Brewer, 1998: 99, Schunk, 2000: 227). The rationale of physical science as stated in the policy document (DoE, 1997: NS – 5) seeks to develop learners with scientific knowledge. As a result, the strategies involved in the teaching and learning of physical science should reflect the investigative nature of knowledge construction and hence knowledge acquisition (Chinn & Brewer, 1998: 99).

The behavioural learning theory seems to be inadequate in fulfilling the intended outcome of empowering physical science learners with the ability to construct their own knowledge and harness their practical (motor) skills (DoE, 2003: 3).

#### **4.4.2. Social cognitive theory**

A social cognitive theorist's (Bandura, 1977) view of learning is as follows:

*Learning: learning which focuses on social interactions. Social cognitive theory considers that people learn from one another and includes concepts such as observational learning.*

Social cognitive theory has its roots in behavioural theory. It defines the human behaviour as a triadic, dynamic and reciprocal interaction of personal factors, behaviour and environment (Bandura, 1977, 1986). According to this theory an individual's behaviour is uniquely determined by these three factors.

Behaviourists contend that learning should result in a change in behaviour. However contrary to this belief, social cognitive theory argues that since individuals can learn through observation alone, their learning may not necessarily be reflected in their behaviour. Therefore learning may or may not result in behaviour change (Ormrod,

1990: 6). The social cognitive theory embraces the principle of cognition in that during the last thirty years the theory has shifted towards being more cognitive in its view of human learning. It is therefore considered as a bridge between the behavioural theory and the cognitive theory of learning.

The social cognitive theory is based on the following assumptions:

- ❖ People can learn by observing others.
- ❖ Learning is an internal process that may or may not result in a behaviour change.
- ❖ Behaviour is directed towards particular goals.
- ❖ Behaviour eventually becomes self-regulated.
- ❖ Reinforcement/rewarding and punishment have several indirect effects.

#### **4.4.2.1. Implications on science learning**

The social cognitive theory has effects on learning similar to the behavioural theory. In a social cognitive setting, a science teacher plays a significant role as he/she must inculcate in learners the appropriate ways to perform a particular experiment. To achieve this, the teacher must, as a role player, demonstrate so as to help learners acquire the new (envisaged) behaviour quickly. The implication of employing the social cognitive theory in physical science, based on the assumptions listed, leads to the traditional laboratory demonstrations or lecture demonstrations approach. In a traditional approach, learners observe an experiment or a demonstration, then the instructor, which is normally a teacher, explains what happened and why (Etkina *et al.*, 2002: 351 & Gunstone, 1991: 69).

In this theory of learning, learners are reinforced for modelling the behaviour of the teacher. Bandura (1986, 127) asserts that the social context also plays a role in modeling learners' behaviour. According to Bandura (1986: 127) to model the behaviour of a science teacher successfully, learners must firstly pay attention to the model (teacher). Secondly learners must be able to remember the behaviour exhibited by the model and retain it. The third condition is that the learner must be able to replicate what the model has demonstrated. The final condition is that learners must want to demonstrate the behaviour. In other words learners must be motivated to exhibit the behaviour that was modelled by the teacher.

The effect of the social cognitive theory therefore reduces learners to passive participants in their learning process. Traditional laboratory demonstrations usually have an objective to verify a principle or a concept that the learners already learned from the instructor. In this way the emphasis is on a quantitative analysis of data, (Etkina *et al.*, 2002: 351, Roadruck, 1993: 1025).

The strategies and approaches of learning applied in physical science should, according to the National Curriculum Statement (2003: 4), produce learners who must demonstrate an ability to think logically and analytically, as well as *holistically* and literally. Therefore the social cognitive theory seems to lack in this area as it does not advocate in favour of the idea that learners should be independent in their own learning. That is learners should be boldly constructing their own knowledge and be interacting with resources. A critical aim encouraged by the National Curriculum Statement (NCS, 2003: 4) is therefore not achieved by the social cognitive theory.

#### **4.4.3. Cognitive learning theory (information processing and information construction)**

According to the cognitive theorists' (Schunk, 1991: 225, Schultz & Schultz, 1996: 453) learning is considered as:

***Learning: learning that focuses on unobservable change in mental knowledge.***

Unlike the behavioural and the social cognitive theories, the cognitive theory focuses on the process of knowing, rather than simply responding to stimuli. The cognitive learning theory considers mental processes, events and how the mind structures experience, as important factors in learning. The fundamental focus of the cognitive theory is on how learners construct their understanding of themselves and of the world around them, a principle which underpins a theory of constructivism (Schunk, 1991: 225, Schultz & Schultz, 1996: 453).

The cognitive learning theory is embedded on the following assumptions:

- ❖ Cognitive processes influence the nature of what is learned.
- ❖ Learners are selective of what they process and learn.
- ❖ Meaning of information is constructed by the learner, rather than derived directly from the environment.
- ❖ Prior knowledge and beliefs play a major role in the meaning that learners construct.
- ❖ Learners are actively involved in their own learning.

From the assumptions which informs cognitive theory it follows that cognitive theorists are constructivists in that they postulate that understanding is not automatic. Teachers do not convey information and learners *do not* simply process it in rote learning. On the contrary, learners cognitively take information and formulate their own knowledge. (Schunk, 2000: 225). This phenomenon is discussed further in subsequent sections (in Section 4.4.4).

#### **4.4.3.1. Implication of cognitive theory on science learning**

Since learning is influenced by cognitive processes (Schunk, 1991: 225, Schultz & Schultz, 1996: 453, Vygotsky, 1986: 81), learners will engage in various cognitive learning strategies to master the content to be learnt and be advised of the most effective cognitive ways to remember it.

The cognitive learning theory attests for learners to be taking a leading role in their learning (Piaget, 1971, 1977). This means that learners will organize and structure their learning. In the process, learners will find out that new information is easily acquired when they associate it with their prior knowledge (Piaget, 1971, 1977). Therefore the cognitive learning theory advocates for discovery learning. To a great extent in a cognitive learning theory context, learners will obtain knowledge for themselves and test the formulated hypotheses (Schunk, 2000: 171).

The role of the teacher in this regard is to arrange activities in which learners search, manipulate, explore and investigate. In this theory teachers are encouraged to ask learners leading questions which relates to their prior knowledge. This is done to assist them to link new knowledge with prior knowledge. This may be done (for instance) by supplying worked out examples of physics calculations that vary in order of complexity (Schunk, 2000: 205).

The cognitive learning theory seems to be in accordance with the kind of learner envisaged by the curriculum (DoE, 2003) in that it fulfils some of the roles endorsed by the National Curriculum Statement. It encourages among other learning aspects, self-assessment; independent discovery learning and interdependence between learners and teachers.

However in recent years learning researchers have realized that some of the cognitive learning theory's assumption about learning and instruction did not fully capture the complexity of how learners learn and understand (Schunk, 2000: 229). According to

Schunk (2000: 229) the constructivist theory of learning is helpful as it can account for the learning and the development thereof. The work done by Vygotsky (1978) further emphasizes the importance of social interaction in acquisition of skills and knowledge, which is not implied in the cognitive learning theory.

#### **4.4.4. The theory of Constructivism**

Learning, according to the constructivist theorists (Appleton & Asoko, 1996: 166, Novodvorsky, 1997: 242, Lazarowitz & Hertz-Lazarowitz, 1998: 450 & Duit & Treagust, 1998: 8) is defined as follows:

***Learning: the process where individuals construct new ideas or concepts based on prior knowledge or experience.***

The cognitive learning theory forms the bedrock on which the theory of constructivism rests. Contrary to the teaching and learning based on the behavioural and social cognitive theories, Piaget believed that children are not passive receivers of environmental stimulation, but they are naturally curious about the world and they actively seek out information to help them understand and make sense of that world. In other words, learning does not assume the transmission model from a teacher (source of knowledge) to a learner (receiver of knowledge) as in the *tabula rasa* model of learning influenced by behaviourist theory (Ormrod, 1995: 35). Knowledge is thus constructed in the mind of the learner and not transmitted.

The acquisition of scientific knowledge, as described in Section 2.2 of this study, does not arise from the object nor from the subject, but from their interactions, that is, between the subject and the perceived object (Malhotra, 1994: 4; Smock, 1981: 53; Ziman, 1968: 5; White, 1988: 121; Chadwick *et al.*, 1984: 4). To know objects, the subject must act upon and transform them. This implies that the learning process involves the characteristic of the learner, and his or her cognitive abilities, attitudes and perceptions of the world. Therefore learner difference is taken into account.

The learning theory of constructivism seems to be relevant to the type of learning envisaged by the National Curriculum Statement (DoE, 2003: 13) as it aims to develop the abilities of constructing and applying scientific knowledge in science learners and instilling values and attitudes. In this approach learners must be actively involved in their learning as they continue to construct knowledge from their interactions with a phenomenon.

Constructivist views about learning have gained acceptance among science teachers 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 many national science education reform recommendations including those of South Africa (Haney *et al.*, 2003: 366).

The theory of constructivism is based on three premises. It firstly states that knowledge is constructed in the mind of the learner (Novodvorsky, 1997: 242, Lazarowitz & Hertz-Lazarowitz, 1998: 450 & Duit & Treagust, 1998: 8). This implies that learners' knowledge is not limited to a collection of isolated pieces of information. Instead, learners use the information they accumulate to construct an overall view of how the world operates. In the process learners select and transform information, construct hypotheses and make decisions relying on cognitive structures (referred to as schema by Piaget) to do so (Bruner, 1990: 86).

In the view-point of a constructivist, learning is a constructive process in which a learner is building an internal illustration of knowledge, a personal interpretation of experience. This representation is continually open to modification, its schema and linkages forming the basis to which other knowledge structures are attached (Bruner, 1990: 86).

According to the second premise of the constructivist theory learners bring with them prior personally constructed knowledge and beliefs that may either be relevant or not with the scientific concepts (Collins, 2002: 9, Gunstone, 1991: 67, Haney *et al.*, 2003: 366 & Novodvorsky, 1997: 242). According to Wesi (1998: 12) this personally constructed knowledge base has a tendency of being resistant to teaching and learning

and may still persist even when contrary scientific explanation or observation is made. Therefore it is crucial to establish the existing knowledge of learners in order to teach accordingly (Ausubel *et al.*, 1968: 112).

It is for such reasons that prior knowledge is considered by science researchers to have a powerful impact on the learning process (Chinn & Brewer, 1998: 104, Toh, 1991: 89, Thjis & Van der Berg, 1995: 318). This argument is in contrast with the view held by behaviourists as they assume that a learner is like an empty vessel to be filled with knowledge.

The constructivist's theory contends that learning is an active process in which meaning is accomplished on the basis of experience.

The third premise is based on the fact that learning is a lifelong process and that it is not confined to a specific period in the life of individuals (Novodvorsky, 1997: 242, Vygotsky, 1978: 67). Vygotsky (1978) asserts that this life long process of development is dependent on social interaction and that social learning actually leads to cognitive development. This phenomenon is called the Zone of Proximal Development (ZPD). Vygotsky (1978) describes it as "*the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers*" (Vygotsky, 1978). In other words, a student can perform a task under adult guidance or with peer collaboration that could not be achieved alone. The Zone of Proximal Development bridges that gap between what is known and what can be known. Vygotsky claimed that learning occurred in this zone.

In the next subsection a brief summary of the important aspects of the theory of constructivism is outlined.

## Conclusion on constructivism

The three premises which underpin the theory of constructivism fulfil the intended role of the NCS observed in the DoE document (2003). When one studies the learning outcomes outlined in the DoE (200: 13 - 15), it becomes clear that the learning outcomes embrace the premise entrenched in the theory of constructivism in that, like the science learning outcomes, the theory of constructivism:

- ❖ Emphasises learning rather than teaching.
- ❖ Encourages and accepts learner autonomy and initiative.
- ❖ Sees learners as creatures of will and purpose.
- ❖ Considers learning to be a process.
- ❖ Encourages learner inquiry.
- ❖ Acknowledges the critical role of experience in learning.
- ❖ Nurtures learners' natural curiosity.
- ❖ Takes the learners' mental model into account.
- ❖ Emphasises performance and understanding when assessing learning.
- ❖ Bases itself on the principle of cognitive theory.
- ❖ Makes extensive use of cognitive terminology such as *predict, create, analyze*.
- ❖ Considers how learners learn.

- ❖ Encourages learners to engage in dialogue with other learners and teachers.
- ❖ Supports co-operative learning.
- ❖ Involves learners in real world situations.
- ❖ Emphasises the context in which learning takes place.
- ❖ Considers the beliefs and attitudes of learners.
- ❖ Provides learners with the opportunity to construct new knowledge and understanding from authentic experience.

#### **4.4.4.1. Implications on science learning**

The work done by Vygotsky (1978: 69) clearly indicates the role a science teacher within the realm of the constructivist theory should assume. Teachers are not perceived as the source of knowledge but only assume the role of facilitators.

Learner characteristics, that include ability, attitude and worldview impact on learning. Therefore it is essential that teachers should establish learners' existing knowledge of the related concepts and teach accordingly (Ausubel *et al.*, 1968: 122).

Because learners interact with the world around them they construct their own view about the world they live in, which often incorrectly assimilate scientific content. This prior knowledge that learners bring with them to a learning encounter, leads to contradiction as it cannot be applied consistently in different situations (Driver *et al.*, 1985: 46). The pre-constructed learner world view clouds all new observation and experience as learners tend to cling emotionally to their constructed knowledge. Therefore learners must be exposed to phenomena and be accorded an opportunity to investigate the scientific

principles underlying a particular concept. This will discredit learner's pre-constructed ideas about phenomena, thereby encouraging them to construct new knowledge. The science centre may present learners with ample opportunity to challenge their prior knowledge as it is based on learning by way of discovery and inquiry (DST, 2004: 5). This discovery and inquiry is arrived at through a process that involves cognitive, affective and practical skills structures in learners.

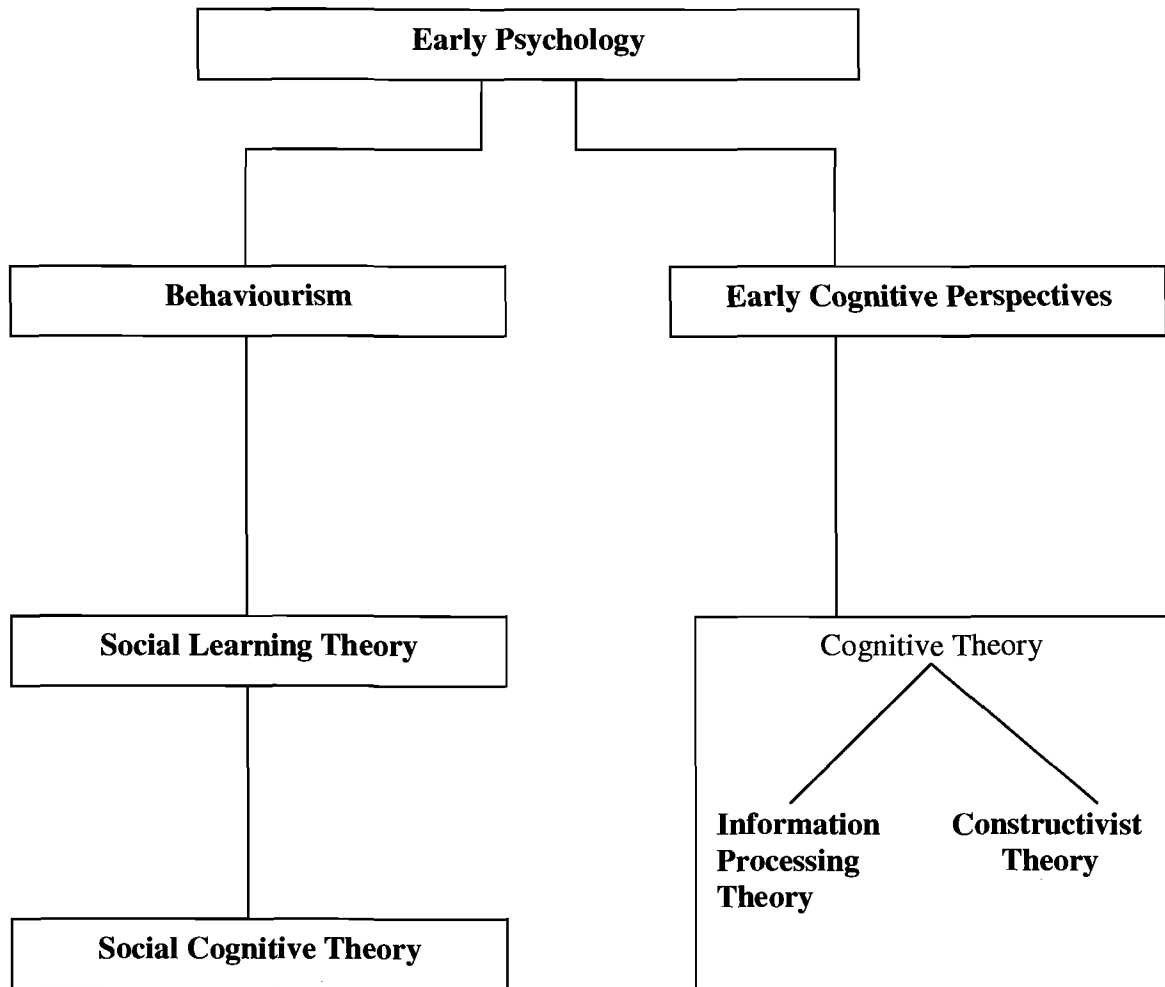
According to Collins (2002: 9) learning is enhanced when it takes place in contexts that learners find meaningful, where they are faced with problems varying in terms of degree of complexity and which have multiple solutions. He further posits that learning is augmented when learners engage in discussions of their discoveries and of the cognitive processes involved.

The process has to be cognitive in that learners will be actively engaged in mental processes to hypothesize, re-arrange and explain scientific phenomena. The affective component plays a major role because learners must be interested and motivated to be successful in their endeavour to construct their own knowledge. Throughout the process they will be actively involved with their motor skills to manipulate resources. These factors are discussed in the subsequent section.

A schematic diagram of how the learning theory has evolved over the years is given in subsection 4.4.5.

#### 4.4.5. Summary of learning theories

The schematic summary of learning theories as evolved is shown in Figure 4.1 below



**Figure 4.1. The evolution of learning theories (Ormrod, 1990: 35)**

The conclusion to be drawn from the work done on learning theories as described in Section 4.1 of this study is that learning theories inform us about the type and nature of learning, just as in the teaching and learning in a constructivist context learning is influenced by what learners already know. Consequently learning will proceed accordingly. The constructivist theory as discussed in Section 4.4 of this study fulfils the

role to be met by three domains of learning, that is, the cognitive, affective and psychomotoric skills. The recent emphasis on hands-on science has placed the theory of constructivism in the middle of the learning theories relevant for the teaching and learning of science. The basic premise of constructivism as discussed is that learners receive sensory input and compare it to existing ideas of what appears to be similar events. Thereafter learners modify the input if necessary and then they construct explanations that seem to make sense to them (Trowbridge *et al.*, 2004: 89).

Bloom and his collaborates (Krathwohl *et al.*, 1964: 1) demonstrated that science teaching tended to be focused on fact-transfer and information recall, which are the lowest levels of training. On the contrary, science teaching should rather focus on meaningful personal development as described by the three learning domains (Krathwohl *et al.*, 1964: 1).

These domains will be discussed hereunder as the domains of Bloom's Taxonomy of learning.

#### **4.5. BLOOM'S TAXONOMY OF LEARNING**

Bloom's Taxonomy of educational objectives, also known as Bloom's Taxonomy of learning domains was initially published in 1956 by a group of psychologists under the leadership of Benjamin Samuel Bloom. The Taxonomy was originally created in and for an academic context but has since being developed and is now relevant to all learning types and subjects or areas of learning (Krathwohl *et al.*, 1964; 1, Anderson *et al.*, 2001: 5).

The concept of Taxonomy of learning domains came about in 1948 as a means to address assessment associated with learning in academic contexts. It was formulated with an endeavour to promote the exchange of test materials and ideas for testing. In other words, the value of creating this framework would be to provide a convenient system for describing, grading and ordering test items, examination techniques and evaluation

instruments. Such a framework, according to the group of psychologists that formulated the Taxonomy, would also be useful in stimulating research on examinations and on the relation between examinations and education. After considerable discussion, there was agreement that the framework will be best constructed through a system of classifying the goals of the educational process in terms of learning objectives (*learning outcomes*), hence the Taxonomy of learning (Bloom, 1994: 2, Anderson *et al.*, 2001: 1, Krathwohl *et al.*, 1964: 1).

A Taxonomy, as described by Krathwohl *et al.*, (1964: 11), Furst (1994: 28) and Bloom *et al.*, (1964: 12), is a set of classifications which are ordered and arranged on the basis of a single principle or on the basis of a consistent set of principles. The Taxonomy may be tested by determining whether it is in agreement with empirical evidence and whether the way in which the classifications are ordered corresponds to a real order among the relevant phenomenon. Based on the facts stated, it follows that the Taxonomy must be consistent with sound theoretical views in a specific field. In the case of this study, the taxonomy must be consistent with the theoretical views of science.

Therefore the Taxonomy employed in this study is based on the tested classification framework of educational goals, called Bloom's Taxonomy of learning domains, also known as the Bloom's Taxonomy of educational objectives (Madaus & Kreitzer, 1994: 64, Krathwohl *et al.*, 1964: 11, Furst, 1994: 28, Bloom *et al.*, 1964: 12).

Bloom's Taxonomy of learning domains is based on three learning domains discussed hereunder, which underpins the classical "*knowledge, attitude, skills*" structure of the learning method and of evaluation.

#### **4.5.1. COGNITIVE DOMAIN OF LEARNING**

According to Bjorklund (2005: 3) and Gross (1985: 3) cognition refers to a mental process by which knowledge is acquired and manipulated. It further reflects on the process of organizing and retaining that knowledge. Therefore cognitive development is

perceived as a constructive process with learners playing an active role in the construction of their own knowledge (Bjorklund, 2005: 481). This is in accordance with the first premise on which the theory of constructivism is based which puts emphasis on the learner constructing his/her own knowledge.

The evidence of the cognitive development of a learner will be demonstrated by a learner who remembers or reproduces information which has been previously learned. Such a learner will recall outcomes which involve the solving of some intellectual task for which he/she has to determine the essential problem and then reorder given material or combine it with ideas, methods or procedures previously learned. That is, the learner has to demonstrate the skill of analysing and synthesizing the given information, with a great deal of creativity (Krathwohl *et al.*, 1964: 6).

As a result the cognitive learning outcomes vary from simple recall of information to complex original and creative ways of analyzing and synthesizing new ideas and information. Generally the cognitive domain will focus on the intellectual capabilities of a learner which include recognition of specific facts, procedural patterns and concepts that serve in the development of the abilities and skills (Krathwohl *et al.*, 1964: 6, Anderson *et al.*, 2001: 29).

There are six major levels/area of competence that encompasses the cognitive domain. They are listed in order of increasing complexity hereunder.

Level	Category/Competence	Skills demonstrated
1	<b>Knowledge</b>	<ul style="list-style-type: none"> <li>❖ Observation and recall of information</li> <li>❖ Knowledge of terminology</li> <li>❖ Knowledge of dates, events, places</li> <li>❖ Knowledge of major ideas</li> <li>❖ Mastery of subject matter</li> <li>❖ <i>Question cues: list, define, tell, describe, show, label, collect, examine,</i></li> </ul>

		<i>tabulate, quote, name.</i>
2	<b>Comprehension</b>	<ul style="list-style-type: none"> <li>❖ Understanding information</li> <li>❖ Grasp meaning</li> <li>❖ Translate knowledge into new context</li> <li>❖ Interpret facts, compare, contrast</li> <li>❖ Order, group, infer causes</li> <li>❖ Predict consequences</li> <li>❖ <i>Question cues: summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend.</i></li> </ul>
3	<b>Application</b>	<ul style="list-style-type: none"> <li>❖ Use of previously learned information in new and concrete situations to solve problems</li> <li>❖ Use methods, concepts, theories in new situations</li> <li>❖ Solve problems using required skills or knowledge</li> <li>❖ <i>Question cues: apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover.</i></li> </ul>
4	<b>Analysis</b>	<ul style="list-style-type: none"> <li>❖ Identifying patterns</li> <li>❖ Organization of parts</li> <li>❖ Recognition of hidden meanings</li> <li>❖ Identification of components</li> <li>❖ <i>Question cues: analyze, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, infer.</i></li> </ul>
5	<b>Synthesis</b>	<ul style="list-style-type: none"> <li>❖ Use old ideas to create new ones</li> </ul>

		<ul style="list-style-type: none"> <li>❖ Generalize from given facts</li> <li>❖ Relate knowledge from several areas</li> <li>❖ Predict</li> <li>❖ Draw conclusions</li> <li>❖ <i>Question cues: combine, integrate, modify, rearrange, substitute, plan, create, design, invent, what if, compose, formulate, prepare, generalize rewrite</i></li> </ul>
6	<b>Evaluation</b>	<ul style="list-style-type: none"> <li>❖ Compare and discriminate between ideas</li> <li>❖ Assess value of theories or presentations</li> <li>❖ Make choices based on reasoned argument</li> <li>❖ Verify value of evidence</li> <li>❖ Recognize subjectivity</li> <li>❖ <i>Question cues: assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarize</i></li> </ul>

**Table 4.1. Six levels of the cognitive domain based on Bloom's Taxonomy (Anderson *et al.*, 2001: 29)**

#### **4.5.1.1. Discussions on the levels of the cognitive domain**

##### **4.5.1.1.1. Knowledge**

The first level of the cognitive domain of the Bloom's Taxonomy, *knowledge*, is concerned with those behaviours and test situations which emphasize remembering

previously learned scientific material. Knowledge is the lowest level of science objectives. The requirement is to simply recall stored information from the long term memory to the working memory. The range of information required may vary from simple facts to complex theories, but the basic evidence of the attainment of the outcome is to remember the information (Bloom *et al.*, 1964: 18, Trowbridge *et al.*, 2004: 91).

#### **4.5.1.1.2. Comprehension**

Trowbridge *et al.* (2004: 91) contend that comprehension is the first level beyond simple recall in that it demonstrates the understanding of scientific knowledge. Comprehending shows the ability of a learner to grasp and understand the meaning of the scientific information. According to Bloom *et al.* (1964: 19) and Trowbridge *et al.* (2004: 91) the attainment of the outcome will be evident when learners demonstrate the following cognitive skills:

- ❖ Translating scientific knowledge into forms.
- ❖ Interpreting scientific knowledge by reordering and showing interrelationships and summarizing.
- ❖ Extrapolating and interpolating scientific knowledge.

#### **4.5.1.1.3. Applying**

The cognitive domain of the Taxonomy is arranged in a hierarchical order such that each classification within it demands the skills and abilities which are lower in the classification order. The application level follows this rule in that to apply something requires comprehension of the principle on which it operates. That is, if a learner comprehends, then he can apply. To show that they have achieved the outcome, learners will demonstrate the ability to show the pertinence of scientific principles to different

situations. They will be able to apply scientific concepts, methods, laws or theories to actual concrete problems (Bloom *et al.*, 1964: 21, Trowbridge *et al.*, 2004: 91).

#### **4.5.1.1.4. Analyzing**

In the comprehension level, the emphasis is on the grasp of the meaning and intent of the material, whilst in the application level the focus is on remembering and bringing to bear upon given material the appropriate generalizations or principles. Analysis requires more than comprehension and application as it puts emphasis on the breakdown of the material into its constituent parts. It further requires the detection of the relationships of the parts and of the way they are organized. According to Bloom *et al.* (1964: 21) and Trowbridge *et al.* (2004: 91) the outcome of this level of the domain will be evident when learners demonstrate the following cognitive skills:

- ❖ Identifying parts.
- ❖ Clarifying relationships among parts.
- ❖ Recognizing organizational principles of scientific systems.

#### **4.5.1.1.5. Synthesizing**

Synthesis is a process of working with elements or parts of a material with the aim of combining them in such a way as to constitute a new pattern or structure. Synthesis requires the formation of new understandings of scientific systems. This is a cognitive level that clearly provides for creative behaviour on the part of the learner (Bloom *et al.*, 1964: 24).

The lower levels of this domain also involve the putting together of elements and the construction of meanings, but they are more partial and less complete than synthesis in the magnitude of the task. There is more emphasis on the uniqueness and the originality

in the synthesis level than is the case for other levels. The outcome in this category will be reached when learners bring together scientific ideas to form a unique idea, place or pattern (Trowbridge *et al.*, 2004: 91).

#### **4.5.1.1.6. Evaluating**

Evaluation is the highest level of learning results in the hierarchy. Bloom *et al.* (1964: 24) define it as the making of judgements about the value, for some purpose, of ideas, works, solutions, methods or material. It involves the use of criteria as well as standards for appraising the extent to which particulars are accurate, effective, economical or satisfying. According to Bloom *et al.* (1964: 24) the judgement may either be quantitative or qualitative in nature and the criteria may be determined by learners themselves or be prescribed to them.

The achievement of this outcome is evident when learners display the ability to make value judgements based on internal evidence and consistency and clearly defined external criteria. It is important to realize that evaluation does not represent the end process of dealing with a cognitive outcome, but it also represents a major link with the affective domain, discussed hereunder, where values, preferences and attitudes are the central processes involved (Bloom *et al.*, 1964: 24, Trowbridge *et al.*, 2004: 91).

### **4.5.2. AFFECTIVE DOMAIN OF LEARNING**

According to White (1988: 14) among the factors that affect learning in science is the factors that appear on the affective domain in learning taxonomy. These factors, attitudes and interest, determine whether or not learners will pay attention to what is to be learnt. Other factors include learners' prior knowledge.

According to Krathwohl *et al.* (1964: 7) the learning outcomes of the affective domain emphasizes a feeling tone, an emotion, or a degree of acceptance or rejection towards the subject. These outcomes vary from simple attention to selected phenomena (or

experiments) to complex but internally consistent qualities of character and conscience. The outcomes of this domain include the manner in which learners deal with interest, attitudes, appreciation, values, motivations, enthusiasms and emotional sets of a scientific phenomenon.

The outcomes of this domain are essential in that attitudes associated with physical science studies appear to be affecting learner participation in the subject (Toh, 1991: 90, Koballa *et al.*, 1990: 370) and appear to be impacting on learner performance in science (Linn, 1992: 830, Schibeci, 1984: 30). According to Hamilton and Ghatala (1994: 242) and Adams (1976: 242) the attitudes impact on the extent to which learners will pay attention to the *new* information presented. Paying attention affects the successful process of encoding; storage and the retrieval memory process and hence knowledge construction (as reflected on Section 3.6.3) of this study.

The second domain of the Taxonomy, the affective domain, was described by Bloom, Krathwohl and Masia. The domain advocates this structure (affective) and sequence for developing attitude. As it is the case with the other two domains, the detailed affective domain provides a framework for education in general, that is, teaching learning, assessing and evaluating (Bloom *et al.*, 1964: 95).

The five major levels of categories listed hereunder are intended to be hierarchical in order. They are arranged along a continuum of internalization from lowest to highest (Bloom *et al.*, 1964: 95).

Level	Category/area of competence	Skill demonstrated
1	<b>Receiving/Attending</b>	<ul style="list-style-type: none"> <li>❖ Awareness</li> <li>❖ Willingness to hear or receive</li> <li>❖ Selected attention</li> <li>❖ <i>Key words: asks, chooses, describes, follows, gives, identifies,</i></li> </ul>

		<i>locates, names, points to, holds, selects, sits, erects, replies, uses.</i>
2	<b>Responding</b>	<ul style="list-style-type: none"> <li>❖ Active participation of learners</li> <li>❖ Attends and reacts to particular phenomenon</li> <li>❖ Willingness to respond</li> <li>❖ Satisfaction in responding</li> <li>❖ Learning outcomes may emphasize compliance to respond.</li> <li>❖ <i>Key words: answers, assists, complies, conforms, discusses, greets, helps, labels, performs, practices, presents, reads, recites, reports, selects, tells, writes.</i></li> </ul>
3	<b>Valuing</b>	<ul style="list-style-type: none"> <li>❖ Attach value</li> <li>❖ Express personal opinion</li> <li>❖ Acceptance of a value</li> <li>❖ Show conviction towards a specific value</li> <li>❖ Preference of a value</li> <li>❖ <i>Key words: completes, demonstrates, differentiates, explains, follows, forms, initiates, invites, joins, justifies, proposes, reads, reports, selects, shares, studies, works.</i></li> </ul>
4	<b>Organization</b>	<ul style="list-style-type: none"> <li>❖ Conceptualize a value</li> <li>❖ Organize values into priorities by contrasting different values</li> <li>❖ Resolving conflicts between values</li> <li>❖ Organize and develop value system</li> </ul>

		<ul style="list-style-type: none"> <li>❖ Comparing, relating and synthesizing values</li> <li>❖ <i>Key words: adheres, alters, arranges, combines, compares, completes, defends, explains, formulates, generalizes, identifies, integrates, modifies, orders, organize, prepares, relates, synthesize.</i></li> </ul>
5	<b>Internalize or characterize values</b>	<ul style="list-style-type: none"> <li>❖ Adopt belief systems and philosophy</li> <li>❖ Generalize set of beliefs</li> <li>❖ Pattern of personal, social and emotional adjustment.</li> <li>❖ <i>Key words: acts, discriminates, displays, influences, listens, modifies, performs, practices, proposes, qualifies, questions, revises, serves, solves, verifies.</i></li> </ul>

**Table 4.2. The five levels of the affective domain based on Bloom's Taxonomy**  
(Bloom *et al.*, 1964: 95).

#### **4.5.2.1. Discussions on the levels of the affective domain**

##### **4.5.2.1.1. Receiving**

Receiving or attending to stimuli related to science is the lowest level of learning result in the affective domain. Receiving means that learners are aware of the existence of and willing to attend to scientific phenomena. It is believed that paying attention is the first step towards behaving at this level of receiving. Bloom *et al.* (1964: 99) suggest three

sublevels at which receiving may be measured, that also demonstrate the attainment of the outcome by learners. These are:

- ❖ Awareness that science related topics and issues exist.
- ❖ Willingness to receive information about science.
- ❖ Selective attention to scientific topics.

#### **4.5.2.1.2. Responding**

Responding, as stated by Bloom *et al.* (1964: 118) refers to a situation whereby a learner does something with or about scientific phenomena. At this level a learner is sufficiently motivated to be actively involved in phenomena that he/she is not merely willing to attend. Although this is a low level that indicates commitment, learners are thus showing some degree of commitment to do something. The outcome of this level will be evident when learners exhibit one or all of the following three levels of responses:

- ❖ Acquiescence: meaning that learners do what they are assigned or required.
- ❖ Willingness: meaning that learners do science study above and beyond requirements.
- ❖ Satisfaction: meaning that learners study science for pleasure and enjoyment.

Satisfaction and emotionality of response are a part of the upper subcategory of the affective domain, called valuing and is discussed hereunder.

#### **4.5.2.1.3. Valuing**

Valuing refers to a consistent behaviour that indicates learners' preference for science. The level thereof is based on internalized values related to science. The category gives more specifics on the term value than is normally presented in that it defines three levels of valuing. Each level represents a stage of deeper internalization. The lowest level, acceptance of scientific values, is concerned with the ascribing of worth to a phenomenon. A learner who has acquired the outcome will be able to demonstrate that he/she is willing to be identified with the scientific value so inculcated in him/her (Bloom *et al.*, 1964: 144).

The higher level of valuing, preference for scientific value implies not just the acceptance of a scientific value to a point of identifying with it, but the learner must be sufficiently committed to the value to pursue it, to seek it out and to want it. Testing for preference for a value essentially requires obtaining concrete evidence of specialized interests or particular values in science.

The highest level of this stage concerns commitment to scientific values. The learner who displays this behaviour at this level is clearly perceived as holding the value. A learner committed to science tries to convince others and seeks converts to his/her cause (Bloom *et al.*, 1964: 148, Trowbridge *et al.*, 2004: 95).

#### **4.5.2.1.4. Organization**

Organizing within this realm means that learners bring together different scientific values and builds a consistent value system. This process occurs because as learners successfully internalize scientific values, they encounter situations for which more than one value is relevant. Bloom *et al.* (1964: 154) and Trowbridge *et al.* (2004: 95) assert that the outcome will be achieved when learners:

- ❖ Conceptualize scientific values.

- ❖ Organize a personal value system.
  
- ❖ Organize a philosophy of life based on scientific values.

#### **4.5.2.1.5. Characterizing or Internalizing values**

Characterizing means that the individual has developed a life-style based on the preferred value system, in this case science. The individual's behaviour is consistently and predictably related to scientific values. According to Krathwohl *et al.* (1964: 165) the individual in this category is described in terms of his unique personal characteristics and his philosophy of life or his world-view. In this particular instance, it would be his science world-view.

Krathwohl *et al.* (1964: 165) assert that formal education cannot reach the aforementioned level because the maturity and personal integration required at this level are not attained until at least some years after an individual has completed his formal education. However collecting evidence about learners' basic orientation or view-points will be in line with assessing the outcomes of this category. These view-points are the poses which characterize and give learners behavioural consistency as in approaching science problems objectively, systematic planning the carrying out of motor activities and confidence in solving problems.

In the next section the psychomotoric domain of the Taxonomy is discussed

#### **4.5.3. PSYCHO-MOTORIC DOMAIN OF LEARNING**

The learning outcomes of the psychomotoric domain include physical movements, coordination and use of the motor skills areas. The development of these skills requires practice and is measured in terms of speed, precision, distance, procedures and techniques in their execution (Krathwohl *et al.*, 1964: 7).

The work of Trowbridge and Bybee (1990: 530) reveals that practical work, or lack of it, impacts on learners' academic performance. As a result it becomes crucial that learners must be exposed to practical work to fulfil Learning Outcome 2 as stated in DoE (2003: 26).

The psychomotoric domain was established essentially to address skills development relating to manual tasks and physical movement. Bloom's initial attention was focused on the cognitive and later the affective domain of the Taxonomy of educational objectives. Various researchers suggested detail for the third, the psychomotoric domain. This accounts for the different views based on the domain. However the most popular referenced versions of the psychomotoric domain are the ones by Simpson (1972), Harrow (1972) and the one by Bloom's student, Dave (1967).

Simpson's interpretation of the psychomotoric domain differs from Dave's chiefly because it contains an extra two levels prior to the initial imitation or copy stage. Simpson's first two levels, *Perception* and *Set* stages are incorporated within Dave's first level. The version given by Simpson seems to be more comprehensive as it is widely used for the psychomotoric development of young adults. Therefore Simpson's version of the psychomotoric domain will be considered in this study.

The levels and categories of the psychomotoric domain are listed hereunder.

Level	Category/area of competence	Skill demonstrated
1	<b>Perception</b>	<ul style="list-style-type: none"> <li>❖ Ability to use sensory cues to guide motor activity</li> <li>❖ Sensory stimulation through cue selection</li> <li>❖ <i>Key words: chooses, describes, detects, differentiates, distinguishes, identifies, isolates, selects.</i></li> </ul>

2	<b>Set</b>	<ul style="list-style-type: none"> <li>❖ Readiness to act (includes mental, physical and emotional sets).</li> <li>❖ <i>Key words: begins, displays, explains, moves, proceeds, reacts, shows, states, volunteers.</i></li> </ul>
3	<b>Guided response</b>	<ul style="list-style-type: none"> <li>❖ Demonstrates skills such as imitation at the beginning</li> <li>❖ Uses trial and error to accomplish outcomes</li> <li>❖ Shows adequate skill in performing experiment</li> <li>❖ Outcomes achieved by practicing</li> <li>❖ <i>Key words: copies, traces, follows, reacts, reproduces, responds.</i></li> </ul>
4	<b>Mechanism</b>	<ul style="list-style-type: none"> <li>❖ Learned responses become habitual</li> <li>❖ Movements can be performed with confidence and proficiency.</li> <li>❖ <i>Key words: assembles, calibrates, constructs, dismantles, displays, fastens, fixes, grinds, heats, manipulates, measures, mends, mixes, organizes, sketches.</i></li> </ul>
5	<b>Complex overt response</b>	<ul style="list-style-type: none"> <li>❖ Performance is quick,</li> </ul>

		<p>accurate and highly coordinated.</p> <ul style="list-style-type: none"> <li>❖ Performs without hesitation</li> <li>❖ Performance is automatic</li> <li>❖ <i>Key words: assembles, calibrates, constructs, dismantles, displays, fastens, fixes, grinds, heats, manipulates, measures, mends, mixes, organizes, sketches.</i></li> </ul>
6	<b>Adaptation</b>	<ul style="list-style-type: none"> <li>❖ Well developed manual skills</li> <li>❖ Modifies patterns to fit special requirements</li> <li>❖ <i>Key words: adapts, alters, changes, rearranges, reorganizes, revises and varies.</i></li> </ul>
7	<b>Organization</b>	<ul style="list-style-type: none"> <li>❖ Creates new movement patterns to fit particular situations or specific problems</li> <li>❖ Emphasis on creativity and originality based on highly developed skills</li> <li>❖ <i>Key words: arranges, builds, combines, composes, constructs, creates, designs, initiates, makes, originates.</i></li> </ul>

**Table 4.3. The seven levels of the psychomotoric domain based on Bloom's Taxonomy (Simpson, 1972)**

#### **4.5.3.1. Discussions on the levels of the psychomotoric domain**

The levels of the psychomotoric domain as shown on Table 4.3 are tabulated in increasing order of complexity. They range from a simple process of using sensory cues of perception to a complex skill of showing originality in manual skills. The levels as formulated by Simpson (1972) are discussed hereunder.

##### **4.5.3.1.1. Perception**

The first level of the psychomotoric domain by Simpson focuses on the category, *perception*. Perception is concerned with learners' *awareness* of the environment, that is, the extent to which a learner can use his senses to absorb data to be used. Perception therefore focuses on the ability of a learner to use sensory cues to guide motor or manual skills.

This initial state of the psychomotoric domain is one which confirms positive readiness and mental set for the learners' further development in this skill area. These skills range from sensory stimulation to translation (Trowbridge *et al.*, 2004: 97).

##### **4.5.3.1.2. Set- stage**

The second level, *set*, focuses on learners' readiness to act upon phenomena. It includes mental, physical and emotional sets. It refers to perceptual readiness (of the sensory modes: touch, smell, visual senses, etc). When learners are exposed to an observable action they begin to perform a covert imitation of that action. Trowbridge *et al.*, (2004: 97) contend that such covert behaviour appears to be the starting point in the growth of psychomotoric skills, which will be followed by overt performance by learners.

#### **4.5.3.1.3. Guided response**

*Guided responses*, the third level of the domain, depicts the early stages in learning a complex skill that includes imitation and a trial and error approach to solving problems. This level puts emphasis on the development of skills in following directions, performing selected actions and fixation of performance through necessary practice. Unlike for the previous levels, at this stage learners are capable of performing an activity/experiment according to instructions rather than just observing (Trowbridge *et al.*, 2004: 97).

#### **4.5.3.1.4. Mechanism**

The intermediate stage in learning a complex skill is shown on the fourth level of the domain, which is *mechanism*. On this level learners show a skill of attempting to solve problems on their own. The achievement of the outcome is characterized by minimal errors, higher degree of control and increased self confidence (Trowbridge *et al.*, 2004: 97).

#### **4.5.3.1.5. Complex overt response**

During the *complex overt response* stage, the fifth stage of the psychomotoric domain, learners exhibit skilful performance of motor acts that involve complex movement patterns. This stage involves the coordination of a series of acts by establishing an appropriate sequence and accomplishing harmony or internal consistency among different acts. The achievement of the outcome includes the evidence of learners' responses becoming habitual (Trowbridge *et al.*, 2004: 97).

#### **4.5.3.1.6. Adaptation**

When learners start to show well developed skills and they can modify movement patterns to fit special requirements, they shall have acquired the outcomes for the sixth

level of the domain, *adaptation*. This will be evident when learners respond effectively to unexpected experiences, or when a learner modifies instructions to meet his/her needs.

#### **4.5.3.1.7. Origination**

The seventh level of the domain, *origination*, reflects a high level of proficiency in the skill or performance of a single act. The activity/experiment at this level is performed with the least expenditure of physical energy. The performance becomes smooth, original, automatic, spontaneous and routinized with learners showing a high degree of confidence (Trowbridge *et al.*, 2004: 97).

The subsequent section deals with the impact the Taxonomy has on science learning.

### **4.6. IMPACT OF THE LEARNING TAXONOMY ON SCIENCE LEARNING**

The contemporary view of learning is that learners actively construct knowledge that they possess. Constructing knowledge is a lifelong and effortful cognitive process, which requires significant mental engagement from the learner (Mestre & Cocking, 2002: 15, Novodvorsky, 1997: 242, Lazarowitz & Hertz-Lazarowitz, 1998: 450 & Duit & Treagust, 1998: 8).

The implication of the fact that learners bring this pre-constructed knowledge to the learning encounter is that the pre-constructed knowledge impacts on their ability to learn new information. Science literature reveals that there are a number of factors that influence learning. These factors, according to Krathwohl *et al.* (1964: 58) stem from the three learning domains as described by Bloom

In the following subsection the relationship between science learning and the three learning domains is discussed.

#### 4.6.1. Cognitive Domain

In support of the factors that influence learning, Vygotsky (1986: 121) asserts that cognitive processes influence learning. According to Vygotsky (1986: 121) as learners grow, they become capable of increasingly more sophisticated thought, for explaining abstract concepts.

As stated in the South African policy document (DoE, 2005) core to the purpose of science learning is the acquisition of scientific knowledge and problem solving skills. The purpose further expands to the understanding of the nature of science and its relationship to technology and society and the environment. The Science National Curriculum Statement (2003) in South Africa envisages a learner who can demonstrate the following skills:

- ❖ Classifying.
- ❖ Communication.
- ❖ Designing an investigation.
- ❖ Evaluating conclusions.
- ❖ Hypothesising.
- ❖ Predicting.
- ❖ Interpreting.

The skills listed above are more of cognitive nature as described by Bloom *et al.* (1964: 18) and Krathwohl *et al.* (1964: 8). These skills cut across the six levels of the cognitive domain which include testing for *knowledge, comprehension, application, analysis,*

*synthesis and evaluation*. This relation is evidence of the fact that Bloom's Taxonomy of learning domains forms the bedrock on which the physical science learning outcomes rest.

#### **4.6.2. Affective Domain**

The affective domain of the Taxonomy in teaching and learning is generally not given the attention it deserves, much to the detriment of successful learning. When one takes a closer look at factors that affect learning in science and learning in general, one finds that top on the list are factors of the affective domain. These, according to Hamilton and Ghatala (1994: 85) include factors such as *motivation, interest, values and attitude*.

On Section 3.2 of this study it was revealed that the process of acquiring knowledge starts with observation (Bjorklund, 2005: 121, Hamilton & Ghatala, 1994: 80). This observation has to do with the ability to use sensory cues to guide motor skills. It is therefore crucial to ensure that the learners are interested and motivated to pay attention to the phenomenon under observation. Failure to keep learners interested will result in a situation where effective and meaningful learning does not proceed.

The National Curriculum Statement (DoE, 2003: 32) in this respect envisages producing learners that appreciate and *value* the impact that science will have on the quality of socio-economic, environmental and human development. Although this level of the domain is critical, Krathwohl *et al.* (1964: 165) assert that the formal education cannot reach this stage of assessment until the individual has at least completed his/her formal education career and fits into society where he/she applies the systematic approach to solving everyday life problems and illustrates the value of science applications. In the process such a learner will show appreciation of science and encourage other members of the society to pursue careers in science or in related fields (Krathwohl *et al.* 1964: 165).

### 4.6.3. Psychomotoric Domain

The National Curriculum Statement (DoE, 2003: 32) on the learning of science does not only focus on the cognitive development of the learner, it also pays attention to the practical skills the learners have to acquire in the process. Some of the practical or motor skills that learners are envisaged to acquire are:

- ❖ Measuring.
- ❖ Observing.
- ❖ Drawing.

Bloom's Taxonomy puts special emphasis on this domain as it is argued that an individual does not act without thinking (Krathwohl *et al.*, 1964: 6). The psychomotoric domain addresses the sensory motor skills of the learner which according to Adams (1976: 256) has relatively long lasting impressions to the memory compared to other senses (see section 3.3.1.3 of this thesis). It is for this reason that science researchers advocate for the use of practical work in the learning thereof (Cantu & Herron, 1978: 136).

From the science learning outcomes and the purpose of science learning as viewed by policy makers and educationists, it follows that the goals or outcomes of science learning set by them have not been chosen randomly but are directly linked to Bloom's learning Taxonomy. It is also important to note that, even though the three domains are separated, they clearly overlap. To illustrate this overlapping, one has to consider, for instance the first level of cognitive continuum, *knowledge*, which begins with a learner *recalling* Newton's third law of motion. On the affective continuum the learner *receives* stimuli and actively attends to it so as to guide the motor skills for the application of the law. This relates to the third level of the domain, the psychomotoric domain.

## 4.7. CONCLUSION

Various researchers like Appleton and Asoko (1996: 166) have outlined the characteristics of the constructivist theory as:

- ❖ A prior awareness of the ideas which children bring to the learning situation and attempt to elicit such ideas.
- ❖ Clearly defined conceptual goals for the learners and understanding of how learners might progress toward the ideas.
- ❖ Use of teaching which involve a challenge to or development of the initial ideas of the learners and ways of making new ideas accessible to them.
- ❖ Provision of opportunities for the learners to utilize new ideas in a range of contexts.
- ❖ Provision of a classroom atmosphere which encourages learners to put forward and discuss ideas.

Considering the characteristics outlined above it becomes necessary to develop and refine science learning objectives/outcomes. According to the South African policy document (DoE, 2003: 7) the nature of these science learning objectives or outcomes must be such that they describe scientific *knowledge, skills* and *values* that learners should acquire by the end of the Further Education and Training (FET) band. The three key aspects highlighted are central to Bloom's Taxonomy of learning as it addresses the *cognitive, psychomotoric* and the *affective* learning outcomes respectively. Therefore Trowbridge *et al.* (2004: 91) assert that the understanding of the three learning domains as formulated by Bloom and his collaborators fits in well with the intensions of science teaching and learning.

Nieuwoudt (1998: 9) contends that context in learning plays a significant role. Trowbridge *et al.* (2004: 90) hold the same view in that they argue that learners must be challenged and be exposed to an educational context where they may extend their conceptual understanding and equip their motor skills. In this environment learners will bring in their preconceived ideas and relate them to the situations they are faced with.

In the next chapter the concept of a science centre as a means of science educational context will be outlined. In the chapter the definition and classification of science centres will be provided.

## CHAPTER 5

### THE CONCEPT OF SCIENCE CENTRES

*Science is forever a search, never really a finding. It is a journey, never really an arrival (Sir Carl Popper)*

#### 5.1. INTRODUCTION

Over the years science education has been perceived to be a “consumer” of knowledge rather than a “producer” of it. In science classrooms learners are engaged in hands-on activities, that is, those who are fortunate enough to have resources that they may associate with authentic scientific discovery. However, teachers often prescribe learners’ thinking to ensure they arrive at predetermined conclusions based on the intent of the activity. This phenomenon may have been encouraged by a number of factors ranging from the demanding nature of the curriculum, to the design of the practical worksheet in science education (Bencze & Lemelin, 2001: 141).

Science seeks to understand reality. Reality on the other hand is made up of both objects and phenomena. Objects are made of matter that takes up space, and phenomena are the changes experienced by objects. Therefore to arrive at reality, logical inferences from empirical evidence must be made by the observer. These logical inferences are constructed by the observer who attaches a meaning to it. It is for this reason that Malhotra (1994: 4) assert that truth resides in nature and is to be investigated by individuals.

In this chapter the concept of a science centre is outlined. The chapter will also look at how science centres in South Africa are classified, their roles in society and their objectives as spelt out by the Department of Science and Technology. The chapter seeks to address objectives (a), (b) and (c) of this study.

In section 5.2 the historical development of science centres is discussed.

## **5.2. HISTORICAL DEVELOPMENT**

The end of the previous decade saw a rapid increase in the number of interactive science centres internationally. The rapid development of these centres was driven by the philosophy that they offer a means of increasing the *awareness* of science and technology in society. Awareness in this context refers generally to an increase in understanding and a more positive attitude towards science and technology (Johnston & Rennie, 1995: 317).

Tradition has it that scientists have always withheld information from the public (Roan, 2001: 11). This was done until at least some sort of comfort level or unanimity among the professionals is achieved. This phenomenon is referred to as a formation of a 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, the 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. The process as it unfolds is not done in absolute secrecy as the findings are continuously published in science journals, magazines and the electronic media. This is done as a means of communicating science to the public (Roan, 2001: 11).

The subject of communicating science to the public has raised so much concern and interests that education authorities around the world are investing in science centres (Roan, 2001: 11). The South African community has also been seen to embrace the idea such that in recent years it has set itself two significant goals to achieve by 2008. These goals cut across the quality of life, growth and wealth creation. These two goals encompass amongst others, research and development and other determinants of innovation, for instance, highly skilled human capital for research and development.

According to the document released by the Department of Science and Technology (DST, 2004) the achievement of these goals depends on sustainable diverse influx of school learners into diverse science education. In doing so, the DST has adopted a three pronged strategic approach, which include:

- ❖ Exciting learners with science and stimulating their interest in science and science related subjects.
- ❖ Increasing learner performance in science and science related subjects, particularly the historically disadvantaged section of the population.
- ❖ Career education to attract matriculants with good passes in science and science related subjects to science-based degree studies.

The first strategic approach envisaged by the DST has its roots embedded in Blooms' Taxonomy of learning (Krathwohl *et al.*, 1964).. The first strategy is of relation to the affective nature of the learning domain. This strategy attends to the crucial aspect of the domain that deals with human emotions. According to Toh (1991: 90) and Koballa *et al.* (1990: 370) the outcomes of the affective domain impact on learner participation in science and hence on academic achievement. Hamilton and Ghatala (1994: 242) contend that the outcomes of the affective domain also impacts on the extent to which a learner will participate or pay attention to the new information encountered.

As it is discussed in Sections 2.3 and 3.6.3 of this study, paying attention is a critical part of the process of knowledge acquisition. Hamilton and Ghatala (1994: 99) assert that before any information can be processed, the individual must pay attention and be aware of the environment around him.

The second strategic approach touches on increasing learner academic performance in Physical Science and science related subjects. This strategy is of cognitive nature. Central to the National Science Curriculum Statement (2003) is the achievement of cognitive skills such as interpreting, comprehension, predicting, classifying, hypothesizing and evaluating. These skills are important as they are seen as directly impacting on the academic achievement of learners and they form an integral part of the six levels of the cognitive domain as described in Bloom's Taxonomy (DoE, 2005, Krathwohl *et al.*, 1964: 8).

The third strategy cuts across the affective domain of Bloom's Taxonomy (Krathwohl *et al.*, 1964: 165) and it is also embedded on one of the premises of the theory of constructivism on lifelong learning. Although the ultimate outcome of science education within the affective domain cannot be reached during the formal education phase, the outcomes become evident when the individual appreciates and attaches value to the systematic approach in science application and problem solving (Krathwohl *et al.*, 1964: 165).

The strategy depicts the character of constructivism as it advocates for lifelong learning. According to the strategy, learners who are exposed to science centres should be attracted to follow careers that are science related. It is during this lifelong learning process that individuals expose the affective dimension and outcomes of the learning domain (Krathwohl *et al.*, 1964: 165). According to Vygotsky (1978: 67) the lifelong process of learning depends on the social interaction of individuals, a fact which Bencze and Lemelin (2001: 153) consider vital for the intellectual riches and *holistic* development of science learners.

The definition and classification of science centres follows hereafter in section 5.3.

### **5.3. DEFINING THE CONCEPT OF A SCIENCE CENTRE**

A comprehensive definition of a science centre as given by the Department of Science and Technology (DST, 2004: 5) is “*a permanently established education facility that provides an interactive educational experience through the use of interactive science, technology, engineering and mathematics exhibits, display and programmes*”.

This definition is comprehensive in that it encompasses and seeks to address the three pronged strategy as envisaged by the Department of Science and Technology (DST, 2004).

The definition carries with it key features which are: *permanently established facility, interactive educational experience, interactive science, displays and programmes*.

A science centre has to be a permanent facility because as revealed by research, schools in South Africa are reported to have a great shortage of resources in Physical Sciences to either entice or educate learners. As a permanent facility learners and educators will have the opportunity to visit it for edutainment purposes at minimal costs (Rapule, 2005).

Limitations mentioned by teachers which relate to practical work in science is the fact that some learners become spectators when others assume leading roles in carrying out the experiment. Lack of adequate resources and declining learners' interest in science are seen as compounding factors to an effective mode of teaching. In the science centre the context is interactive and learners are encouraged to take centre stage as they interact with apparatus so as to make meaning of the learning encounter, a phenomenon based on constructivism (DST, 2004).

The broad understanding of a science centre attaches a unique character in that it supports both the formal and informal education by bringing back quality through interactive,

practical, science approach. Quin (1990: 244) and Gregory (1990: 233) contend that science centres are:

- ❖ Largely devoted to science and technology.
- ❖ Contemporary rather than historic (as compared to museums).
- ❖ Interactive with specially constructed exhibits that encourage visitors to investigate natural phenomena and experiment with technology.
- ❖ Informed places where guides/pilots are always on hand to welcome visitors and offer help where and when it is needed. Help may even be in the form of discussion or explanations.
- ❖ Laboratories that illustrate scientific phenomena.
- ❖ Publicly and educationally oriented for the purpose of edutainment.
- ❖ Offering a variety of exhibits. They do not only focus on one branch or discipline of science. They cover a wide range of the science spectrum.

In the next section the classification of science centres is discussed.

#### **5.4. CLASSIFICATION OF SCIENCE CENTRES**

The Department of Science and Technology (DST) has tasked various groups to conduct a feasibility study on the extended support programmes for science, mathematics and technology. The intention was to report back on how science centres can effectively be used to supplement extended support programmes in South African schools. According to the report (DST, 2004) it was found that science centres in the country are unevenly distributed and that they vary in terms of definition, ownership, type, size and capacity.

It is for this reason that a more comprehensive definition of a science centre was adopted so as to reflect, within the definition, the three pronged strategy of the Department of Science and Technology.

From the findings it can be deduced that science centres can be classified in terms of their geographic size and space. The Department of Science and Technology (DST) has set itself standards to be achieved through a network of science centres in the country. The department aims to provide 3, 75 million experiences annually by the year 2020 for 15 million visitors. This ideal would be realized if the network of science centres take an active role to meet the set principles of science centres, according to the size of the particular centre.

Science centres are classified by DST as full service, limited service and mobile centres. This classification is discussed hereunder.

#### **5.4.1. Full Service Centre**

The dimensions of a full service centre (DST, 2004) should at least be 1 800 m<sup>2</sup> and should be able to cater for 50 000 school visitors annually in groups, as set out by DST standards. The Department of Science and Technology recommends that full service centres should be capacitated to handle 200 000 learners who reside in a radius of 100 km.

SciBono centre ([www.sci-bono.co.za](http://www.sci-bono.co.za)) is an example of a full service science centre. It is situated in Johannesburg in the Gauteng province of South Africa. The centre is said to be the largest in Africa and compares favourably in size with international interactive science centres such as the Exploratorium in San Francisco ([www.exploratorium.edu](http://www.exploratorium.edu)).

The SciBono centre intends to expand to 11 000 m<sup>2</sup> in future, a size meeting one of the criteria set by the Department of Science and Technology (DST, 2004).

#### **5.4.2. Limited Service Centre**

The specification, in terms of size, of a limited service centre is at least 600 m<sup>2</sup>. A limited service centre should be designed to serve 25 000 learners annually in the form of school groups (DST, 2004).

The Potchefstroom Science Centre in the North West province ([www.puk.ac.za/fakulteite/natuur/ws/index.html](http://www.puk.ac.za/fakulteite/natuur/ws/index.html)) is an example of a limited service centre. The centre is situated on the Potchefstroom campus of the North-West University. The actual dimensions of the centre is 600 m<sup>2</sup> which includes a lecture room that can accommodate 120 learners/visitors. The centre has at least 64 exhibits which cover the Physical Sciences, Mathematics and Technologies. The selection of the Potchefstroom Science Centre exhibits supports the National Curriculum Statement (DoE, 2003) in that it includes exhibits from the fields of mechanics = 27; optics = 4; electricity and electromagnetism = 9, waves, sound and light = 15, heat and energy = 3 and diverse exhibits = 10 (see the Science Centre's web page).

In its first year of its inception, October 2005 – October 2006, the Science Centre had 101 076 visitors. Of the total, 59 063 visitors were in school groups, a figure which is appealing to the Department of Science and Technology. According to the norms of the Department of Science and Technology a science centre of this size should accommodate 25 000 learners in the form of school groups. However attendance records prove that 34 063 learners more than what is recommended by the DST, visited the Science Centre in school groups. This centre is trimmed with Upptäckerland, the science centre at the University of Gävle in Sweden.

The method of presentation in the Potchefstroom Science Centre is embedded on the theory of constructivism. The method of presentation is discussed in detail in Section 9.5.

This study focuses on whether or not science centres impact on learners' holistic development. The empirical part of this study was carried out in the Potchefstroom Science Centre.

#### **5.4.3. Mobile centres**

Mobile science centres have been developed with the intention of carrying scientific phenomena to remote rural areas where sophisticated laboratory techniques and facilities cannot be provided due to difficult terrain access. The Department of Science and Technology recommends that a mobile science centre should be able to reach 50 000 learners annually. The main target of the outreach programme is rural and remote communities. The Potchefstroom Science Centre has a unit which is called "science on wheels" earmarked for that specific purpose. It is to render a service to remote and rural schools. Mobile science centres have certain benefits, however according to Rapule (2005: 153), the following are limitations that are associated with mobile science centres/units:

- ❖ One cannot transport all the 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.

The objectives of science centres are discussed hereunder.

### **5.5. THE OBJECTIVES OF SCIENCE CENTRES**

Objectives and goals for exhibits and how best to accomplish them are an ongoing subject of discussion in all science centres and museums. Studies done in 2004 in Brazil and Japan and 2005 in Vietnam (Ansbacher, 2005: 1) revealed the problems associated with science education. Top of the list were the factors related to the affective domain (attitude, motivation, etc) that hinders the enhancement of science in learners. However the developing countries on the other hand revealed the positive role played by science

centres in addressing and developing learners in three areas of importance: cognitive, affective and psychomotoric skills (Ansbacher, 2005: 1).

According to Ansbacher (2005: 1) most science centres and museums focus on thinking as the explicitly identified goal for visitors. Other equally important objectives envisaged by science centres are construction of scientific knowledge and inquiry learning. It is critical to note that scientific knowledge does not arise from the subject (learner) nor from the perceived object (apparatus/exhibits), but from the interaction of the two (Malhotra, 1994: 4; Smock, 1981: 53; Ziman, 1968: 5; White, 1988: 121; Chadwick *et al.*, 1984: 4). Ansbacher calls this phenomenon *process*.

Ansbacher (2005: 1) holds that the *process* of science is valuable as it develops learners *holistically*, that is, cognitively, affectively and skilfully. This is attained as in the process learners observe, think rationally and experiment. In the process learners interact with objects, ask questions, solve problems and make choices. It is through this kind of interaction that one comes to the understanding of concepts.

Humans tend to be goal oriented; therefore the education department has set itself objectives/goals, through the national curriculum statement (DoE, 2003: 9) to contribute towards the *holistic* development of learners by:

- ❖ Giving learners the ability to work in scientific ways and to apply scientific principles, which have proved effective in understanding and dealing with the natural and physical world in which they live.
- ❖ Stimulating learners' curiosity, deepening their interest in the natural and physical world in which they live and guiding them to reflect on the universe.
- ❖ Developing useful skills and attitudes that will prepare learners for various situations in life.

It is evident that the three objectives listed above are purposely structured so that they relate to the cognitive, affective and psychomotoric domain of Bloom's Taxonomy of learning. The first objective is of cognitive nature as it focuses on the application of the acquired scientific knowledge and the mental process thereof. The second objective deals with factors that are affecting learners' emotions. These factors, for instance interest, are considered critical and determine whether or not learners will participate in the learning process (Toh, 1991: 90, Koballa *et al.*, 1990: 370). According to (Linn, 1992: 83) and (Schibeci, 1984: 3) these are the factors that impact on learners' academic performance, therefore careful consideration must be taken when these factors are part of the objectives envisaged. The third objective concerns the practical skills that learners must acquire in the learning of Physical Sciences.

From the definition of science centres it follows that a science centre is perceived as a key part of the infrastructure for the implementation of the Department of Science and Technology's three pronged strategy (DST, 2004).

In the subsequent section the advantages of science centres is discussed.

## **5.6. ADVANTAGES OF SCIENCE CENTRES**

The benefits that come with science centres are entrenched within the aims and objectives discussed in Section 4.5 above. These benefits cut across the three pronged strategy; the principle of constructivism; the objectives set out by the Departments of Education and Science and Technology and most importantly the three learning domains referred to in this study as learners' *holistic* development. The benefits of the science centre will be discussed according to these three categories.

### **5.6.1. Advantages of cognitive nature**

In this context the cognitive domain is concerned with the knowledge that learners gain from a visit to a science centre. Science as we have come to know it refers to the

organized body of *knowledge* humans have gained by interacting with nature or by research (Malhotra, 1994: 3). This *knowledge* is aimed at a systematic acquisition based on experimentation, experience and methodological research aimed at finding the truth about nature. In science, the basic unit of *knowledge* is the theory which is a hypothesis that has been proven and expanded.

Science centres help learners in the acquisition of knowledge of facts, and knowledge of principles and theories. These appear on the low levels of Bloom's Taxonomy of educational objectives. However learners can also benefit by gaining knowledge pertaining to application and gain the ability to synthesize and create new knowledge (Wellington, 1990: 249). The interaction of learners with displays in the science centre stimulates their thought process and their working memory (Hamilton & Ghatala, 1994: 81). Because of the lasting impression created by motivation and interest (affective elements of the affective domain) the information/memory is then retained in the long-term memory for future use.

It is clear that science centres contribute to the cognitive development of science learners in two important ways: firstly by providing new awareness that certain things happen in certain circumstances, but secondly and most importantly by sowing seeds and leaving indelible prints in learners' memories which may ultimately lead to better understanding (Wellington, 1990: 250).

### **5.6.2. Advantages of affective nature**

The affective domain of the Taxonomy is much neglected in traditional formal science education. Perhaps this can be attributed to the recent low intake of first year physics and chemistry students and other related courses in universities. Science centres can make a major contribution to the affective domain; they can even begin to complement the formal science education for the realization of the attainment of affective outcomes (Wellington, 1990: 249, Russell, 1990: 260).

Science centres have a powerful effect on the affective development of learners in changing their attitudes towards science. This, according to Russell (1990: 260) is compounded by the level of motivation that learners gain from the visit to the science centre. This kind of attitude change is fundamental and a major feature of what science centres must offer. It is because science centres, according to Wellington (1990: 250) generate such enthusiasm, excitement and interest that their failure to contribute immediately and directly to deeper understanding of science is insignificant.

According to Wellington (1990: 250) and Russell (1990: 260) the development of the motivation and interest (that is the elements of the affective domain) of learners for science, will eventually help learners to have a broader understanding of science and science concepts and assist them in gaining different types of knowledge (from factual to conceptual knowledge). The attainment of the affective learning outcomes contributes effectively to the achievement of other cognitive skills.

### **5.6.3. Advantages of psychomotoric nature**

The psychomotoric domain of Bloom's Taxonomy of educational objectives involves the development of manipulative skills, manual dexterity and eye-to-hand coordination. These skills are enhanced to a maximum when learners are physically and actively involved and are motivated in their learning. Wellington (1990: 248) asserts that in an interactive science centre learners' interest is kept at a high and as a result they focus and learn and understand better. According to Wellington (1990: 249) this enhances learners' psychomotoric skills and their power of observation is enriched. The eye to hand coordination will also be perfected by continued exposure to interactive science centres.

Exhibits that are attractive and catching to the eye are set to encourage learners' curiosity. According to Morris (1990: 264) learners' curiosity is a factor that stimulates learning in science. When learners are curious about something they become actively (minds-on and hands-on) engaged in it, ask questions, formulate possible answers and then do the

practical aspect of it. In the process they discover new things and formulate their own knowledge structure.

The principles guiding science centres are discussed in the next section.

## **5.7. PRINCIPLES GUIDING SCIENCE CENTRES**

For sustainable development of science centres the following principles are recommended:

### **❖ Access.**

Science centres must be accessible to both urban and rural areas so as to provide the necessary professional development and training in science and technology. This accessibility will go a long way in developing links between schools, parents, tertiary institutions, industry and business in rural and urban areas. Science centres should also provide access to an expanded range of on-line learning material (DST, 2004).

### **❖ Equity.**

Science centres should ensure that all members of the community have access to it. It should ensure equal educational opportunities for all members of the community. It should further create, present and provide equal access to scientific knowledge and facilities to all members of the community (DST, 2004).

### **❖ Redress.**

The Department of Science and Technology focuses on improving accessibility to science centres in terms of the target audience. The department is aiming at promoting smaller science centres to the category of limited service science centres with a wide range of exhibits and benefits. In cases where this redress model is not fulfilled, mobile

units will be used for outreach programmes with the aid of nearby limited service centres. The idea is to expose learners and parents to science based career options (DST, 2004).

❖ Key performance indicators.

A science centre must meet its own performance indicators. The performance indicators of science centres depend on the existence of robust benchmarks and objectives set by individual science centres. In other words it is essential for a science centre to be unique in its approach to serve its own community. This will be achieved by local and international comparable standards against which individual science centres can assess their own performance. For instance a limited service science centre must have exhibits, an auditorium where science shows or talks are held, a mobile unit for outreach programmes on science shows, a career centre to expose learners, a computer lab for computer literacy programmes, innovation and knowledge development space and a mini workshop for repairs (DST, 2004).

❖ Synergy.

The success of a science centre will depend on the strength of the management thereof. Therefore it will be wise for the management to synergize by networking with managers of other science centres and plan to rotate exhibits on a semester or quarterly basis (DST, 2004).

❖ Sustainability.

To sustain science centres a capacity building process is essential. The Department of Science and Technology is taking this task upon itself to ensure that science centre managers are empowered in areas such as financial management, marketing, project-management and networking skills (DST, 2004).

❖ Inclusivity.

It is within the right of every South African to have access to education and other educational benefits. Therefore there must be a principle of inclusive education in science centres. People who have physical disabilities must be accommodated in science centres and be entitled to all benefits. As a result, care must be taken when planning for the science centre layout (DST, 2004).

❖ Outcomes based education.

Outcomes based education embeds the principle of life-long learning. Science centres must be aimed at encouraging learners and teachers (in various programmes like a career centre) to maintain a life-long learning interest in science. Science centres must be able to offer valuable opportunities to enhance and broaden learning outcomes in science through facilitating innovative and stimulating programmes. OBE advocates for integrated teaching strategies, therefore in a science centre there must be integrated teaching/learning approaches to problem solving. The exhibits must therefore cut across *Physical Sciences*, mathematics and technology (DST, 2004).

❖ Marketing and political buy in.

Through innovative and stimulating programmes offered in the science centre, the centre may be able to involve the business sector in the funding. The strategic positioning and accessibility of science centres must be such that it links learners, parents, tertiary institutions and the business sector for marketing purposes (DST, 2004).

❖ Expansion.

Because the Department of Science and Technology has a plan to upgrade science centres it is important that during the developmental phase, science centre managers take into consideration that there might be a possibility for expansion. Therefore there must

always be room for further development in terms of building and growth for exhibits as well as for the audience (DST, 2004).

Following the principles and advantages that are mentioned above, science centres according to the researcher should be able to develop science learners along the lines of Bloom's Taxonomy. This is discussed in the following section.

### **5.8. LEARNERS' DEVELOPMENT i.t.o THE TAXONOMY OF LEARNING**

According to the report (Wellington 1990: 247) learners who visit science centres are found to be more motivated and consequently frequent visit impact on their academic achievement in Physical Sciences. Wellington (1990: 247) suggests the two areas of learning which must be considered in examining science education; the two are embedded in the theory of constructivism and cut across the aspects of Bloom's Taxonomy. He considers public understanding of science and the advancement of science, referred to as formal and informal science learning to be important in developing learners in science.

Wellington (1990: 247) reports that there is evidence to support the notion that learning outside the classroom context (such as learning in interactive science centres) have strong a influence on learners' educational outcomes. McManus (1988) and Wynne (1990) quoted by Wellington (1990: 247) point out that the promotion of cognitive (scientific literacy) is important but that the promotion of the social dimension and affective domain to the science centres' visitors will be left out to the detriment of the visitors' important domain of development.

The fact that learners in the science centre are learning through play and entertainment (edutainment) is seen by those involved in science education and education in general as an added advantage to learning. This phenomenon is seen as creating a conducive and free atmosphere to learning. In a free and conducive environment learners interact with their peers freely, express their emotions and opinions without fear. In such an

atmosphere learners' knowledge (various types) and alternative conceptions about phenomena come to the fore (Wellington, 1990: 248, Driver, 1983: 8, Driver *et al.*, 1985: 12).

The next section summarizes the impact and role that science centres have on the *holistic development* of a science learner.

### 5.9. SUMMARY OF ROLE PLAYED BY SCIENCE CENTRES

The impact science centres have on science learners can be summarized in a tabular form as follows (Wellington, 1990: 248):

<b>In a science centre (informal setting) learning is</b>	<b>In a classroom (formal setting) learning is</b>
Voluntary	Compulsory
Haphazard	Structured
Open-ended	More closed
Learner-led	Teacher-led
Learner-centred	More teacher-centred
Reaching many unintended learning outcomes	Reaching fewer unintended learning outcomes
Capable of achieving more difficult outcomes (of affective domain)	Not so capable in achieving affective learning outcomes
Social aspect central (stresses social interactions between learners and visitors in general)	Social aspect is less central

**Table 5.1 Summary of learning in science centres compared to classroom learning**  
(Wellington, 1990: 248)

## 5.10. CONCLUSION

When one looks at the advantages/responsibilities of a science centre one concludes that a science centre is or should be an agent of change, that is, in individuals as well as generally in society. It is an agent of change in that a visitor to the science centre must leave the centre a different person in terms of cognitive, affective and psychomotoric development (Bloom *et al.*, 1971: 8). In its ideal function, science centres should stimulate visitors (Wagensberg, 2005: 310). Stimulation is a powerful tool with its origin in the affective domain, a fact that proves that the affective domain is essential in science learning. Wellington (1990: 250) and Morris, (1990: 264) assert that enhancing the affective aspects of the learning domain have enormous advantages as they (affective outcomes) impacts on cognitive and psychomotoric skills development. The learning outcomes of the affective domain deals with attitudes towards science. Once attitudes are positive then learning becomes a bearable journey, a journey that is assured of learners' *holistic development* in science.

In the next chapter the assessment of a science centre will be discussed. The chapter seeks to assess the concept of a science centre in terms of Bloom's Taxonomy of educational objectives.

## CHAPTER 6

### ASSESSING THE SCIENCE CENTRE

*It is in fact nothing short of a miracle that the modern methods of instruction have not entirely strangled the holy curiosity of inquiry (Albert Einstein)*

#### 6.1. INTRODUCTION

The success and effectiveness of and sustainability of a project or system rely on the quality of it being assessed against its own objectives. The term assessment is preferred to the traditional term, test, as the former is more inclusive and provide a bridge between teaching and learning. It even goes further as it brings in other dimensions in terms of the role players in the academic assessment of learners.

In a report released by the Department of Science and Technology (DST, 2004: 2) it is confirmed that science centres in our country have not undergone any formal evaluation up to date. Nursall (2003: 381) argues that it is as a result of the lack of extensive evaluation that science centres fail to fulfil the intended roles as specified in the Norms and Standards (2004: 4) and the education policy document (DoE, 2003: 13).

This chapter seeks to assess or formulate the assessment tool that will be used to determine the extent to which science centres are effective. Because the study is aimed at investigating the impact science centres have on the learning of Physical Sciences in a holistic manner, the assessment tool will be compiled in terms of Bloom's Taxonomy of learning. In this chapter various assessment types and methods in science will be discussed in order to have the three aspects of the objectives, that is the cognitive, affective and psychomotoric domains. This is done to address objectives (a) and (c) of this study.

## **6.2. DEFINING ASSESSMENT**

Assessment in educational context refers to a process where a teacher/educator receives invaluable information about the academic performance of the learners and/or it can be used as a measure of the degree and extent to which the teaching or learning encounter was successful. As stated by White and Gunstone (1992: 58) assessment is an essential ongoing component of instruction that guides the process of learning and not a tack onto learning.

If we are to make any strides in the development of learners in a holistic manner, then we should make a concerted effort to examine not only our instructional methods, but most importantly our ultimate educational outcomes which entrenches assessment. The methods of assessment employed in the past had its focus on the superficial aspects of learning, hence the term testing rather than assessing (Cohen, 1993: 798, Olivier, 2002: 99).

In a culture of testing teachers were seen as carriers of knowledge which they had to transfer into the learners' heads (empty vessel). In this case knowledge acquisition was perceived as a mechanical process. On the other hand, the culture of assessment is in accord with the constructivist approach to education as it allows and encourages learners to create their own meaning in learning. In the assessment realm, the teachers' role is that of a mentor who provides learners with interesting and challenging opportunities and tasks, as is the case in a science centre (Dochy & McDowell, 1997: 282).

Assessment is therefore a comprehensive method of gathering valuable information or feedback of how effectively learners are proceeding in their quest to learn. This information may be used to change the direction of instruction in order to meet the learning outcomes intended. To be successful, this process of gathering information on learning has to be authentic and move away from the behavioural to the cognitive views of learning and assessment. The authenticity of the assessment process refers to the

application of learners' cognitive abilities (knowledge), physical skills (abilities) and interest (Gummer & Shepardson, 2001: 59).

The next section focuses on assessment in Physical Sciences.

### **6.3. ASSESSMENT IN SCIENCE**

From the preceding section of this chapter it becomes evident that assessment should be considered as three-fold in Physical Sciences. Assessment in science education should seek to address the three learning domains (cognitive, affective and psychomotor domains) as classified by Bloom *et al.* (1956). An achievement in this regard will go a long way towards developing learners in a holistic manner. However context in achieving outcomes plays a crucial role (Nieuwoudt, 1998: 3). It is for this reason that this study is carried out in the context of a science centre.

According to Skevington (1994: 115) a narrowly focused system of assessment in Physical Science will produce undesirable effects on learners' schooling career. To avoid such negative and lasting impact on life-long learning, Skevington (1994: 115) suggests that science teachers should focus on the learning outcomes which go beyond the boundaries of transmission of a body of facts and focus on the assessment system which seeks to develop science learners in a *holistic manner*, a system based on learning outcomes.

Assessment in Physical Sciences according to the National Curriculum Statement (DoE, 2005) should cut across the three learning outcomes. It should focus on learners' ability to use processing skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in various scientific and technological contexts. In some assessment tasks, learners should demonstrate inquiry skills that include skills like observing, data collection, comprehending and synthesizing, hypothesizing, generalizing and communicating conclusions in various contexts. The outcome envisaged by the National Curriculum Statement in assessment tasks has objectives based on Bloom's Taxonomy in

Section 4.5 of this study. These skills that are intended in the outcomes are of cognitive, affective and psychomotor nature and they range from the lowest level of knowledge acquisition to the synthesis process of applying knowledge. They address Learning Outcome 1, 2 and 3 of the Physical Sciences' curriculum.

The National Curriculum Statement of the Further Education and Training Band Physical Sciences, grades 10 – 12, emphasizes that the assessment in these grades should focus on investigating physical and chemical phenomena through scientific inquiry. In its nature Physical Science seeks to understand the world we live in and this will be achieved by the application of scientific models, theories, principles and laws (DoE, 2005).

According to the NCS (DoE, 2005) the assessment in Physical Sciences should be formative in that learners must have immediate feedback on tasks to see their strengths and weaknesses so as to help them develop effective strategies in learning tasks. This type of assessment is said to be of great assistance to teachers as it informs them of their own progress and help them to implement better learning and teaching strategies.

In the next section types of assessment are briefly discussed.

#### **6.4. TYPES OF ASSESSMENT**

The types of assessment are classified according to the role they play in education.

The outcomes in *formative assessment* are diagnostic in nature. As a result formative assessment is a type of assessment which helps teachers and learners to diagnose problem areas. When problem areas are determined, decisions will be made as to how to educationally combat the learning obstacles and which remedial action should be taken (Skevington, 1994: 116).

Formative assessment has in its nature the principle of constructivism in that it embraces learners' prior knowledge. Bloom *et al.* (1971: 12) hold that teachers should determine

what learners are bringing with them to the learning task that is relevant. The task of the teacher includes determining the problem areas in previous tasks. In doing that, teachers are able to diagnose the relevant characteristics of their learners in that they shall know whether or not their learners are *ready* and *willing* for the learning tasks. This fact is crucial because it carries two aspects that impacts on the cognitive and most importantly the affective domain of learning. If there is willingness to learn, learners will pay attention and the cognitive as well as the psychomotoric skills will be active and in the receptive mode (Toh, 1991: 90, Koballa *et al.*, 1990: 370).

Therefore the purpose of formative assessment is to determine the degree of mastery/achievement of given learning tasks and to reveal the part(s) of the tasks not mastered/achieved (Bloom *et al.*, 1971: 72).

The type of assessment which is used to inform other stakeholders about the progress in learning is referred to as *summative assessment*. It is usually made at the end of the learning course. It focuses on the level of achievement obtained by individual learners. The academic results of the summative assessment are used to assist in making choices of an envisaged study field (Bloom *et al.*, 1971: 72).

Because summative assessment is directed toward a much more general assessment of the degree to which the larger outcomes have been attained over a grade or phase, the results of this assessment must be valid and reliable, hence graded (Bloom *et al.*, 1971: 72).

## **6.5. GRADING OF ASSESSMENT**

The grading of an assessment in Physical Sciences should be done *holistically* in terms of the three learning domains, that is the cognitively, affectively and in terms of the psychomotoric skills (Shephardson & Britsch, 2001: 120). If done appropriately, this grading will take into account the three Physical Sciences learning outcomes as stipulated by the National Curriculum Statement (DoE, 2005).

Shephardson and Britsch (2001: 120) assert that carefully graded assessment has a number of benefits for learners. It fosters conceptual understanding, which is a network of knowledge linking relationships between concepts and enhances understanding. Shaw and Wilson (1976: 198) contend that a basic characteristic of human intelligence is the ability to formulate conceptual knowledge about objects (apparatus) and events (procedure). Conceptual knowledge is therefore exemplified when learners can deal appropriately with novel instances of a concept, that is, when learners' knowledge goes beyond just the instances experienced. Conceptual knowledge is at the highest order of the cognitive domain.

By means of graded assessment learners also are ensured of gaining factual knowledge, knowledge of terminology and specific details (Sherphard & Britsch, 2001: 120, Anderson *et al.*, 2001: 45). Even though this knowledge appears on the lowest level of the cognitive domain (Krathwohl *et al.*, 1964: 24), it involves a large body of scientific information and facts that scientists use in their various disciplines (Anderson *et al.*, 2001: 45).

The National Curriculum Statement (DoE, 2005) states that learners' tasks should focus on ability to use scientific processes and inquiry skills to solve problems in a variety of scientific and technological contexts – Learning Outcome 1. In this graded assessment learners sharpen their motor skills whilst they also gain cognitively (Sherphard & Britsch, 2001: 120).

Like Krathwohl *et al.*, (1964: 24), Sherphard and Britsch (2001: 121) consider the affective domain of Bloom's Taxonomy to be crucial in learning. They assert that in Physical Sciences learners should be assessed on their attitude towards science as factors of affective nature impacts on learners' progress. These factors are vital to learning as they affect learners' interest, motivation and the will to participate in learning (Hamilton & Ghatala, 1994: 85).

Sherphard and Britsch (2001: 121) contend that affective factors also impede on the cooperative learning in that learners who are not motivated generally do not participate in group discussions and become passive. Gunter *et al.*, (1995: 222) argue that the power of cooperative learning should not be undermined. Cooperative learning has other benefits that include listening skills, personal skills and skills of argument, of sharing ideas and of learning to work in a group.

It is important to note that the grading of assessment is essential as it guides both teachers and learners to cover all aspects of the learning outcomes. Most importantly, the assessment if graded, will satisfy the requirements of the tested Taxonomy like Bloom's Taxonomy of learning objective, which cuts across the three levels of learning regarded as important in science.

In the next section the methods of assessment will be discussed.

## **6.6. METHODS OF ASSESSMENTS IN SCIENCE**

The basis of the method of assessment in Physical Sciences is the principle of constructivism (DoE, 2005). The theory of constructivism places learners on the centre stage of their own learning. In this view the assessment methods in Physical Sciences are embedded on this principle because they are based on the following:

### **6.6.1. Self-assessment**

Self-assessment provides the fundamental link with learning. It is concerned with learners valuing their own learning and achievements. It is designed to engage learners in reflecting upon their own performance and understanding, in order to promote responsibility for learning and to build learners' confidence. Self assessment promotes learners' sense of ownership and as a result it contributes to authentic, learner-centred assessment practices that in turn promote learning (Van der Horst & McDonald, 1997: 202).

### **6.6.2. Peer-assessment**

Like in group assessment, peer assessment may be used to provide feedback about group work and the quality of the content knowledge. It also develops the level of individual accountability. In peer assessment learners express themselves freely and therefore this will lead to discussions where one learner defends his/her own thoughts. This is important because possible alternative conceptions will emerge and be dealt with swiftly (Driver, 1983: 6). When properly handled, peer assessment is an excellent learning experience and it is effective in developing learners' critical thinking, an outcome envisaged by the National Curriculum Statement (DoE, 2005).

### **6.6.3. Group assessment**

Group assessment is another example of a class of assessment under cooperative learning. Group assessment forms the basis of the assessment of critical outcomes, as it requires learners to work effectively with other members of the assigned group, on a task. It has all the advantages of peer assessment; but it engages more learners in a group, where different learners can assume different roles in discussions. In small groups, one can assume a role of a leader and the other one a scribe whilst one can be a reporter for the group. These roles may also be different. One of the advantages of the group assessment is that learners assume leadership roles and learn to work together. This is one of the important principles entrenched in the National Curriculum Statement, as a critical outcome (DoE, 2003: 2).

## **Conclusion**

Science centres as agents of life-long learning have proved to support formal education in helping learners to achieve cognitive, affective as well as psychomotoric outcomes. Bencze and Lemelin (2001: 141) contend that displays/experiments in the science centres could engage learners in activities which enable them to conduct scientific inquiries and technological design projects individually, or with the help of a friend (self-assessment

and peer assessment), or even in small groups (group assessment). The outcomes of the activities as measured by various assessment methods are evident when learners perform a range of skills that include classifying; hypothesizing; showing interest; keeping motivated to do hands on and minds on experiments, or observing with keen interest.

In the next section the levels of assessment are discussed.

## **6.7. LEVELS OF ASSESSMENT**

The National Curriculum Statement (2005: 7) explicitly define the purpose of Physical Sciences as a subject with the purpose to equip learners with investigating skills, relating to physical and chemical phenomena. Examples of skills envisaged by the NCS in the learning of Physical Sciences are classifying, communicating, measuring, designing, evaluating concluding, formulating models, hypothesizing, predicting, observing and comparing, interpreting and problem solving.

The skills mentioned above are also entrenched in the three learning outcomes for Physical Sciences. It is important to note that these skills are occurring throughout the three levels of Bloom's learning domain (Bloom's Taxonomy). The NCS (DoE, 2005) emphasizes the fact that Physical Sciences promote or should promote in learners, knowledge and skills in scientific inquiry and problem solving (*cognitive and psychomotoric nature*) and an understanding of the nature of science and its relationship to technology, society and the environment (*affective nature*).

From the above it is clear that the NCS aims at developing Physical Science learners in a *holistic manner*, that is, cognitively, affectively and at improving their psychomotoric skills. Therefore the assessment within Physical Sciences and the context thereof should be in line with the National Curriculum Statement to ensure that the aims are attained (NCS, 2005: 7).

In the next subsections the *holistic manner* of assessment on different levels for Physical Sciences is discussed.

### **6.7.1. Cognitive skills**

Dochy and McDowell (1997: 280) assert that the successful functioning of an assessment tool should seek to find specific skills in learners. These skills include the cognitive competencies such as problem solving, critical thinking, conducting observations, data analysis, assessing, generating ideas, evaluating and creating new things. Careful consideration of the skills mentioned reveals that the skills cover the various levels of the cognitive domain as set out by Bloom and his collaborators. It is important that the listed skills are developed in the teaching and learning of Physical Sciences because without demonstrating evidence of being competent in these skills, it is argued that learners cannot claim to understand the related concepts. Sadly, without understanding of the related science concepts, there is no meaningful learning (Ausubel *et al.*, 1968: 288, Hudson, 1994: 97).

The acquisition of the cognitive skills are enhanced effectively when the teaching and learning strategies employed in Physical Sciences are learner centred rather than the teacher centred traditional methods. As discussed in Chapter 4 of this study, the cognitive learning theory advocates that the learner should assume the centre role in his/her studies as he is given the opportunity to make his own discoveries in the process of learning (Schunk, 2000: 171).

Cognitive skills require the manipulation and control of other memory elements that include, memory of episodes; images of the iconic memory and different levels of knowledge (see Section 2.6 of this study). It is therefore crucial to consider learners' prior knowledge as it impacts on the learning of *new* material (Roschelle, 1997: 1). Thompson and Zamboanga (2003: 96) argue that learning proceeds primarily from prior knowledge and that presented materials play only a secondary role. Therefore it is important to note that prior knowledge does not only influence learning, but it forces a

theory of learning to view learning as a conceptual and knowledge change (Chinn & Brewer, 1998: 104; Thompson & Zamboanga, 2003: 96; Roschelle, 1997: 2).

Strategies for developing the cognitive skills will be discussed in subsequent sections.

### **6.7.2. Affective skills**

The other equally important competencies which according to Dochy and McDowell (1997: 280), should be addressed by the assessing process include the dispositions such as perseverance, internal motivation, self-efficacy, independence, self-esteem, emotional development, interests, preferences, self-concepts and flexibility. These competencies form the basis of the affective domain of Bloom Taxonomy of learning (Krathwohl et al., 1964: 24).

Education, specifically in Physical Sciences, should be guided by the view that there is intrinsic merit and pleasure in learning the subject. The learning thereof has a value beyond the solely utilitarian and usefulness and enjoyment should be derived from the subject, which will again enhance understanding. It is argued that if there is little or no immediate gain or interest in the learning of Physical Sciences, learners lose focus and lose their interest in the subject. This loss of interest in learners impacts on the encoding process of the acquisition of scientific knowledge (Bjorklund, 2005: 121, Spear, 1978: 2).

Klopfer (1971) holds that learners are more proficient in cognitive operations like problem solving when they enjoy what they are doing. Affective traits, as they are called, are internal states that have a bearing on what learners are likely to pay attention to. These traits are considered as positive/negative or favourable/unfavourable from the learner's point of view towards a learning situation or context of learning. Klopfer (1971) classifies the affective domains into six categories which are related to learners': (1) *attitude towards the subject matter*, (2) *attitude towards inquiry*, (3) *adoption of attitudes similar to the subject matter at hand*, (4) *enjoyment of the learning experience*,

(5) *interest in the subject matter at hand*, and (6) *interest in the subject of study as a career*.

According to Klopfer (1971: 577) a learner who displays acceptance to the process of *scientific inquiry* has a particular way of thinking and of being consistent with the method of scientific process like scientists. Learners who show this kind of attitude towards scientific inquiry commit themselves to the subject.

Learners who show *enjoyment of the learning experience* learn better, learn more and remember longer because they find pleasure in the learning experience. Klopfer (1971: 578) assert that Physical Sciences provide learners with opportunities to find pleasure in learning that include discovering new relationships, explanations, generalizations and discussions. This aspect is helpful to teachers, peers, parents and other stakeholders in the education of a learner because learners who enjoy their learning experience in science will express their feeling either in words or in actions.

A general criterion for *learners' interest in science* is that they do related activities voluntarily and without regard to the requirements of a specific science level. This kind of interest goes beyond the walls of the classroom and extends to a way of life when learners subscribe to science magazines, collect science related items for discoveries and further investigations, watch television programs on science related discoveries and read extensively on science research and on vocational guidance about science for careers (Klopfer, 1971: 578).

### **6.7.3. Psychomotoric skills**

The seven steps of memory elements outlined by White (1988: 32) addresses, at a higher level of the ladder, the three skills referred to in this study as the holistic development. Hudson (1994: 94) interprets the development of these skills as a progression of depth of learning from simple recall to complex reasoning skills. Images and episodes as discussed in Section 3.3.1.1 of this study are important elements in many Physical

Sciences lessons. Lecture demonstrations and other forms of practical work are common teaching and learning strategies of enhancing these elements in the iconic memory of learners.

Hudson (1994: 95) argues that recalling knowledge stored in the iconic memory, as with strings and propositions, does not involve understanding. The common teaching and learning strategies in science make use of the elements of image, episodes and motor skills. However activities are very often passive and this result in a sit and watch demonstration or a recipe experiment. In this scenario little or no intellectual, cognitive and psychomotoric skills are developed. To develop the psychomotoric skills learners must be engaged in active learning. Learning should become a personal change, rather than a task of just recalling isolated pieces of information.

The psychomotoric skills involve the ability to carry out and coordinate a wide range of physical tasks. The psychomotoric skills involve the haptic memory, that is, the ability to hold knowledge from the physical world, gained through hands-on interaction with material/apparatus, in the short term memory (Adams, 1976: 256). In the process the muscles are coordinated to perform various tasks. Hudson (1994: 103) asserts that motor skills, just like cognitive skills, are transferable in that a learner who is skillful in drawing will transfer that skill in graphing.

Once mastered, psychomotoric skills will be permanently retained in the long term memory and become automatic. However they need to be practiced to maintain good performance. Knapp (1963) quoted by Hudson (1994: 103) maintain that psychomotoric skills should not be separated from cognitive skills as they compliment each other. These skills are used widely in the teaching and learning of Physical Sciences.

The reason why psychomotoric skills remain permanent in memory is that they are learnt by *doing*. This fact is compounded by the repetitive nature of the skill. Mastery of the manipulative skills may lead to boredom. Therefore it is crucial that learners are exposed

to an environment where they are continuously stimulated, like that of a *science centre* (Hudson, 1994: 104).

In the following section the three skills discussed above will be assessed in the context of a science centre. This is done with the aid of literature relative to objectives (a) and (c) of this study.

## **6.8. ASSESSING THE SCIENCE CENTRE In Terms Of BLOOM'S TAXONOMY**

The recent emphasis on hands-on science learning has placed the theory of constructivism on the centre stage of science education. As illustrated in Section 4.5 of this study, the theory of constructivism is based on the premise that learners receive sensory input, compare it to the existing knowledge then modify the input. Then learners construct their own meaning that fits the explanation to the phenomenon (Russell, 1990:258).

According to Trowbridge *et al.* (2004: 89) the construction of knowledge by learners from a learning situation is unique to each individual. The outcome intended by the teacher may even not be achieved because of the learners' knowledge base (see Rapule, 2005). The science centre presents learners with the opportunity to interact with phenomena, find out how they operate and possibly attach a meaning and draw a conclusion from the encounter (Russell, 1990:258).

The Potchefstroom Science Centre has adopted a strategy of providing learners the opportunity to benefit *holistically* from visits to the Centre.

### **6.8.1. Strategies for cognitive development**

In the learning context learners should be encouraged to take a leading role in the process of knowledge acquisition, attach their own meaning to the learning tasks and ultimately

come to their own conclusion about phenomena. This gives learners the opportunity for learning through discovery and inquiry (Piaget, 1971, 1977).

In the science centre learners are presented with the opportunity to interact with displays and “interrogate” them. For the cognitive development learners must not be passive in a learning environment (Piaget, 1971, 1977). The acquisition of scientific knowledge, as envisaged by the NCS (DoE, 2005), does not arise from the object (displays), or the subject (learner), but from the interaction (White, 1988: 121). The implication is that learning and knowledge acquisition involves the cognitive characteristics of the learner as he has to think, hypothesize, decide and analyze in the process of problem solving. Problem solving is regarded as an overarching, composite skill that draws heavily on many intellectual and cognitive skills and it is therefore an immensely important strategy in cognitive development.

In enhancing cognitive development in science learners, Hudson (1994: 99) contend that questions that require simple recall or repetition of a statement should be avoided. Therefore the style and level of questioning in the science centre should be such that it demands from learners a variety of cognitive skills of higher order, such as required for a critical analysis in solving problems. It is crucial that the development of cognitive skills is enhanced so as to understand underlying physics concepts. Hudson (1994: 99) argues that understanding is enhanced by engaging cognitive skills.

In order to enhance cognitive skills optimally, learners should be encouraged to design their own investigations. This strategy is in line with the principle of constructivism as it advocates for learners to be placed on the centre stage of their own learning. In the learning process learners will be given freedom of interpretation. To start a learning task in a learning context, such as a science centre for example, there must be a question or questions that stimulate their thought process so as to set their mind in a curious state. Learners will then engage in cooperative learning and will start to reason and debate issues (Hudson, 1994: 71).

The other strategy that can be employed in cognitive development of skills is discovery learning. In this strategy learners are given a lot of responsibility for discovering knowledge that requires a great deal of processing and analysis. This calls for the highest order of thinking (Krathwohl *et al.*, 1964: 24). In discovery learning, learners are not presented with the content of the knowledge in its final form, but they are required to design and organize it themselves. They should discover how ideas relate to each other and to their existing (prior) knowledge. In the process learners integrate and incorporate new information with existing knowledge in order to discover new connections. Learners, in applying discovery learning, may even draw concept maps of related scientific concepts (Hudson, 1994: 100). This strategy can ideally be pursued in the science centre, because for discovery learning, learners must be supplied with teaching/learning resources.

### **6.8.2. Strategies for developing affective skills**

Affective skills are not easy to measure. However cognitive and psychomotoric skills are not developed independently. The two domains have the affective components embedded in them. For instance, learning will not proceed if the individual is not motivated to learn. Components such as willingness, interest and attitude play a critical role in achieving and gaining cognitive and psychomotoric skills (Simpson *et al.*, 1994).

Therefore the strategies that should be employed in achieving the affective skills are inherent in the visitor to the science centre. However the environment should be such that it is appealing to the visitor. The atmosphere should not be intimidating. The benefits and affective components that are encouraged in the science centre are discussed in chapter 5 of this study.

### **6.8.3. Strategies for developing psychomotoric skills**

Psychomotoric skills are not independent from cognitive and intellectual (mental) skills; but they involve the haptic memory. Haptic memory refers to the ability to hold

information from the physical world through hands-on interaction with the material in the short term memory. The encoding of this memory is also momentarily but has a relatively lasting impression on the memory compared to the iconic and the echoic memory (see Chapter 3 of this study) (Adams, 1976: 256).

The reason why psychomotoric skills have lasting impressions is that they are learnt by an interactive physical learning process (doing). Depending on the level of complexity of the experiment, psychomotoric skills are perfected by repetition so that the muscle movements can be remembered. Once they are perfected psychomotoric skills are transferable in other situations. Hudson (1994: 104) suggests that to enhance psychomotoric skills one should ensure that complex operations in instructions to perform an experiment should be broken down into smaller elements. This principle is referred to as chunking. Chunking refers to breaking large units of information into smaller, meaningful and manageable pieces (White, 1988: 129).

## **6.9. CONCLUSION**

The context through which Physical Sciences is taught needs to be assessed in an ongoing process. This is aimed at providing responses to both learners and teachers for corrective measures. It has to be kept in mind that the fundamental purpose of assessment is to provide information to be used for planning and for sustainable development. Sustainable development will ensure that science centres continue to develop learners in a holistic manner.

In the next chapter the research methodology employed in this study will be outlined. The chapter focuses on the use of questionnaires as one of the measuring means of research instruments. The chapter further details aspects of data collection, data analysis, the population under survey and finally, the processing of the data. This is done in accordance with objectives (a), (b) and (c) of this study.

## CHAPTER 7

### RESEARCH METHODOLOGY

*The most exciting phrase to hear in science is not Eureka! (I found it), but rather “Hmm ... that’s funny! (Isaac Asimov)*

#### 7.1. INTRODUCTION

As discussed in Chapter 2 of this study, scientists use systematic thinking in acquiring and gaining knowledge about nature. In so doing, a scientist places much value on the adequacy of the information and on the way the information is processed. Although there are various methods of gathering information, science includes rationalism (a method of developing valid ideas using existing ideas and principles of logic) and *empiricism* (a method of gaining knowledge through observation) as systematic methods of information gathering (Graziano & Raulin, 2004: 8).

This chapter illustrates how the process of acquiring data for this study unfolded. This is done by dissecting the layout of the chapter as indicated hereunder.

#### 7.2. RESEARCH LAY-OUT

The study is structured such that it comprises of the conceptual framework which stems from the literature. The conceptual framework, based on the literature, forms the basis of this study as it consists of the theories that the research study is embedded in. The conceptual framework also encompasses the research problem: *determining the impact science centres have on the holistic developments in science learners.*

The second part of the study deals with the method of acquiring data and the statistical processing thereof. This will be illustrated in the following subsection.

### 7.3. LITERATURE STUDY

The literature study was done for two main reasons. Firstly the literature was reviewed to provide a theoretical background to the study and secondly to enable the researcher to contextualize the findings in relation to the existing body of knowledge. In fulfilling the first function, the researcher started by identifying the structure of scientific knowledge. The process of knowledge acquisition and the form of the knowledge required were identified (Refer to Chapter 2 of this study). The aim of this chapter is to identify the types of knowledge that learners can acquire in their learning, more specifically in the Potchefstroom Science Centre as a context of learning.

The researcher continued to expand the theoretical background on the functioning of memory. This section deals with how to improve memory elements as learners acquire scientific knowledge. Chapter 3 serves to formulate strategies effectively retaining the acquired knowledge. In the last section (Chapter 4) of the theoretical framework the researcher focused on learning as a means of knowledge construction. This section identifies and describes various learning theories relevant to the Physical Sciences and specifies limitations in the theories. It is through an extensive literature review that the researcher extracted the most appropriate learning theory for science, relevant to the purpose of this study.

The last two sections (Chapters 5 & 6) of the theoretical framework of the study play a critical role as they position the study itself in a particular context, that of the science centre. This forms a transition from the theoretical framework to the empirical study. Therefore the two sections (Chapters 5 & 6) form the basis of the second function of the literature study. They begin to position the research by defining the concept of a science centre and its envisaged objectives as related to the *holistic* development of science learners. The literature concerning the chapter further illustrates how learners may benefit from their visits to science centres in a *holistic* manner. In Chapter 6 the assessment of a science centre in terms of Blooms' Taxonomy is discussed (Klopfer, 1971: 578; Krathwohl *et al.*, 1964: 165). Emphasis is put on the levels of assessment that

learners are, or should be, exposed to in the science centre, which are the cognitive, affective and the psychomotoric skills. This section consolidates the theoretical framework (derived from the literature) by showing the connection between various learning theories (Chapter 4) to acquire knowledge (Chapter 2). How to retain the acquired knowledge in memory (Chapter 3) and how to optimally benefit from a visit to an assessed science centre (Chapters 5 & 6) are then analysed.

## **7.4. EMPIRICAL STUDY**

The second function of the literature survey is to contextualize the findings of the study. This is done in a systematic manner and requires several aspects for it to be a meaningful whole. In the next subsection the aspects of this study are outlined.

## **7.5. ASPECTS OF THE EMPIRICAL STUDY**

### **7.5.1. Population**

The population targeted for this study comprised of learners who were at the time of the study (2007) in Grades 10 – 12 and enrolled for Physical Sciences. The study focused on the five secondary schools in Ikageng (a suburb of Potchefstroom, SA) as the experimental group and five other secondary schools outside the perimeters of Ikageng which are considered as the control group. The schools outside the boundaries of Potchefstroom were chosen randomly. The control group was preferred to be outside the boundaries of Potchefstroom to avoid “spillage” and for the reason that there are no science centres in the specified areas of the control group. Spillage refers to the occurrence where the subjects of the experimental group share information of the intervention with the subjects of the control group. The smallest radial distance between the Potchefstroom Science Centre and the areas where the control groups were situated is 50 km. Therefore the chances of the control group visiting the Potchefstroom Science Centre were minimal.

The 25 learners per grade per school were selected randomly from their class lists. Therefore the population for this study was  $N = 750$ .

The current teacher to learner ratio as recommended by the education department is 1: 35 in secondary schools (DoE, 2003). It was decided that the experimental group would be visiting the science centre in groups of 75 each. The researcher together with the assistance of the promoter would receive the groups. Therefore the ratio between facilitator and learners would be 1: 37,5; a ratio close enough to the proposed one. Kumar (2005: 166) warns that in order for the statistical results of research to be generalizable, the researcher must ensure that the sampling unit is large enough to have a statistical influence on the results. That means the sample chosen must be reflective of the actual number of the population such that the difference between the sample average and the population average must be minimal.

Teachers whose learners' were subjects of this study were also considered and played an important role in that they provided adequate information on not only their learners' academic performance, but also on aspects concerning learners' attitudes and other factors related to the affective domain of Bloom's Taxonomy. The information reflected on the states learners in the experimental group were in before and after the visit to the Potchefstroom Science Centre.

### **7.5.2. Nature of research**

To pursue the objectives of this study a quantitative approach was decided on. The particular experimental design used in this study was selected because according to Graziano and Raulin (2004: 210) it has two benefits. Firstly the experimental design tests the effects/*impact* of the independent variable on the dependent variable. In the case of this study the quantitative experimental design was used to test the *impact science centres* (independent variable) *have on the three domains of learning* classified as Bloom's Taxonomy of learning (dependent variable).

The second advantage of the use of the experimental design is that it ensured the internal validity. This means that the experimental design ensured that the independent variable (science centre) was responsible for the observed statistical change in the dependent variable (*holistic development in learners*) (Graziano & Raulin, 2004: 210).

The experimental design chosen as a method of research was such that it would be performed on the experimental group (N = 375) and the control group (N = 375). The experimental group comprised of the sample taken from the five secondary schools in Potchefstroom district in Ikageng. The control group was constituted by the secondary schools in Fochville; Klerksdorp; Viljoenskroon; Mafikeng and Rustenburg, and was chosen randomly.

A pre-test was administered to the two groups at their respective schools. The curriculum of Physical Sciences on the Further Education and Training Band (FET-Band) at secondary schools comprised of the Physics and Chemistry sections. Three knowledge areas were selected from each of Physics and Chemistry. The three knowledge areas in the Physics section covered mechanics, optics and electricity and magnetism. Therefore, the pre- and the post tests were structured such that the questions asked covered these Physics sections (Appendix 1).

Thereafter the experimental group was exposed to the Potchefstroom Science Centre. The subjects of the experimental group were selected randomly from their class-lists as described in Section 7.5.2. In random sampling there is equal possibility for every subject of the population to be selected as the process advocates for the avoidances of bias (Kumar, 2005: 23; Stoker, 1989: 104).

The experimental group was divided into five groups of 75 each. A group of 75 learners is regarded as manageable in the Potchefstroom Science Centre. Each group consisted of learners from grades 10, 11 and 12 (refer to Table 7.1). Groups were allocated specific days to be transported to the Science Centre. This was carried out after the normal school hours. The groups were exposed to the exhibits and other demonstrations in the

Potchefstroom Science Centre for up to three hours per visit. Each group of 75 visited the Science Centre on three occasions, at a frequency of once a month.

The following table indicates the Science Centre visits of the groups during a particular day (January – September 2007).

<b>No OF DAY</b>	<b>GRADES</b>	<b>SCHOOL</b>
DAY 1	10	SCHOOL A
GROUP 1	11	SCHOOL B
	12	SCHOOL C
DAY 2	10	SCHOOL D
GROUP 2	11	SCHOOL E
	12	SCHOOL A
DAY 3	10	SCHOOL B
GROUP 3	11	SCHOOL C
	12	SCHOOL D
DAY 4	10	SCHOOL E
GROUP 4	11	SCHOOL A
	12	SCHOOL B
DAY 5	10	SCHOOL C
GROUP 5	11	SCHOOL D
	12	SCHOOL E

**TABLE 7.1. Timetable for the Science Centre visits**

The Potchefstroom Science Centre daily attendance register was used to control the participation of the learners per school. Absentiism during the intervention phase was minimal, such that the average of absentees for the intervention phase was two. This number is not significant as it is discussed in Chapter 8.

Observations were made and recorded while the group interacted with the exhibits in the Science Centre. Data was collected in writing and some were captured on video. Interviews were conducted with learners about aspects of the research. The matters discussed with the learners were their responses to questionnaires and their academic gain tests.

During the periods of exposure to the exhibits, the experimental group was brought to the Potchefstroom Science Centre in groups of 75 for observation purposes. After the treatment of the experimental group, the two groups were subjected to the post-test at their respective schools to observe if there was any statistically meaningful change in academic performance because of the effect the science centre had on them. Interviews were again conducted with the teachers whose learners participated in the experimental group, to discuss changes they may have observed. The interviews were recorded (refer to Sections 7.5.3 and 8.8 of this study).

### **7.5.3. Data collection**

Data in this study were firstly collected in the form of questionnaires and interviews which sought to probe the situation at respective schools concerning learning. The questionnaires as discussed in Section 7.5.6 below sought to probe three different areas according to the objectives of the study. The first part of the questionnaire dealt with the biographical information of respondents and was administered by the researcher with the assistance of the teachers. This part of the questionnaire was administered two weeks before the two groups (experimental and control) were exposed to the pre-test. This part was kept confidential.

For completing the questionnaires, a 5 point Likert-scale was used. The 5 point Likert type scale was chosen because it offers a wide range of constructs on measurement. It is also flexible in terms of construction and administration (Schnetler, 1989: 70).

The pre- and post tests formed the second type of data collected in this study. This was done so as to measure the learning gain if any, or change in academic achievement brought about by the visit and interaction of learners with exhibits in the Science Centre. Achievement marks of both the experimental and control groups were recorded and processed statistically.

The pre-test for the two groups was administered by the teachers at their respective schools. The two groups were exposed to the pre-test a month before the experimental group was brought to the Science Centre for intervention. Teachers were encouraged to administer the test within two weeks of the specified time so that none of the schools will have an unfair advantage over the other.

The experimental group was exposed to the Potchefstroom Science Centre in small groups of 75 (from 5 identified schools) for intervention. The intervention phase lasted up until the month of August. A month later the experimental as well as the control group were exposed to the post test which was administered at various schools by the teachers. This was also controlled around the same period of time.

A week later the experimental group completed the questionnaire concerning their experiences and reflection about the Science Centre. This part of the data collection was administered by the researcher and teachers at respective schools.

Interviews were conducted and the process was video recorded during and after the intervention phase with learners and teachers. Videos were taken randomly for about 25 minutes of groups at a visit. At the end, a video recording (of five groups: see Table 7.1) that runs for 98 minutes was compiled. Aspects of the two domains of learning, the psychomotoric and the affective domains, were recorded on video. These aspects included the handling skills (psychomotoric domain) and the emotions and interestes (affective domain) shown by learners.

A summary of how the empirical survey was conducted is given in the table hereafter:

Group	Learners' Biographic Information & Information on learning	Pre-test	Science centre visit & interviews	Science Centre questionnaire	Post test	Teachers biographic information	Teachers' feedback on learners & interviews
Experimental	Jan – Feb 2007	Mar 2007	Mar – Aug 2007	Sep 2007	Sep 2007	Sep 2007	Sep 2007
Control	Jan – Feb 2007	Mar 2007			Sep 2007		

**Table 7.2. Summary of empirical survey**

#### **7.5.4. Data analysis**

The Statistical Services of the North-West University Potchefstroom campus were consulted to assist with the analysis of the results of the empirical study. The software employed for the statistical analysis of the results was supplied by Statistical Services (Ellis & Steyn, 1999).

#### **7.5.5. Research instruments**

Central to any inquiry or information seeking process is measurement (Schnetler, 1989: 44; Kumar, 2005:66). Questionnaires, pre- and post tests as well as personal interviews were used as instruments for data gathering. The aim of this study was to investigate the impact that science centres have on the *holistic* development of Physical Sciences learners. The *holistic* development cuts across the cognitive, affective and the psychomotoric skills that learners should acquire through their interaction in the learning (*developmental*) process. It is illustrated in Chapters 4 and 5 of this study that the affective aspects of the Bloom's Taxonomy (Krathwohl *et al.*, 1964), like emotions,

cannot be easily translated into words; therefore it was the intention of the researcher to capture those aspects on video.

Since the research instruments formed the bedrock on which the research rests, it was critical that the instruments should comply with certain criteria.

In the next two subsections the relevant characteristics of the research instruments are outlined.

#### **7.5.5.1. Validity of research instruments**

The validity of a measurement instrument refers to the extent to which the instrument measures what is supposed to be measured (Leedy & Ormrod, 2001: 98; Kumar, 2004: 154, Graziano & Raulin, 2004: 90). To establish whether or not the instrument is valid a researcher has to constantly ask himself/herself the question: am I measuring what I should be measuring? To ensure the extent to which the empirical measure adequately reflects the real meaning of the impact science centres have on the holistic development of learners, the researcher considered and structured the instrument according to the objectives and hence the aim of the study. The instruments used encompass the following: the situation analysis and probing of the respondents' convictions in their emotions and feeling about the science centre environment. The instrument also sought to gather information on the learning gain or academic achievement.

#### **7.5.5.2. Reliability of research instrument**

For the research instrument to be considered reliable in any study, the design thereof must be such that they consistently yield the same results when characteristics being measured have not changed (Kumar, 2005: 90; Leedy & Ormrod, 2001: 98). It is for this reason that the instruments used in this study were carefully chosen and designed to measure exactly what they were intended to measure (refer to Section 8.4).

The next subsection explains how the questionnaire was constructed. It was also mentioned in Section 7.5.3 of this study that the other form of data used was that of interviews. All this was done in accordance with the objectives and aim of the study.

#### **7.5.6. Questionnaires**

The work on the previous two subsections indicates that a well designed questionnaire consolidates the reliability and validity of the data to acceptable tolerances (Schnetler, 1989: 44). The content of the questionnaire (Appendix 4) included the three types of questions. It included the factual questions which entails socio-demographic and personal information from the respondents (learners and teachers). The questionnaire also had items that seek opinion and attitude of the respondents. These types of questions probed respondents' feelings and convictions related to the science centre. The third type of items of the questionnaire sought information so as to discover what respondents knew about their learning and about the Science Centre.

As pointed out the items of the questionnaire probed the three learning domains (*holistic development*) that learners are likely to gain by visiting a science centre. The total number of items on the questionnaire for learners was 35. Therefore the proportion of representation per domain was as follows: 48,57 % of the items probed the cognitive development of learners through their interaction with exhibits in the Science Centre. Of the items 40 % were about learners' convictions towards their personal emotions, feelings and attitudes about science centres as places of learning Physical Sciences. The items about the psychomotoric domain constituted 20 % of the questionnaire.

It should be noted that the psychomotoric skills are not independent of cognitive and intellectual skills (Adams, 1976: 256). Therefore some of the items in the questionnaire will probe more than one domain of learning. See for instance item 17 (which probed both the cognitive and the affective learning domain) (Appendix 4). Item 26 sought to probe into the cognitive and the psychomotoric learning domain, whilst item 31 cut across the three learning domains.

The questionnaire was constructed in close cooperation with an expert on assessment with reputable experience as a national moderator for Physical Sciences.

The three different types of items of the questionnaire in this study were constructed such that they should elicit the objectives of the study stated in Section 1.2 , and thereby achieve the aim of the study, to determine *the impact science centres have on the holistic development of learners*.

## **7.6. CONCLUSION**

The focus of this chapter was to illustrate how the empirical procedure unfolded according to the researcher. The chapter revealed the method of research followed in this study and the method of data collection. The chapter also outlined the importance of the validity and reliability of the research questionnaires.

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

## CHAPTER 8

### DISCUSSION OF EMPIRICAL SURVEY AND ANALYSIS OF RESULTS

*The important thing is not to stop questioning. Curiosity has its own reason for existing.*  
(Albert Einstein)

#### 8.1. INTRODUCTION

This chapter seeks to present the statistical processing and analysis of the empirical results obtained by means of questionnaires and learning gain tests. The questionnaires were administered to the two groups, the control and experimental groups. The two groups completed the biographical questionnaires (Section 8.2) and the first part of learners' questionnaires relating to general information on learning (Section 8.3) (see Table 7.2 for procedure of empirical survey).

After the intervention, the experimental group completed the questionnaire based on their experiences in the Science Centre. The results thereof are tabulated and discussed in Section 8.4 of this chapter. That section sought to address objective (a) of the study and hence the aim of the study: *assessing the impact science centres have on the holistic development of science learners.*

This chapter also presents the learning gain scores obtained by means of pre- and post-tests administered to the control and experimental groups at their respective schools. This was done before and after the intervention or treatment phase to the experimental group. The results and discussion thereof are presented in Section 8.5.

The intentions of this chapter are such that they address objectives (a), (b) and (c) of this study. The chapter mainly intends to reveal the extent to which science centres

contribute to the holistic development of science learners as outlined in the literature, by making use of the empirical survey.

The subsequent sections tabulate and discuss the empirical results. The results are tabulated and discussed in terms of statistical parameters, the meaning thereof is summarised on the table hereunder:

<b>Rho (<math>\rho</math>)</b>	<b>d-value</b>	<b>Phi-coefficient</b>	<b>Spearman Correlation Coefficient</b>	<b>p-value</b>	<b>Cronbach's Alpha</b>
0,1 – small	0,2 - small	0,1 – small	0,1 – small	0,1 – small	0,1 – small
0,3 – medium (visible effect)	0,5 – medium (visible effect)	0,3 – medium (visible effect)	0,3 – medium (visible effect)	0,3 – medium (visible effect)	0,3 – medium (visible effect)
0,5 – large (statistically significant and practical)	0,8 – large (statistically significant and practical)	0,5 – large (statistically significant and practical)	0,5 – large (statistically significant and practical)	0,5 – large (statistically significant and practical)	0,5 – large (statistically significant and practical)

**Table 8.1. Summary of Statistical Parameters**

## **8.2. ANALYSIS OF LEARNERS' BIOGRAPHICAL INFORMATION (Section 8.2.)**

As discussed in Sections 7.5.1 and 7.5.2 of this study the population comprised of a sample of learners (N=750) on the FET-Band from ten different schools selected randomly around the Potchefstroom area. From each school a sample of 75 learners (25 per grade) was selected from the class list (randomly). This section (Section 8.2) reflects the number of learners per school.

### 8.2.1. Name of your school (*Item 1*)

The statistical analysis confirm that the sample taken from each of the participating ten schools was N=75. Therefore the percentage representation per school was then 20,0 % of the control and experimental groups.

Table of Groep by v1

Groep	v1	1'	2'	3'	4'	5'	Total
C	Frequency'						
	Percent						
	Row Pct						
	Col Pct						
		75	75	75	75	75	375
		10.03	10.03	10.03	10.03	10.03	50.00
		20.00	20.00	20.00	20.00	20.00	
		50.00	50.00	50.68	50.34	49.67	
E	Frequency'						
	Percent						
	Row Pct						
	Col Pct						
		75	75	73	74	76	373
		10.03	10.03	10.03	10.03	10.03	50.00
		20.00	20.00	20.00	20.00	20.00	
		50.00	50.00	50.00	50.00	50.00	
Total		150	150	148	149	151	748
		20.05	20.05	19.79	19.92	20.19	100.00

Frequency Missing = 2

Statistics for Table of Groep by v1

Statistic	DF	Value	Prob
Chi-Square	4	0.0350	0.9998
Likelihood Ratio Chi-Square	4	0.0350	0.9998
Mantel-Haenszel Chi-Square	1	0.0007	0.9794
Phi Coefficient		0.0068	
Contingency Coefficient		0.0068	
Cramer's V		0.0068	

**Table 8.2. Item 1 of Learners' Biographic Information**

The *phi-coefficient* between the control and experimental group in this item has a value of 0,0068, which proves the independence of the two groups. Therefore the difference between the schools that were chosen for the study was not statistically significant.

**8.2.2. Name of province where your school is situated (Item 2)**

The sample (schools) as discussed in Section 7.5.1 were chosen randomly. As a result the control group comprised of 80,0 % of the subjects being from schools in the North-West province and 20,0 % were from the school in the Free State province. The experimental group was purely (100,0 %) constituted from the schools in the North-West province. Therefore of the total sample 90,0 % were from the schools in the North-West province and 10,0 % from the school in the Free State province.

Groep	v2		
Frequency,			
Percent ,			
Row Pct ,			
Col Pct ,	1,	2,	Total
C	300	75	375
	40.00	10.00	50.00
	80.00	20.00	
	44.44	100.00	
E	375	0	375
	50.00	0.00	50.00
	100.00	0.00	
	55.56	0.00	
Total	675	75	750
	90.00	10.00	100.00

**Table 8.3. Item 2 of Learners’ Biographic Information**

**8.2.3. Gender (Item 3)**

Although one of the subjects chose the “inappropriate” option on the response card, the gender representation was revealed to be well balanced. The results show that 49,9 % of the sample were males and 50,0 % were females. The value of phi-coefficient is less than 0,3 which indicates that there is no statistical significance in the gender of the two groups. The results are shown hereunder:

Groep	v3
Frequency,	
Percent ,	

Row Pct	1	2	3	Total
Col Pct				
C	183	192	0	375
	24.40	25.60	0.00	50.00
	48.80	51.20	0.00	
	48.93	51.20	0.00	
E	191	183	1	375
	25.47	24.40	0.13	50.00
	50.93	48.80	0.27	
	51.07	48.80	100.00	
Total	374	375	1	750
	49.87	50.00	0.13	100.00

Statistics for Table of Groep by v3

Statistic	DF	Value	Prob
Chi-Square	2	1.3871	0.4998
Likelihood Ratio Chi-Square	2	1.7735	0.4120
Mantel-Haenszel Chi-Square	1	0.2582	0.6113
Phi Coefficient		0.0430	
Contingency Coefficient		0.0430	
Cramer's V		0.0430	

WARNING: 33% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 750

### Table 8.4. Item 3 of Learners' Biographic Information

#### 8.2.4. Ages in years (Item 4)

The ages (in years) of the subject of this study are revealed in the following table.

Groep	v4							Total
Frequency,								
Percent								
Row Pct								
Col Pct	1	2	3	4	5	6	7	Total
C	23	58	102	97	90	4	1	375
	3.07	7.74	13.62	12.95	12.02	0.53	0.13	50.07
	6.13	15.47	27.20	25.87	24.00	1.07	0.27	
	56.10	41.73	41.80	47.32	82.57	57.14	25.00	
E	18	81	142	108	19	3	3	374
	2.40	10.81	18.96	14.42	2.54	0.40	0.40	49.93
	4.81	21.66	37.97	28.88	5.08	0.80	0.80	
	43.90	58.27	58.20	52.68	17.43	42.86	75.00	
Total	41	139	244	205	109	7	4	749
	5.47	18.56	32.58	27.37	14.55	0.93	0.53	100.00

Frequency Missing = 1

Statistics for Table of Groep by v4

Statistic	DF	Value	Prob
Chi-Square	6	58.9525	<.0001
Likelihood Ratio Chi-Square	6	63.0474	<.0001
Mantel-Haenszel Chi-Square	1	19.3084	<.0001
Phi Coefficient		0.2805	
Contingency Coefficient		0.2701	
Cramer's V		0.2805	

**Table 8.5. Item 4 of Learners' Biographic Information**

The frequency table shown in this item indicates the spreading of the results of the sample age in years. The results revealed that the age of the sample increased with the grade. That is, those in grade 10 were younger than the ones in grades 11 and 12, and those in grade 11 were younger than the ones in grade 12

### 8.2.5. Present grade (Item 5)

The sample was selected such that N=375 formed part of the control group and N=375 formed the experimental group as revealed by the statistical analysis in the table below.

Groep	v5			Total
Frequency,	1,	2,	3,	
Percent ,				
Row Pct ,				
Col Pct ,				
C	123	128	124	375
	16.40	17.07	16.53	50.00
	32.80	34.13	33.07	
	49.00	50.79	50.20	
E	128	124	123	375
	17.07	16.53	16.40	50.00
	34.13	33.07	32.80	
	51.00	49.21	49.80	
Total	251	252	247	750
	33.47	33.60	32.93	100.00

Statistics for Table of Groep by v5

Statistic	DF	Value	Prob
Chi-Square	2	0.1671	0.9198
Likelihood Ratio Chi-Square	2	0.1672	0.9198
Mantel-Haenszel Chi-Square	1	0.0722	0.7882
Phi Coefficient		0.0149	
Contingency Coefficient		0.0149	
Cramer's V		0.0149	

**Table 8.6. Item 5 of Learners' Biographic Information**

**8.2.6. Number of years in the grade (Item 6)**

The results indicate that most learners were in their first year of learning in the particular grade. Of the sample 93,0 % were in their first year of the grade and only 7,0 % were repeating the grade for the first time whereas one learner from the control group was repeating the grade for the second time.

The Department of Education stated in a policy document (DoE: 2003) that a learner is not supposed to be in one learning phase for more than four years. The other determining factor for the number of years in the phase is learners' age. It is recommended that learners who have exceeded the required age for the phase must be promoted to the subsequent phase. It is probably for this reason that we still have learners who are 19 years and older in the FET band.

The results further confirm that there was no statistical difference with regard to the number of years in a phase between the control and the experimental groups as the phi-coefficient for this factor was less than 0,3.

Groep	v6			
	1	2	3	Total
Frequency				
Percent				
Row Pct				
Col Pct				
C	340	34	1	375
	45.33	4.53	0.13	50.00
	90.67	9.07	0.27	
	48.57	69.39	100.00	
E	360	15	0	375
	48.00	2.00	0.00	50.00
	96.00	4.00	0.00	
	51.43	30.61	0.00	
Total	700	49	1	750
	93.33	6.53	0.13	100.00

Statistics for Table of Groep by v6

Statistic	DF	Value	Prob
Chi-Square	2	8.9388	0.0115
Likelihood Ratio Chi-Square	2	9.5219	0.0086
Mantel-Haenszel Chi-Square	1	8.8915	0.0029
Phi Coefficient		0.1092	
Contingency Coefficient		0.1085	
Cramer's V		0.1092	

WARNING: 33% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Sample Size = 750

**Table 8.7. Item 6 of Learners' Biographic Information**

**8.2.7. What was your most recent mark/symbol in the Physical Sciences examination? (Item 7)**

The table gives the distribution of marks obtained by the sample in their recent Physical Sciences examination.

Groep	v7							Total
Frequency,								
Percent ,								
Row Pct ,								
Col Pct ,	1,	2,	3,	4,	5,	6,	7,	
C	9	30	73	119	107	30	6	374
	1.20	4.02	9.77	15.93	14.32	4.02	0.80	50.07
	2.41	8.02	19.52	31.82	28.61	8.02	1.60	
	81.82	61.22	40.33	48.57	62.21	40.00	42.86	
E	2	19	108	126	65	45	8	373
	0.27	2.54	14.46	16.87	8.70	6.02	1.07	49.93
	0.54	5.09	28.95	33.78	17.43	12.06	2.14	
	18.18	38.78	59.67	51.43	37.79	60.00	57.14	
Total	11	49	181	245	172	75	14	747
	1.47	6.56	24.23	32.80	23.03	10.04	1.87	100.00

Frequency Missing = 3

Statistics for Table of Groep by v7

Statistic	DF	Value	Prob
Chi-Square	6	27.4321	0.0001
Likelihood Ratio Chi-Square	6	27.9855	<.0001
Mantel-Haenszel Chi-Square	1	0.0040	0.9496
Phi Coefficient		0.1916	
Contingency Coefficient		0.1882	
Cramer's V		0.1916	

**Table 8.8. Item 7 of Learners' Biographic Information**

The analysis indicates that from the two groups only a small percentage (1,5 %) of learners obtained high marks while 53,6 % were lying in the average mark bracket. The table depicts that the marks of the learners in the experimental group were shifted more towards the left hand side of the table (low marks), although that was not statistically significant.

**8.2.8. I have visited the Potchefstroom Science Centre before (Item 8)**

A total of 94,4 % of the sample from the control group had never been to the Potchefstroom Science Centre and only 5,6 % indicated that they had visited the Science Centre once. On the other hand, prior to the completion of this questionnaire (that is before the 2007 National Science Week), 51,3 % of the sample of the experimental group had never visited the Science Centre. The analysis indicate that 37,2 % had visited the science centre once, 8,3 % twice, 1,1 % three times where as 2,1 % had been to the science centre more than three times.

The experimental group was from the catchment area of the Potchefstroom Science Centre and the percentage of learners that have been to the science centre indicate that schools gave the senior grades preference for participation in activities related to visits to the Science Centre and other extra-curricular activities. It will be interesting to find the reasons why the GET band was not considered for such educational endeavours. The table is supplied below.

Groep	v8					Total
Frequency,						
Percent ,						
Row Pct ,						
Col Pct ,	1,	2,	3,	4,	5,	
C	354	21	0	0	0	375
	47.26	2.80	0.00	0.00	0.00	50.07
	94.40	5.60	0.00	0.00	0.00	

	64.84	13.13	0.00	0.00	0.00	
E	192	139	31	4	8	374
	25.63	18.56	4.14	0.53	1.07	49.93
	51.34	37.17	8.29	1.07	2.14	
	35.16	86.88	100.00	100.00	100.00	
Total	546	160	31	4	8	749
	72.90	21.36	4.14	0.53	1.07	100.00

Frequency Missing = 1

Statistics for Table of Groep by v8

Statistic	DF	Value	Prob
Chi-Square	4	178.0899	<.0001
Likelihood Ratio Chi-Square	4	205.8117	<.0001
Mantel-Haenszel Chi-Square	1	142.1880	<.0001
Phi Coefficient		0.4876	
Contingency Coefficient		0.4383	
Cramer's V		0.4876	

WARNING: 40% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Effective Sample Size = 750

**Table 8.9. Item 8 of Learners' Biographic Information**

The phi-coefficient in this item is 0,4876 which indicates a statistically significant difference between the pre-exposure to a science centre for the two groups. The subjects in the experimental group have been exposed to the Science Centre more than the subjects in the control group. This was expected by the researcher as the sample in the experimental group is in the catchment area of the Potchefstroom Science Centre.

**8.2.9. I have been to the Potchefstroom Science Centre during the National Science Week (Item 9)**

This item was included to test if learners had visited the Science Centre on their own accord or only during the National Science Week together with their school groups. The results confirm that schools awaited their participation and visit to the Science Centre per invitation or visited when there was a need on their side. The table with the results is given below;

Groep v9

```

Frequency,
Percent ,
Row Pct ,
Col Pct ,      1,      2,  Total
ffffffff^ffffffff^ffffffff^
C      ,      21 ,      354 ,      375
      ,      2.80 ,      47.20 ,      50.00
      ,      5.60 ,      94.40 ,
      ,      10.55 ,      64.25 ,
ffffffff^ffffffff^ffffffff^
E      ,      178 ,      197 ,      375
      ,      23.73 ,      26.27 ,      50.00
      ,      47.47 ,      52.53 ,
      ,      89.45 ,      35.75 ,
ffffffff^ffffffff^ffffffff^
Total      199      551      750
          26.53      73.47      100.00

```

Statistics for Table of Groep by v9

Statistic	DF	Value	Prob
Chi-Square	1	168.5993	<.0001
Likelihood Ratio Chi-Square	1	187.0831	<.0001
Continuity Adj. Chi-Square	1	166.4584	<.0001
Mantel-Haenszel Chi-Square	1	168.3745	<.0001
Phi Coefficient		-0.4741	
Contingency Coefficient		0.4284	
Cramer's V		-0.4741	

Fisher's Exact Test

```

ffffffffffffffffffffffffffffffff
Cell (1,1) Frequency (F)      21
Left-sided Pr <= F           2.832E-42
Right-sided Pr >= F          1.0000

Table Probability (P)         2.648E-42
Two-sided Pr <= P            5.664E-42

```

Sample Size = 750

**Table 8.10. Item 9 of Learners' Biographic Information**

**8.2.10. I have been to other science centre(s) before (*Item 10*)**

There is no statistical difference between learners in the control as well as those in the experimental group in that a total of 6,0 % said that they had been to other science centre(s) before. This was not satisfactory in the opinion of the researcher. The statistical results follow:

```

Groep      v10

Frequency,
Percent ,
Row Pct ,
Col Pct ,      1,      2,  Total
ffffffff^ffffffff^ffffffff^

```



Contingency Coefficient 0.1545  
 Cramer's V -0.1563

Fisher's Exact Test  
 ffffffffffffffffffffffffffffffffff  
 Cell (1,1) Frequency (F) 2  
 Left-sided Pr <= F 7.046E-06  
 Right-sided Pr >= F 1.0000  
 Table Probability (P) 6.517E-06  
 Two-sided Pr <= P 7.609E-06

Effective Sample Size = 750

**Table 8.12. Item 11 of Learners' Biographic Information**

**8.2.12. Conclusion**

The questionnaire was designed to give the demographic information of the sample. The sample consisted of a balanced representation in terms of numbers between the control (N=375) and experimental (N=375) groups. However, there were instances of a statistically significant difference in the results of the two groups. In those events, like in items 3 and 4 of the questionnaire, the ages of the subjects in years and their present grades differed and the phi-coefficient of the two items indicated a value of 0,7236 as shown below.

	v4	v5		
Frequency,				
Percent ,				
Row Pct ,				
Col Pct ,	1,	2,	3,	Total
1,	37,	4,	0,	41
,	4.94,	0.53,	0.00,	5.47
,	90.24,	9.76,	0.00,	
,	14.74,	1.59,	0.00,	
2,	111,	23,	5,	139
,	14.82,	3.07,	0.67,	18.56
,	79.86,	16.55,	3.60,	
,	44.22,	9.13,	2.03,	
3,	61,	141,	42,	244
,	8.14,	18.83,	5.61,	32.58
,	25.00,	57.79,	17.21,	
,	24.30,	55.95,	17.07,	
4,	27,	57,	121,	205
,	3.60,	7.61,	16.15,	27.37
,	13.17,	27.80,	59.02,	
,	10.76,	22.62,	49.19,	

5	13	25	71	109
	1.74	3.34	9.48	14.55
	11.93	22.94	65.14	
	5.18	9.92	28.86	
~~~~~				
6	2	1	4	7
	0.27	0.13	0.53	0.93
	28.57	14.29	57.14	
	0.80	0.40	1.63	
~~~~~				
7	0	1	3	4
	0.00	0.13	0.40	0.53
	0.00	25.00	75.00	
	0.00	0.40	1.22	
~~~~~				
Total	251	252	246	749
	33.51	33.64	32.84	100.00

Frequency Missing = 1

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Statistics for Table of v4 by v5

Statistic	DF	Value	Prob
Chi-Square	12	392.1929	<.0001
Likelihood Ratio Chi-Square	12	391.2767	<.0001
Mantel-Haenszel Chi-Square	1	253.8495	<.0001
Phi Coefficient		0.7236	
Contingency Coefficient		0.5862	
Cramer's V		0.5117	

WARNING: 29% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

Effective Sample Size = 750

### Table 8.13. Correlation Coefficient of Items 3 and 4 of Learners' Biographic Information

The value of the phi coefficient is 0,7236 which is statistically significant and hence of practical value. It makes sense that learners at grade 10 will be younger than the ones in grades 11 and 12. That is the trend measured by the correlation of the two items.

The outcomes on the information on learning are analysed in the next section.

### 8.3. ANALYSIS OF INFORMATION ON LEARNING QUESTIONNAIRES

The intent of the questionnaire was to give learners (control and experimental groups) the opportunity to reveal the prevailing situation with regards to how practical work is

conducted at their respective schools. The questionnaire also required of the learners to indicate their confidence about their physical skills in handling apparatus.

The statistical results of the items of the questionnaire are discussed hereunder

### 8.3.1. Frequency at which practical work is conducted at schools (*Item 1*)

The item probed into the whether or not practical work was done at schools and if it was done, at what frequency was it conducted. Woolnough and Allsop (1985: 31) posit that the benefits that are brought by practical work are three pronged, that is practical work embeds the following fundamental outcomes in science learning:

- ❖ Development of practical skills and techniques.
- ❖ Development of problem solving skills.
- ❖ Development of a feeling for scientific phenomena.

Despite the reasons stated above, it was still evident that practical work was not done at schools. This conclusion was drawn from the fact that 74,0 % (control and experimental groups) of the respondents confirmed that they totally disagree that practical work was done regularly at their schools. The results show that some practical work was done by the experimental group in that 17,9 % as opposed to 1,1 % of the control group totally agreed with the item. When given an opportunity to comment on the item learners revealed that it was only at higher grades (grade 12) that some demonstrations were conducted by their teachers. The table below verify the frequency at which practical work was done at the participating schools.

Groep	v1					Total
Frequency,						
Percent ,						
Row Pct ,						
Col Pct ,	1,	2,	3,	4,	5,	Total
#####^#####^#####^#####^#####^#####^						
C	4	6	14	30	321	375
	0.53	0.80	1.87	4.00	42.80	50.00

	1.07	1.60	3.73	8.00	85.60	
	5.63	27.27	41.18	44.78	57.73	
E	67	16	20	37	235	375
	8.93	2.13	2.67	4.93	31.33	50.00
	17.87	4.27	5.33	9.87	62.67	
	94.37	72.73	58.82	55.22	42.27	
Total	71	22	34	67	556	750
	9.47	2.93	4.53	8.93	74.13	100.00

Frequency Missing = 3

Statistics for Table of Groep by v1

Statistic	DF	Value	Prob
Chi-Square	4	75.5392	<.0001
Likelihood Ratio Chi-Square	4	87.5149	<.0001
Mantel-Haenszel Chi-Square	1	73.9600	<.0001
Phi Coefficient		0.3174	
Contingency Coefficient		0.3025	
Cramer's V		0.3174	

Effective Sample Size = 750

**Table 8.14. Item 1 of Information on learning**

### 8.3.2. Confidence in carrying out experiments (Item 2)

Learners in this item were asked about the level of their confidence in carrying out experiments on their own. From the table supplied below, it can be concluded that the response shifted more to the negative (disagree – strongly disagree) in that 31,7 % - 59,7 % of the control group and 36,5 % - 36,3 % confirmed that they were not confident in conducting experiments on their own. The phi-coefficient of 0,3 confirms that there is no statistically significant difference between the two groups with respect to confidence in carrying out experiments. The statistical results are tabulated hereunder:

Groep	v2					Total
Frequency,						
Percent						
Row Pct						
Col Pct	1,	2,	3,	4,	5,	
C	7	13	12	119	224	375
	0.93	1.73	1.60	15.87	29.87	50.00
	1.87	3.47	3.20	31.73	59.73	
	22.58	27.08	21.82	46.48	62.22	
E	24	35	43	137	136	375
	3.20	4.67	5.73	18.27	18.13	50.00
	6.40	9.33	11.47	36.53	36.27	

	77.42	72.92	78.18	53.52	37.78	
Total	31	48	55	256	360	750
	4.13	6.40	7.33	34.13	48.00	100.00

Frequency Missing = 3

Statistics for Table of Groep by v2

Statistic	DF	Value	Prob
Chi-Square	4	59.6554	<.0001
Likelihood Ratio Chi-Square	4	61.8649	<.0001
Mantel-Haenszel Chi-Square	1	52.6865	<.0001
Phi Coefficient		0.2820	
Contingency Coefficient		0.2714	
Cramer's V		0.2820	

Effective Sample Size = 750

**Table 8.15. Item 2 of Information on learning**

**8.3.3. I can easily follow instructions stipulated in the book to carry out experiments at school (Item 3)**

The distribution of the response on this item indicated that 36,9 % from the control group and 37,9 % from the experimental group disagree with the statement. Again towards the left-hand side of the table there was a small percentage that agreed with the statement as indicated by the attached table.

Groep	v3					Total
Frequency,						
Percent ,						
Row Pct ,						
Col Pct ,	1,	2,	3,	4,	5,	Total
C	37	14	56	138	129	374
	4.94	1.87	7.48	18.42	17.22	49.93
	9.89	3.74	14.97	36.90	34.49	
	52.11	18.92	60.87	49.29	55.60	
E	34	60	36	142	103	375
	4.54	8.01	4.81	18.96	13.75	50.07
	9.07	16.00	9.60	37.87	27.47	
	47.89	81.08	39.13	50.71	44.40	
Total	71	74	92	280	232	749
	9.48	9.88	12.28	37.38	30.97	100.00

Frequency Missing = 4

Statistics for Table of Groep by v3

Statistic	DF	Value	Prob
-----------	----	-------	------

```

ffffffffffffffffffffffffffffffffffffffffffffffffffffffffffff
Chi-Square          4      36.0388    <.0001
Likelihood Ratio Chi-Square  4      38.2844    <.0001
Mantel-Haenszel Chi-Square  1      6.5825    0.0103
Phi Coefficient                    0.2194
Contingency Coefficient            0.2143
Cramer's V                      0.2194

```

Effective Sample Size = 750

**Table 8.16. Item 3 of Information on learning**

**8.3.4. Level of understanding after teacher demonstrations (Item 4)**

In the control group, 17,9 % totally agreed with the item and 29,6 % disagreed whilst 32,0 % totally disagreed with the item. On the other extreme, on the sample constituting the experimental group, 21,6 % totally agreed with the item, and 30,9 % disagreed whilst 28,8 % totally disagreed with the item. Overall there were only 19,7 % of the total sample that agreed with the item and 30,3 % who disagreed and a further 30,4 % who totally disagreed with the item.

Based on the statistical results a conclusion can be drawn that learners did not benefit from teachers' demonstrations. Reasons could be the technique/method employed by the teachers in executing demonstrations, a fact that was revealed in interviews with the teachers.

The results of this item follow hereunder:

Groep	v4	1,	2,	3,	4,	5,	Total
Frequency,							
Percent							
Row Pct							
Col Pct							
C		67	16	61	111	120	375
		8.93	2.13	8.13	14.80	16.00	50.00
		17.87	4.27	16.27	29.60	32.00	
		45.27	30.19	64.89	48.90	52.63	
E		81	37	33	116	108	375
		10.80	4.93	4.40	15.47	14.40	50.00
		21.60	9.87	8.80	30.93	28.80	
		54.73	69.81	35.11	51.10	47.37	
Total		148	53	94	227	228	750
		19.73	7.07	12.53	30.27	30.40	100.00

Frequency Missing = 3

Statistics for Table of Groep by v4

Statistic	DF	Value	Prob
Chi-Square	4	18.7272	0.0009
Likelihood Ratio Chi-Square	4	19.0901	0.0008
Mantel-Haenszel Chi-Square	1	2.8239	0.0929
Phi Coefficient		0.1580	
Contingency Coefficient		0.1561	
Cramer's V		0.1580	

Effective Sample Size = 750

**Table 8.17. Item 4 of Information on learning**

**8.3.5. I can easily handle apparatus when conducting experiments (Item 5)**

The item was used to determine the extent to which learners possess the practical skill in conducting experiments on their own. The results depict that the shift is more towards the right hand side of the table. In total 24,6 % of the sample disagreed and 53,7 % indicated that they totally disagreed with the item. The results generally gave a picture of learners lacking the practical handling skills that were required to execute experiments. When asked to comment on the item, learners revealed that they handled glassware apparatus such as test-tubes and glass-beakers. It also came out clear during the interaction of learners with the researcher that learners did not know the names of apparatus like spatula or deflagrating spoons. Instead of the names, they gave a description of the apparatus.

The statistical results are tabled below:

Groep	v5					Total
Frequency,						
Percent ,						
Row Pct ,						
Col Pct ,	1,	2,	3,	4,	5,	
C	21	12	35	114	192	375
	2.80	1.60	4.67	15.22	25.63	50.00
	5.61	3.21	9.36	30.48	51.34	
	36.84	36.36	47.95	61.96	47.76	
E	36	21	38	70	210	375
	4.81	2.80	5.07	9.35	28.04	50.07



Likelihood Ratio Chi-Square	1	0.5107	0.4748
Continuity Adj. Chi-Square	1	0.1263	0.7222
Mantel-Haenszel Chi-Square	1	0.5047	0.4774
Phi Coefficient		0.0260	
Contingency Coefficient		0.0259	
Cramer's V		0.0260	

**Table 8.19. Item 6 of Information on learning**

An overwhelming 98,9 % considered practical work to be very important and 1,1 % said it was important. Therefore the response favoured that there should be a component of practical work.

### 8.3.7. Conclusion

The importance of the validity and reliability of the questionnaires in research has been emphasised respectively in Sections 7.5.5.1 and 7.5.5.2 of this study. To verify the validity and reliability of the research instrument used in this study, the correlation between items 1, 2, 3 and 5 have been determined.

The correlations of related items are tabulated and discussed in the subsequent subsections.

#### 8.3.7.1. Analysis of items 1 and 2.

The frequency table of the correlation of items 1 and 2 is given below:

Table of v1 by v2

v1	v2					
Frequency,	1,	2,	3,	4,	5,	Total
Percent						
Row Pct						
Col Pct						
1	22	10	24	11	4	71
	2.93	1.33	3.20	1.47	0.53	9.47
	30.99	14.08	33.80	15.49	5.63	
	70.97	20.83	43.64	4.30	1.11	
2	1	9	4	7	1	22
	0.13	1.20	0.53	0.93	0.13	2.93
	4.55	40.91	18.18	31.82	4.55	
	3.23	18.75	7.27	2.73	0.28	



because in general practical work was not conducted frequently enough. This is supported by a phi-coefficient of 0,5211.

The results are shown below:

Table of v1 by v3

v1	v3					Total
Frequency,	1,	2,	3,	4,	5,	
Percent						
Row Pct						
Col Pct						
1	21	6	26	17	1	71
	2.80	0.80	3.47	2.27	0.13	9.48
	29.58	8.45	36.62	23.94	1.41	
	29.58	8.11	28.26	6.07	0.43	
2	3	10	2	6	1	22
	0.40	1.34	0.27	0.80	0.13	2.94
	13.64	45.45	9.09	27.27	4.55	
	4.23	13.51	2.17	2.14	0.43	
3	2	13	10	8	1	34
	0.27	1.74	1.34	1.07	0.13	4.54
	5.88	38.24	29.41	23.53	2.94	
	2.82	17.57	10.87	2.86	0.43	
4	3	9	8	33	14	67
	0.40	1.20	1.07	4.41	1.87	8.95
	4.48	13.43	11.94	49.25	20.90	
	4.23	12.16	8.70	11.79	6.03	
5	42	36	46	216	215	555
	5.61	4.81	6.14	28.84	28.70	74.10
	7.57	6.49	8.29	38.92	38.74	
	59.15	48.65	50.00	77.14	92.67	
Total	71	74	92	280	232	749
	9.48	9.88	12.28	37.38	30.97	100.00

Frequency Missing = 4

First questionnaire- correlations

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Statistics for Table of v1 by v3

Statistic	DF	Value	Prob
Chi-Square	16	203.3825	<.0001
Likelihood Ratio Chi-Square	16	179.8146	<.0001
Mantel-Haenszel Chi-Square	1	103.7025	<.0001
Phi Coefficient		0.5211	
Contingency Coefficient		0.4621	
Cramer's V		0.2605	

Table 8.21. Analysis of Items 1 and 3 of Information on learning

**8.3.7.3. Analysis of items 1 and 5.**

Item 5 of the questionnaire on learning needed the conviction of learners about their skill in handling apparatus against item 1. The responses on the table revealed that learners did not possess the psychomotoric skills for conducting experiments. This conclusion emanates from the value of the phi-coefficient (0,6599) that indicates a statistical significance between the two items. The value is more than 0,5 which proves a statistically significant relationship between the frequency at which practical work was conducted at the schools (*item 1*) and the possession of practical handling skills (*item 5*).

The table of the results is shown hereunder:

Table of v1 by v5

v1	v5					Total
Frequency,	1,	2,	3,	4,	5,	
Percent ,						
Row Pct ,						
Col Pct ,						
1	28	4	29	10	0	71
	3.74	0.53	3.87	1.34	0.00	9.48
	39.44	5.63	40.85	14.08	0.00	
	49.12	12.12	39.73	5.43	0.00	
2	3	7	4	5	3	22
	0.40	0.93	0.53	0.67	0.40	2.94
	13.64	31.82	18.18	22.73	13.64	
	5.26	21.21	5.48	2.72	0.75	
3	2	3	7	16	6	34
	0.27	0.40	0.93	2.14	0.80	4.54
	5.88	8.82	20.59	47.06	17.65	
	3.51	9.09	9.59	8.70	1.49	
4	3	7	3	22	32	67
	0.40	0.93	0.40	2.94	4.27	8.95
	4.48	10.45	4.48	32.84	47.76	
	5.26	21.21	4.11	11.96	7.96	
5	21	12	30	131	361	555
	2.80	1.60	4.01	17.49	48.20	74.10
	3.78	2.16	5.41	23.60	65.05	
	36.84	36.36	41.10	71.20	89.80	
Total	57	33	73	184	402	749
	7.61	4.41	9.75	24.57	53.67	100.00

Frequency Missing = 4

First questionnaire- correlations

The FREQ Procedure

Statistics for Table of v1 by v5

Statistic	DF	Value	Prob
Chi-Square	16	326.1818	<.0001
Likelihood Ratio Chi-Square	16	270.3410	<.0001
Mantel-Haenszel Chi-Square	1	222.8488	<.0001
Phi Coefficient		0.6599	
Contingency Coefficient		0.5508	
Cramer's V		0.3300	

**Table 8.22. Analysis of Items 1 and 5 of Information on learning**

**8.3.7.4. Analysis of items 2 and 3**

The phi-coefficient for this correlation is 0,5264 which suggests statistical significance. The correlation indicates that the learners' level of confidence in conducting experiments (*item 2*) was low with the results that they (learners) could not follow instructions to perform an experiment described in a text-book (*item 3*).

The results follow hereunder:

	v2		v3			
Frequency,						
Percent ,						
Row Pct ,						
Col Pct ,	1,	2,	3,	4,	5,	Total
1	13	1	10	6	0	30
	1.74	0.13	1.34	0.80	0.00	4.01
	43.33	3.33	33.33	20.00	0.00	
	18.31	1.35	10.87	2.14	0.00	
2	8	19	7	12	2	48
	1.07	2.54	0.93	1.60	0.27	6.41
	16.67	39.58	14.58	25.00	4.17	
	11.27	25.68	7.61	4.29	0.86	
3	8	5	22	14	6	55
	1.07	0.67	2.94	1.87	0.80	7.34
	14.55	9.09	40.00	25.45	10.91	
	11.27	6.76	23.91	5.00	2.59	
4	12	35	15	111	83	256
	1.60	4.67	2.00	14.82	11.08	34.18
	4.69	13.67	5.86	43.36	32.42	
	16.90	47.30	16.30	39.64	35.78	
5	30	14	38	137	141	360
	4.01	1.87	5.07	18.29	18.83	48.06
	8.33	3.89	10.56	38.06	39.17	
	42.25	18.92	41.30	48.93	60.78	
Total	71	74	92	280	232	749

9.48 9.88 12.28 37.38 30.97 100.00

Frequency Missing = 4

First questionnaire- correlations

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Statistics for Table of v2 by v3

Statistic	DF	Value	Prob
Chi-Square	16	207.5127	<.0001
Likelihood Ratio Chi-Square	16	180.8162	<.0001
Mantel-Haenszel Chi-Square	1	93.1210	<.0001
Phi Coefficient		0.5264	
Contingency Coefficient		0.4658	
Cramer's V		0.2632	

**Table 8.23. Analysis of Items 2 and 3 of Information on learning**

**8.3.7.5. Analysis of items 2 and 5.**

When measuring the level of the sample's confidence (*item 2*) against the sample's psychomotoric skills (*item 5*) it emerged that the level of confidence impacted on their psychomotoric skills. The results (tabulated) prove that learners lacked psychomotoric skills and did not feel confident about carrying out experiments.

	v2	v5					Total
Frequency,		1,	2,	3,	4,	5,	
Percent ,							
Row Pct ,							
Col Pct ,							
1	10	5	12	2	1	30	
	1.34	0.67	1.60	0.27	0.13	4.01	
	33.33	16.67	40.00	6.67	3.33		
	17.54	15.15	16.44	1.09	0.25		
2	12	11	7	11	7	48	
	1.60	1.47	0.93	1.47	0.93	6.41	
	25.00	22.92	14.58	22.92	14.58		
	21.05	33.33	9.59	5.98	1.74		
3	10	5	19	18	3	55	
	1.34	0.67	2.54	2.40	0.40	7.34	
	18.18	9.09	34.55	32.73	5.45		
	17.54	15.15	26.03	9.78	0.75		
4	5	5	13	91	142	256	
	0.67	0.67	1.74	12.15	18.96	34.18	
	1.95	1.95	5.08	35.55	55.47		
	8.77	15.15	17.81	49.46	35.32		
5	20	7	22	62	249	360	

```

, 2.67 , 0.93 , 2.94 , 8.28 , 33.24 , 48.06
, 5.56 , 1.94 , 6.11 , 17.22 , 69.17 ,
, 35.09 , 21.21 , 30.14 , 33.70 , 61.94 ,
ffffffff~ffffffff~ffffffff~ffffffff~ffffffff~ffffffff~
Total 57 33 73 184 402 749
7.61 . 4.41 9.75 24.57 53.67 100.00

```

Frequency Missing = 4

First questionnaire- correlations

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Statistics for Table of v2 by v5

Statistic	DF	Value	Prob
Chi-Square	16	293.2216	<.0001
Likelihood Ratio Chi-Square	16	261.6129	<.0001
Mantel-Haenszel Chi-Square	1	168.8238	<.0001
Phi Coefficient		0.6257	
Contingency Coefficient		0.5304	
Cramer's V		0.3128	

**Table 8.24. Analysis of Items 2 and 5 of Information on learning**

### 8.3.7.6. Analysis of items 3 and 5.

Following instruction in carrying out experiments (*item 3*) require cognitive skills. Psychomotoric skills are not acquired in isolation as they also impact and depend on cognitive skills (Malhotra, 1994: 3; Wellington, 1990: 249). Therefore the results confirm that the learners had been challenged on the two important dimensions in practical work, that is, the cognitive as well as the psychomotoric skills.

The results are shown below:

```

v3          v5
Frequency,
Percent ,
Row Pct ,
Col Pct ,
, 1, 2, 3, 4, 5, Total
ffffffff~ffffffff~ffffffff~ffffffff~ffffffff~ffffffff~
1 , 27 , 8 , 13 , 11 , 12 , 71
, 3.60 , 1.07 , 1.74 , 1.47 , 1.60 , 9.48
, 38.03 , 11.27 , 18.31 , 15.49 , 16.90 ,
, 47.37 , 24.24 , 17.81 , 5.98 , 2.99 ,
ffffffff~ffffffff~ffffffff~ffffffff~ffffffff~ffffffff~
2 , 3 , 9 , 9 , 17 , 36 , 74
, 0.40 , 1.20 , 1.20 , 2.27 , 4.81 , 9.88
, 4.05 , 12.16 , 12.16 , 22.97 , 48.65 ,

```

	5.26	27.27	12.33	9.24	8.96	
3	19	7	32	29	5	92
	2.54	0.93	4.27	3.87	0.67	12.28
	20.65	7.61	34.78	31.52	5.43	
	33.33	21.21	43.84	15.76	1.24	
4	5	9	15	96	155	280
	0.67	1.20	2.00	12.82	20.69	37.38
	1.79	3.21	5.36	34.29	55.36	
	8.77	27.27	20.55	52.17	38.56	
5	3	0	4	31	194	232
	0.40	0.00	0.53	4.14	25.90	30.97
	1.29	0.00	1.72	13.36	83.62	
	5.26	0.00	5.48	16.85	48.26	
Total	57	33	73	184	402	749
	7.61	4.41	9.75	24.57	53.67	100.00

Frequency Missing = 4

First questionnaire- correlations

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The FREQ Procedure

Statistics for Table of v3 by v5

Statistic	DF	Value	Prob
Chi-Square	16	373.4549	<.0001
Likelihood Ratio Chi-Square	16	353.3807	<.0001
Mantel-Haenszel Chi-Square	1	203.5506	<.0001
Phi Coefficient		0.7061	
Contingency Coefficient		0.5768	
Cramer's V		0.3531	

**Table 8.25. Analysis of Items 3 and 5 of Information on learning**

It is indicated in Section 7.5.3 of this study that the experimental group was brought to the Potchefstroom Science centre for exposure to the exhibits and the completion of the second part of the questionnaires. The analysis of the items in the questionnaires is provided in the next subsections. This part of the questionnaire was completed by the experimental group only (see Table 7.2 for procedure of empirical survey).

## 8.4. ANALYSIS OF ITEMS IN LEARNERS' QUESTIONNAIRES (PART 2)

### 8.4.1. Level of understanding after visits to the Science Centre (*Item 1*)

The item probed the cognitive nature of the Science Centre and aimed at measuring whether or not visitors (learners) gained any form of understanding by visiting the science centre. Understanding in this context refers to the acquisition of scientific knowledge and being able to apply it in different situations in future. In other words the researcher envisaged to measure whether the Science Centre encouraged rote learning or conceptual understanding in Physical Sciences.

v1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	171	45.60	171	45.60
2	23	6.13	194	51.73
3	180	48.00	374	99.73
4	1	0.27	375	100.00

**Table 8.26. Analysis of Item 1 of Information on Science Centre Learning**

The results showed that 45,6 % strongly agreed with the statement and 48,0 % agreed. The shift of the response was on the positive side, a sign that proved that interaction with exhibits in the Science Centre fostered conceptual learning. This fact was also evident from the positive shift of results (learning gain) discussed in subsequent sections.

### 8.4.2. The atmosphere/environment in the science centre stimulates or promotes my scientific thinking (*Item 2*)

The study was carried out in the Science Centre as a learning context (Chapter 7 of this study). The Science Centre as a context of learning is seen as a relaxed and not formally structured system like a school. The learners are said to be at ease in this kind of environment (Stocklmayer and Gilbert, 2002: 143). The item probed the learners' convictions about their feelings in the science centre.

v2	Frequency	Percent	Cumulative Frequency	Cumulative Percent
----	-----------	---------	-------------------------	-----------------------

////////////////////////////////////				
1	119	31.73	119	31.73
2	17	4.53	136	36.27
3	239	63.73	375	100.00

**Table 8.27. Analysis of Item 2 of Information on Science Centre Learning**

The statistical results obtained from the sample agreed with literature in that all agreed that the environment of the Science Centre according to the sample was stimulating and provoked their thinking.

**8.4.3. I like Physical Sciences more after the visit to the Science Centre (Item 3)**

Studies conducted in other countries revealed that exposure to science centres and other informal centres impact on learners' affections to the subject (Witschey, 2001:2). The item sought to investigate whether visits to the science centre yielded the same result or not.

v3	Frequency	Percent	Cumulative Frequency	Cumulative Percent
////////////////////////////////////				
1	173	46.13	173	46.13
2	17	4.53	190	50.67
3	184	49.07	374	99.73
4	1	0.27	375	100.00

**Table 8.28. Analysis of Item 3 of Information on Science Centre Learning**

Only 0,3 % ( a negligile percentage) of the sample disagreed that a visit to the Science Centre had not changed their perception and attitude toward science. Of the responses 99,9 % declared a change to the positive in attitude since the visits to the Science Centre.

**8.4.4. I have learned new things in the Science Centre (Item 4)**

Science centres are renowned for their vast coverage of technological and science related fields (Witschey, 2001:2). The item was aimed at investigating the value of the visit to the science centre with regard to the cognitive as well as the psychomotoric skills benefit.

Cumulative      Cumulative

v4	Frequency	Percent	Frequency	Percent
1	244	65.07	244	65.07
2	6	1.60	250	66.67
3	122	32.53	372	99.20
4	3	0.80	375	100.00

**Table 8.29. Analysis of Item 4 of Information on Science Centre Learning**

A number of 65,1 % of the sample strongly agreed while 32,5 % agreed that they have learnt new things in the Science Centre. The responses verified the cognitive value and importance of the Science Centre in the learning of science and related careers.

**8.4.5. I have learned how to investigate things in the Science Centre (Item 5)**

The approach to the Potchefstroom Science Centre as discussed in Section 9.6 of this study is such that it engages visitors (*learners*) by using the POE model. In this model learners are prompted to predict the outcome of the experiment/*investigation* before they perform the experiment. They then perform the experiment for observation and thereafter explain their observations. In this approach learners are provided with the opportunity for investigation in the Science Centre. The item intended to verify whether the Science Centre actually fulfil this function.

v5	Frequency	Percent	Frequency	Percent
1	219	58.56	219	58.56
2	15	4.01	234	62.57
3	130	34.76	364	97.33
4	9	2.41	373	99.73
5	1	0.27	374	100.00

**Table 8.30. Analysis of Item 5 of Information on Science Centre Learning**

The results indicate that 93,0 % of the respondents agreed with the statement that they have learned to investigate things in the Science Centre. This proves that the Science centre fulfils this function.

**8.4.6. The experiments I have conducted in the Science Centre demand/require understanding (Item 6)**

The table presented hereunder gives the statistical results of the respondents according to the frequency of the responses.

v6	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	260	69.33	260	69.33
2	12	3.20	272	72.53
3	101	26.93	373	99.47
4	2	0.53	375	100.00

**Table 8.31. Analysis of Item 6 of Information on Science Centre Learning**

The item aimed at probing the cognitive aspect of the Science Centre with regard to the perception of visitors. That is, whether or not visitors valued the level of understanding required for the experiments. The results showed that experiments conducted in the Science Centre do require understanding in that 99,5 % agreed with the statement.

**8.4.7. The Science Centre gave me the opportunity to learn by doing experiments on my own (Item 7)**

Research has it that science centres offer significant support for practical work, and enhances the opportunity for learners to do practical work on their own (Witschey, 2001:1). This was an opportunity very rare in their structured schooling system (Item 1 of learners' questionnaires: part 1). The item sought to investigate the extent to which learners perceive the Science Centre to give them the opportunity to do practical work on their own.

v7	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	257	68.53	257	68.53
2	14	3.73	271	72.27
3	103	27.47	374	99.73
4	1	0.27	375	100.00

**Table 8.32. Analysis of Item 7 of Information on Science Centre Learning**

One of the objectives of science centres is to entice and give learners (visitors) an opportunity to have a mind-on , hands-on experience with exhibits. According to White (1988: 117) learning proceeds from individual interacting with exhibit(s). The frequency table shows that 99,0 % of the respondents had an opportunity to interact with exhibits.

**8.4.8. In the Science Centre I have learnt to identify a problem (Item 8)**

The next three items were included to cover the higher order of competence that encompasses the cognitive domain as described by Bloom (Krathwohl *et al.*, 1964: 6, Anderson *et al.*, 2001: 29). The researcher needed to test if the Science Centre had the ability to challenge learners/visitors in seeing patterns in related exhibits or connections with everyday life experience. The item also required of learners to recognize hidden meaning in exhibits, for example, the functioning of the zinc–copper plates when one places one’s hands on the plates to complete the electric circuit.

v8	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	207	55.20	207	55.20
2	17	4.53	224	59.73
3	134	35.73	358	95.47
4	15	4.00	373	99.47
5	2	0.53	375	100.00

**Table 8.33. Analysis of Item 8 of Information on Science Centre Learning**

The Science Centre helped visitors in identifying problems in situations. This conclusion was drawn from the fact that only 4,5 % disagreed with the statement.

**8.4.9. In the Science centre I have learned to find answers to problems (Item 9)**

It was the intention of the researcher with this item to test if learners could use old ideas to create new ones from the situation in the Science Centre. In other words learners were expected to relate knowledge in an attempt to find answers to problems identified by predicting the outcome of the experiment and hypothesizing. If that can be achieved, it

would mean that science centres have the capacity to enhance conceptual learning in learners/visitors (see Chapter 2 of this study).

v9	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	106	28.27	106	28.27
2	32	8.53	138	36.80
3	224	59.73	362	96.53
4	8	2.13	370	98.67
5	5	1.33	375	100.00

**Table 8.34. Analysis of Item 9 of Information on Science Centre Learning**

After identifying problems, visitors to the Science Centre are expected to find solutions to the identified problems. A total of 97,0 % of the respondents were able to find answers to the identified problem(s) in the Science Centre.

#### 8.4.10. The Science Centre helped me to analyze problems *Item 10)*

Analysis requires a higher order of thinking, as one has to draw conclusions from experience. An example given by learners in response to this item was that of a compound see-saw. After careful thought they managed to identify and outline the differences between a normal see-saw and a compound one.

v10	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	95	25.33	95	25.33
2	22	5.87	117	31.20
3	246	65.60	363	96.80
4	9	2.40	372	99.20
5	3	0.80	375	100.00

**Table 8.35. Analysis of Item 10 of Information on Science Centre Learning**

The researcher was also interested in the higher order of thinking in the cognitive development of learners. The results show that the Science Centre is a platform to be used to help learners attain the level of thinking of analysis. This is because 98,0 % of the respondents were able to analyse the identified problem through interaction with exhibits.

**8.4.11. I could easily collaborate (work) with my peers/friends in the Science Centre**  
*(Item 11)*

The video footage captured during learners' visit to the Science Centre show inter-action between learners. They discuss, argue, differ in opinion, formulate hypothesis from different points of view and work together in carrying out the experiment.

v11	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	304	81.07	304	81.07
2	10	2.67	314	83.73
3	58	15.47	372	99.20
4	3	0.80	375	100.00

**Table 8.36. Analysis of Item 11 of Information on Science Centre Learning**

Another benefit to the visit to the Science Centre was that, there was clearly much cooperative learning. Learners just automatically engaged in discussions or arguments during the prediction phase of the experiment. In their answers 81,0 % of the respondents indicated that they strongly agreed and recommended cooperative learning in the Science Centre.

**8.4.12. Working in a small group of 2 – 5 in science experiments in the Science Centre is**  
*(Item 12)*

Pleasant	1
Impossible	2
Not recommended	3

The item was included as a follow up to the preceding one (item 11) to complete learners' convictions on cooperative learning. The evidence recorded on the video also confirmed that learners spontaneously worked in small groups and freely expressed their opinion during the prediction and explanation phase of the POE-model.

Cumulative      Cumulative

v12	Frequency	Percent	Frequency	Percent
1	354	94.40	354	94.40
2	7	1.87	361	96.27
3	12	3.20	373	99.47
4	1	0.27	374	99.73
5	1	0.27	375	100.00

**Table 8.37. Analysis of Item 12 of Information on Science Centre Learning**

There is a correlation between the preceding item (item 11) and this item in that the results of this item confirmed that cooperative learning in the Science Centre was appreciated and encouraged. This could be because one of the advantages brought about by cooperative learning and peer assessment is that in the Science Centre age does not form a barrier between different members of a group (Gunter *et al.*, 1995: 257). In this item 94,0 % strongly agreed with the statement that cooperative learning was pleasant.

**8.4.13. It is boring in the Science Centre (Item 13)**

In this item the researcher tested the affective aspect of the learning domain as characterised by Bloom and Klopfer. Research confirms that it is the elements of the affective domain that largely determines learning and knowledge acquisition and hence storage of the information in memory (see Chapters 2; 3 and 4 of this study).

v13	Frequency	Percent	Cumulative Frequency	Cumulative Percent
2	1	0.27	1	0.27
3	1	0.27	2	0.53
4	58	15.47	60	16.00
5	315	84.00	375	100.00

**Table 8.38. Analysis of Item 13 of Information on Science Centre Learning**

Scientific inquiry is based on the belief that we learn best that which intrigues and puzzles us (Gunter *et al.*, 1995: 257). It is even said that when learners ask *why*, out of genuine interest, they are likely to grasp the information and retain it as their own understanding. Therefore in a boring atmosphere it is likely that no learning will take place. Evidence to this fact is that 99,5 % disagreed that the Science Centre environment is boring.

Item 13 probes into the affective nature of a science centre. If learners were bored during the visit to the Science Centre, it could have been expected that they would not have appreciated to work and interact with their peers (*item 12*). It was further expected that if they were bored they would not have enjoyed their visit (*item 21*) and they would certainly not have visited the Science Centre again (*item 35*). Therefore the researcher determined if a correlation existed between the items.

To verify whether a correlation existed between items 12, 13, 21 and 35, a Spearman Correlation Coefficient (Rho) was determined. Rho, for these items is 0,3000 which indicate a small figure. Therefore there is no visible correlation between the items. The small value of r was brought by the shift in the mean of the responses, which ranged from 1 to 4.

#### 8.4.14. I did not learn anything in the Science Centre (*Item 14*)

The item was included as a measure of the correlation with items 4, 5 and 8. The researcher aimed at investigating the consistency with which the sample responded to these items.

v14	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	2	0.53	2	0.53
3	1	0.27	3	0.80
4	33	8.80	36	9.60
5	339	90.40	375	100.00

**Table 8.39. Analysis of Item 15 of Information on Science Centre Learning**

There was a consistency in the responses to items 4, 5 and 8 and item 14. It appeared that 98,0 % of the respondents revealed that they have definitely learnt something from the Science Centre visit. In item 4 of the questionnaire, 66,0 % of the respondents agreed that they had learnt something new from the visit to the Science Centre.

The Spearman Correlation Coefficient ( $\rho$ ) of the *items 4, 5, 8 and 14* is  $\rho = 0,1$ . This figure is statistically small and does not show any visible difference between the four items.

**8.4.15. I think that the experiments in the Science Centre will help me to become creative in science (Item 15)**

When the Science Centre is placed within the context of education through science, it develops skills such as *creativity, initiative* and safe working (Holbrook & Rannikmae, 2007: 1355). The item sought to establish whether science centres inculcate creativity in visitors through interaction with exhibits.

v15	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	144	38.40	144	38.40
2	7	1.87	151	40.27
3	224	59.73	375	100.00

**Table 8.40. Analysis of Item 15 of Information on Science Centre Learning**

All (100,0 %) of the respondents agreed with the statement, a result that seems to be in line with the findings published in the literature.

**8.4.16. Because of the experiments conducted in the Science Centre I developed a positive attitude towards Physical Sciences (Item 16)**

Of the factors that affect learning (Chapter 4) and knowledge construction (Chapter 2) and hence memory elements (Chapter 3), is the attitude towards the material to be learnt. Attitude towards Physical Sciences is the critical determinant in paying attention and focusing on the task in hand. This item probed the possible change of attitude in learners towards the subject when they are exposed to the Science Centre and offered the opportunity to actively interact with exhibits on their own.

v16	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	173	46.13	173	46.13
2	14	3.73	187	49.87
3	187	49.87	374	99.73
4	1	0.27	375	100.00

**Table 8.41. Analysis of Item 16 of Information on Science Centre Learning**

The item as described above assessed the opinions of learners on attitude change. The frequency table revealed that learners agreed that the opportunity granted to learners to handle apparatus and interact with them plays a meaningful role. Of the respondents 99,7 % confirmed that the affective domain of learning is enhanced by active learning rather than being passive.

**8.4.17. The visits to the Science Centre taught me to concentrate while doing science**  
(Item 17)

This item is of a cognitive nature. It prompted the experimental group to comment on their concentration while interacting with the exhibits. The results revealed that the concentration span of visitors is enhanced and cultivated after visits to the Science Centre. The statistical results tabled below confirm the fact.

v17	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	193	51.47	193	51.47
2	13	3.47	206	54.93
3	169	45.07	375	100.00

**Table 8.42. Analysis of Item 17 of Information on Science Centre Learning**

**8.4.18. The visits to the Science Centre have developed my understanding in science**  
(Item 18)

This item correlates with *item 1* of the questionnaire. The statistical analysis of the results showed that 99,0 % of the respondents in *item 1* agreed that there had been an improvement in their level of science understanding after visits to the Science Centre. In their responses to this item, all respondents commended the Science Centre for having developed their understanding of science. The strength of the cognitive domain of learning is enhanced by a visit to the Science Centre. The statistical results shown below borne out this fact:

v18	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	206	54.93	206	54.93
2	13	3.47	219	58.40
3	156	41.60	375	100.00

**Table 8.43. Analysis of Item 18 of Information on Science Centre Learning**

**8.4.19. The visits to the Science Centre have developed my skills to handle apparatus (Item 19)**

One of the benefits brought about by the science centres is the fact that it accords visitors the opportunity to freely interact with exhibits and thereby to strengthen their psychomotoric skills (Wellington, 1990: 248).

v19	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	152	40.53	152	40.53
2	22	5.87	174	46.40
3	196	52.27	370	98.67
4	4	1.07	374	99.73
5	1	0.27	375	100.00

**Table 8.44. Analysis of Item 19 of Information on Science Centre Learning**

The results indicated that 98,0 % of the respondents had benefited in terms of the psychomotoric skills from the visit to the Science Centre. This item reveals the other important aspect of the Science Centre, the ability to inculcate practical skills in visitors.

**8.4.20. Before the visit to the Science Centre I had problems to execute experiments on my own (Item 20)**

In this item the researcher aimed at obtaining the convictions of the experimental group with regard to the benefits brought about by science centres to their psychomotoric skills. This item served as a confirmation to the preceding item (*item 19*). Therefore a correlation between the two items was expected.

v20	Frequency	Percent	Cumulative Frequency	Cumulative Percent
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1	42	11.20	42	11.20
2	120	32.00	162	43.20
3	113	30.13	275	73.33
4	85	22.67	360	96.00
5	15	4.00	375	100.00

**Table 8.45. Analysis of Item 20 of Information on Science Centre Learning**

Prior to the visit to the Science Centre learners had difficulty in executing experiments on their own. Only 26,7 % of the respondents that indicated that they did not have a problem in conducting experiments. The findings of this study are that the small percentage of learners that had a chance to conduct experiments on their own at their respective schools, were those at the higher levels of learning – i.e. grade 12. However it was only at a specific school that this was the case. Practical work at schools still remain a challenge despite acknowledgements of the fact that practical work is essential in science (Bradley & Durbach, 1998: 1407, Woolnough & Allsop, 1985: 31).

The Spearman Correlation Coefficient of *items 19* and *20* was determined and gave a small value of  $r = 0,11251$ . a value which is not statistically visible, according to Ellis and Steyn (2003: 52).

**8.4.21. I have enjoyed the visit to the Science Centre. (Item 21)**

The item probed the visitors’ convictions about their feelings with regard to the Science Centre. The respondents’ convictions were that they enjoyed the visit to the Science Centre to the extent that 100,0 % responded that they have enjoyed themselves. This item dealt with the affective domain of learning in science, which is said to be the important in learning (Hamilton & Ghatala, 1994: 85).

v21	Frequency	Percent	Cumulative Frequency	Cumulative Percent
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1	163	43.47	163	43.47
2	8	2.13	171	45.60
3	204	54.40	375	100.00

**Table 8.46 Analysis of Item 21 of Information on Science Centre Learning**

**8.4.22. I see a Science Centre as a place for learning science (Item 22)**

Science centres are regarded as part of the informal science education sector (Witschey, 2001:1)

v22	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	192	51.20	192	51.20
2	17	4.53	209	55.73
3	166	44.27	375	100.00

**Table 8.47. Analysis of Item 22 of Information on Science Centre Learning**

With this item the researcher aimed at determining the respondents' perception about the Science Centre. The respondents' perception about the role science centres should play was that they were to be regarded as places where science could be learnt. The spreading of the responses were such that 51,2 % totally agreed with the statement, 4,5 % agreed with reservations and 44,3 % agreed.

**8.4.23. A Science Centre is a place for entertainment (Item 23)**

Learners who participated in this research held different perceptions about a Science Centre. Not only did they perceived the Science Centre as a place of learning, they also saw it as a place for entertainment. This perception agrees with one of the definitions of science centres, as places for edutainment.

v23	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	192	51.20	192	51.20
2	14	3.73	206	54.93
3	156	41.60	362	96.53
4	9	2.40	371	98.93
5	4	1.07	375	100.00

**Table 8.48. Analysis of Item 23 of Information on Science Centre Learning**

**8.4.24. The experiments in the Science Centre captured my interest for the entire visit to the science centre (Item 24)**

The intention of this item was to measure the extent to which exhibits/experiments kept the visitors interested. The literature study in Section 4.6.2 of this study revealed that the elements of the affective nature determines whether or not a person will engage in a cognitive or psychomotoric task (Hamilton & Ghatala, 1994: 85).

v24	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	225	60.00	225	60.00
2	15	4.00	240	64.00
3	131	34.93	371	98.93
4	3	0.80	374	99.73
5	1	0.27	375	100.00

**Table 8.49. Analysis of Item 24 of Information on Science Centre Learning**

The statistical results agreed with the literature that science centres are able to capture the interest of visitors thereby fostering conceptual change in them (Gunter *et al.*, 1995: 257).

**8.4.25. A visit to the Science Centre is worthwhile (Item 25)**

When asked if the visit to the Science Centre was worthwhile, learners answered affirmatively, to the extent that 93,3 % agreed with the statement. The respondents in this study all valued the visits to the Science Centre because of various reasons. The reasons were their perceptions about the benefits brought about by the Science Centre. Some mentioned the opportunity granted to conduct experiments on their own (psychomotoric skills), whilst other listed the benefits of combining the cognitive and affective domains of learning. This aspect is central to this study (*holistic development*).

v25	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	219	58.40	219	58.40
2	25	6.67	244	65.07
3	131	34.93	375	100.00

**Table 8.50. Analysis of Item 25 of Information on Science Centre Learning**

**8.4.26. The visit to the Science Centre motivated me to pursue my studies after grade 12 in science related careers (Item 26)**

It is the intention of the Department of Science and Technology to see learners from grade 12 pursuing science related careers at institutions of higher learning. The Department of Science and Technology hopes to achieve this goal by *exciting learners with science and stimulating their interest in science and science related subjects*. The results revealed by this research confirmed that the Science Centre is a vehicle to help realize this ideal. This is verified by the fact that 97,0 % of the respondents confirmed that they will pursue science related careers after being influenced by the visit to the Science Centre.

v26	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	186	49.60	186	49.60
2	28	7.47	214	57.07
3	153	40.80	367	97.87
4	7	1.87	374	99.73
5	1	0.27	375	100.00

**Table 8.51. Analysis of Item 26 of Information on Science Centre Learning**

**8.4.27. I would like to work in an environment such as a Science Centre. (Item 27)**

As a follow up to *item 26* of this questionnaire, this item intended to obtain the learners' convictions about the Science Centre environment. The response would therefore reveal the affective nature of the respondent. As further verification of the validity of the response in item 26 about pursuing careers in science and science related fields, 96,0 % of the respondents to item 27 showed an interest in working in an environment such as a science centre.

v27	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	146	38.93	146	38.93
2	11	2.93	157	41.87
3	207	55.20	364	97.07
4	8	2.13	372	99.20
5	3	0.80	375	100.00

**Table 8.52. Analysis of Item 27 of Information on Science Centre Learning**

The findings of this item confirmed that the respondents did not find the Science Centre to be boring. The Spearman Correlation Coefficient for the two items (items 13 & 27) give  $r = 0,4240$ . According to Ellis and Steyn (2003: 52) the value of  $r = 0,4$  indicate a statistically visible effect on the variables. Therefore there is a visible effect between the answers to the items. Learners would like working in the Science Centre because they were not bored by that environment.

**8.4.28. The visit to the Science Centre has improved my scientific knowledge. (Item 28)**

Amongst the advantages of the science centres is that they offer visitors of different age groups and cognitive development, an opportunity to improve their scientific background and their related scientific knowledge (see Chapter 5 of this study).

v28	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	154	41.07	154	41.07
2	28	7.47	182	48.53
3	191	50.93	373	99.47
4	1	0.27	374	99.73
5	1	0.27	375	100.00

**Table 8.53. Analysis of Item 28 of Information on Science Centre Learning**

Of the respondents 92,0 % agreed with the statement that the Science Centre served as a source of knowledge and that it also improved the scientific knowledge of individuals. This is one leg of the three – pronged strategy envisaged by the Department of Science and Technology (DST, 2004), namely that science centres should increase the level of scientific knowledge in learners so as to realise the influx of students in science related careers (see Chapter 5 of this study).

**8.4.29. I see a science centre as a place where I can sharpen my handling skills of apparatus. (Item 29)**

Science centres provide first hand experience with apparatus and an opportunity to the visitors to develop their practical skills. These practical skills are developed when visitors actively interact with exhibits. The practical skills will be gained due to the mental activity of the visitor during the interaction with the exhibit in the science centre, seeing that there are not just passive actions between the visitor and the exhibit. The statistical results tabled below confirm the fact that science centres do offer visitors an opportunity to do practical work on their own.

v29	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	103	27.54	103	27.54
2	28	7.49	131	35.03
3	241	64.44	372	99.47
4	2	0.53	374	100.00

**Table 8.54. Analysis of Item 29 of Information on Science Centre Learning**

Lagowski (1989: 12) contends that practical work in science makes the fact of science easy enough to learn and impressive enough to remember. This statement is supported by Bjorklund (2005: 120) and Hamilton and Ghatala (1994: 80) in that they argue that when individuals interact with exhibits their different memory elements are enhanced. The three elements of the sensory memory, the iconic, the haptic and the echoic memory are engaged sufficiently so that the working memory encode the information and the long-term memory stores the information encoded (see Chapter 3 of this study).

**8.4.30. I could easily relate the experiments that I conducted in the Science Centre with the science we study at school. (Item 30)**

The ability of an individual to identify and relate concepts is a sign of the acquisition of conceptual knowledge. Conceptual knowledge is a complex structure of knowledge, it requires of individuals to use schema to relate to different situations and come to a conclusion about the situation (Chapters 2 and 4 of this study). With this item the

researcher wanted to test if the exhibits in the science centre could enhance conceptual knowledge in the learners.

v30	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	119	31.73	119	31.73
2	11	2.93	130	34.67
3	241	64.27	371	98.93
4	2	0.53	373	99.47
5	2	0.53	375	100.00

**Table 8.55. Analysis of Item 30 of Information on Science Centre Learning**

To support the statistical results, learners identified similarities between the school work and the experiments they conducted during their visits in the Science Centre. Examples cited dealt with the mechanics section, where the momentum of two trolleys was experimented with, graphs were plotted and equations of motion were studied.

**8.4.31. The experiments in the Science Centre relate to my everyday life experience**  
(Item 31)

This item is a continuation of *item 30* above. The item reflected on the amount of conceptual knowledge gained by the visit to the Science Centre. Learners were asked if they could see the connection between the Science Centre and their daily lives. The responses showed that the Science Centre had the capacity to inculcate much knowledge in visitors. When learners reach a point where they can form relations between their lives and what they learn, they have achieved conceptual knowledge (see Chapter 2 of this study).

The results show that 99,0 % of the respondents could relate what they encountered at the Science Centre with their everyday lives.

v31	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	112	29.87	112	29.87
2	16	4.27	128	34.13
3	243	64.80	371	98.93
4	2	0.53	373	99.47

5                      2                      0.53                      375                      100.00

**Table 8.56. Analysis of Item 31 of Information on Science Centre Learning**

When they had to motivate their statements, the respondents could identify the use of solar panels, interestingly the use of mirrors in beauty shops and hair salons.

**8.4.32. I consider visiting the Science Centre again because it offers me an opportunity for doing practical work on my own (Item 32)**

Items 32 – 34 were aimed at grading the purpose of the visits according to the learners' views. The aim of this research was to be achieved by addressing various objectives. One of the objectives was to establish the extent to which the Science Centre contributed to the cognitive, affective and the psychomotoric skills of learners (Objective a(i), (ii) and (iii) of this study reflected in Chapter 1).

v32	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	355	94.67	355	94.67
2	14	3.73	369	98.40
3	6	1.60	375	100.00

**Table 8.57. Analysis of Item 32 of Information on Science Centre Learning**

From the tabulated statistical analysis listed above it is clear that 95,0 % of the respondents would consider visiting the Science centre again purely because of the opportunity granted for handling and interacting with exhibits.

The Spearman Correlation Coefficient between items 29 and 32 is 0,7901. The subjects of this study did see the Science Centre as a place where they could sharpen their practical skills (item 29) and they confirmed that they would visit the Science Centre again for the same benefit. The value of the coefficient is larger than 0,5 which indicates that the correlation between the two items is statistically significant and practical. Therefore a science centre can be seen as a place where handling skills (psychomotoric skills) of visitors are not only gained but improved as well.

**8.4.33. I will visit the Science Centre again because I gain scientific knowledge** (*Item 33*)

As discussed in item 32, item 33 also covers the cognitive aspect of the objective of the study (Chapter 1). Of the respondents 98,0 % would certainly have visited the Science Centre again because of the benefit the Centre offers in terms of the scientific knowledge. The results are shown hereunder:

v33	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	342	91.20	342	91.20
2	28	7.47	370	98.67
3	5	1.33	375	100.00

**Table 8.58. Analysis of Item 33 of Information on Science Centre Learning**

Item 28 of the questionnaire asked if the visit to the Science Centre improved learners' scientific knowledge or not. Since the two items probed scientific knowledge gained by visiting the Science Centre, the correlation could be expected. The statistical analysis revealed that there is a correlation between the two items in that the coefficient,  $r$  yielded 0,9237. Because this figure is larger than  $r = 0,5$ , it proves that the correlation is significant and practical. The respondents answered consistently in the two items, which could mean that they gained scientific knowledge in interacting with exhibits in the Science Centre.

**8.4.34. I will visit the Science Centre again because I enjoy/love the environment** (*Item 34*)

The third aspect of objective (a) of this study concerned the affective domain of Bloom's Taxonomy. Of the respondents 65,0 % said that they would visit the Science Centre again because of the affective benefits of such a visit. On the other hand 33,0 % agreed with reservations on the item. The results are indicated below:

v34	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	141	37.60	141	37.60
2	122	32.53	263	70.13
3	103	27.47	366	97.60
4	8	2.13	374	99.73
5	1	0.27	375	100.00

**Table 8.59. Analysis of Item 34 of Information on Science Centre Learning**

Item 23 probed the perception of learners about the Science Centre with regard to the affective domain of Bloom’s Taxonomy. Therefore the correlation between items 23 and 34 was calculated, yielding a value of  $r = 0,5494$ . This value according to Ellis and Steyn (2003: 52) indicates that the relation between the two items is statistically significant and practical since it is larger than 0,5.

Literature has it that it is the elements of this domain that impact on the other two domains. The third strategy envisaged by the Department of Science and Technology (DST) covers the affective domain of Bloom’s Taxonomy and it is also embedded in one of the premises of the theory of constructivism on lifelong learning. Although the ultimate outcome of science education within the affective domain cannot be reached during the formal education phase, the outcomes become evident when the individual appreciates and attaches value to the systematic approach in science application and problem solving (Krathwohl *et al.*, 1964: 165).

The strategy depicts the character of constructivism as it advocates for lifelong learning. According to the strategy, learners who are exposed to science centres should be attracted to follow careers that are science related. It is during this lifelong learning process that individuals expose the affective dimension and outcomes of the learning domain (Krathwohl *et al.*, 1964: 165). According to Vygotsky (1978: 67) the lifelong process of learning is dependent on social interaction between individuals, a fact which Bencze and Lemelin (2001: 153) consider vital for the intellectual riches and *holistic* development of science learners (Chapters 1 and 5 of this study).

**8.4.35. I will not visit the Science Centre again (Item 35)**

This is an item that tested the impression the Science Centre made on the learners. The results of this item should be read with the results of *item 25* in mind. Item 25 was concerned about the value of visiting the Science Centre. Of the respondents 99,0 % of the respondents showed that they would visit the Science Centre again due to the benefits mentioned.

v35	Frequency	Percent	Cumulative Frequency	Cumulative Percent
4	38	10.16	38	10.16
5	336	89.84	374	100.00

**Table 8.60. Analysis of Item 35 of Information on Science Centre Learning**

The correlation between the response to item 35 and those of items 25, 32, 33 and 34 was calculated. The coefficient revealed that learners appreciated the visits to the Science Centre as there was consistency in responding to these items of the questionnaire. The r value for this correlation is 0,5803 and confirms what has been said about the consistency of the response in the five items (Ellis & Steyn, 2003: 52). Learners would have visited the Science Centre again because they firstly gain scientific knowledge (cognitive skills). Secondly the Science Centre benefitted them because of the gaining and improving of their handling skills (psychomotoric skills). Thirdly the Science Centre had an appealing feel to the learners (affective skills).

**8.4.36. Conclusion**

From the analysis of the statistical results one may arrive at the following conclusions:

- ❖ *Items 9, 30 and 31* of the learners’ questionnaire in this study probed learners’ conceptual knowledge with regard to the acquisition of scientific knowledge through interaction with exhibits. As discussed in Section 2.6 of this study, conceptual knowledge is the type of knowledge that deals with schemas and mental models in

different cognitive psychological models. Conceptual knowledge is rich in relationships and understanding. It is a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information (Anderson *et al.*, 2001: 48).

The response in these items revealed that the Science Centre has that capability to accord learners (visitors) the opportunity of acquiring conceptual knowledge and indeed contribute to this. The evidence of this acquisition is seen in two ways. Firstly from the positive shift in academic achievement between the pre and post tests. Secondly from the ability in learners to relate prior knowledge and *new* knowledge encountered through interaction with exhibits, to identify, analyse and solve problems (*Items 8, 9 and 10* of the questionnaire). This leads to what is referred to as meaningful learning, learners own the knowledge as they have constructed it.

❖ The first objective (objective a) of this study as mentioned in Section 1.2 was about the three learning objectives, the cognitive, affective and psychomotoric domains classified as Bloom's Taxonomy. The questionnaire of this study was designed such that the items covered the spectrum of the three learning domains.

However, *items 32, 33 and 34* summarized the questionnaire in that the items asked for learners' conviction about the reason why they would visit the Science Centre again. The reasons cited constitute the aim of this study, in that learners mentioned that they would visit the Science Centre because of the Science Centre with its conducive atmosphere offered them an opportunity to enhance their practical skills (*item 32*; psychomotoric domain).

Of the respondents 93,0 % indicated that they would visit the science centre again because of the scientific knowledge they gain by interacting with the exhibits (*item 33*; cognitive domain). The responses to the questions that assessed the affective (*item 34*) showed that 98,0 % of the learners are emotionally attached to the science centre as they like the atmosphere.

Therefore the responses to these items (*items 32, 33 & 34*) address the aim of this study, *assessing the impact science centres have on the holistic development of learners.*

❖ The Science Centre can and should be used as a vehicle for science learning as it provides opportunity for learners to continue to learn new things (*items 4 and 26*). Therefore it serves as an agent for life-long learning. According to the statistical results 90,0 % of the respondents to item 26 confirmed that due to the influence aroused by the visit to the Science Centre they would like to pursue careers related to science.

This findings are in line with the goals set by the Department of Science and Technology (DST, 2004). The two goals as mentioned in Section 5.2 of this study encompass amongst others, research and development and other determinants of innovation, for instance, highly skilled human capital for research and development. The strategy to achieve the two goals rests on the sustainable diverse influx of school learners into diverse science careers.

Therefore it becomes evident that the Department of Science and Technology should use the development of science centres as a vehicle to attain the desired outcomes and goals.

In the next paragraph the summary of the response is tabulated.

The frequency of the responses of learners' questionnaire is summarised in Table 8.61 hereafter. The Likert 5-point scale was used to answer the items of the questionnaire (see Section 7.5.3). The following key was used to respond to corresponding items of the questionnaire: *1 = Strongly agree, 2 = Agree with reservation, 3 = agree, 4= Disagree and 5 = Strongly disagree with the statement.*

Item	Statement	1	2	3	4	5
1	It was my experience that after a visit to the science centre, I understood science better	171	23	180	1	0
2	The atmosphere/environment in the science centre	119	17	239	0	0

	stimulates or promotes my scientific thinking.					
3	I like Physical Sciences more after the visit to the science centre	173	17	184	1	0
4	I have learned new things in the science centre	244	6	122	3	0
5	I have learned how to investigate things in a science centre	219	15	130	9	1
6	The experiments I have conducted in the science centre demand/require understanding	260	12	101	2	0
7	The science centre gave me the opportunity to learn by doing experiments on my own	257	14	103	1	0
8	In the science centre I have learnt to identify a problem	207	17	134	15	2
9	In the science centre I have learned to find answers to problems	106	32	224	8	5
10	The science centre helped me to analyze problems	95	22	246	9	3
11	I could easily collaborate (work) with my peers/friends in the science centre	304	10	58	3	0
12	Working in a small group of 2 – 5 in science experiments in the science centre is pleasant/impossible/not recommended	354	7	12	1	1
13	It is boring in the science centre	0	1	1	58	315
14	I did not learn anything in the science centre	2	0	1	33	339
15	I think that the experiments in the science centre will help me to become creative in science	144	7	224	0	0
16	Because of the experiments conducted in the science centre I developed a positive attitude towards Physical Sciences	173	14	187	1	0
17	The visits to the science centre taught me to concentrate while doing science	193	13	169	0	0

18	The visits to the science centre have developed my understanding in science	206	13	156	0	0
19	The visits to the science centre have developed my skills to handle apparatus	152	22	196	4	1
20	Before the visit to the science centre I had problems to execute experiments on my own	42	120	113	85	15
21	I have enjoyed the visit to the science centre	163	8	204	0	0
22	I see a science centre as a place for learning science	192	17	166	0	0
23	A science centre is a place for entertainment	192	14	156	9	4
24	The experiments in a science centre captured my interest for the entire visit to the science centre	225	15	131	3	1
25	A visit to the science centre is worthwhile	219	25	131	0	0
26	The visit to the science centre motivated me to pursue my studies after grade 12 in science	186	28	153	7	1
27	I would like to work in an environment such as a science centre	146	11	207	8	3
28	The visit to the science centre has improved my scientific knowledge	154	28	191	1	1
29	I see a science centre as a place where I can sharpen my handling skills in apparatus	103	28	241	2	0
30	I could easily relate the experiments that I conducted in the science centre with the science we study at school	119	11	241	2	2
31	The experiments in the science centre relate to my everyday life experience	112	16	243	2	2
32	I consider visiting the science centre again because practical work	355	14	6	0	0
33	I will visit the science centre again because because of scientific knowledge	342	28	5	0	0
34	I will visit the science centre again because of its	141	122	103	8	1

	atmosphere					
35	I will not visit the science centre again	0	0	0	38	336

**Table 8.61: Frequency table of the learners' responses**

In the following section the learning gain scores acquired from the pre- and post-test results are tabulated and discussed.

## **8.5. LEARNING GAIN SCORE**

### **8.5.1. Reliability of the pre-test**

As discussed in Section 7.5.3 of this study, part of the data was collected in the form of pre- and post tests administered to both the control and experimental groups. It is essential to ensure that the instruments used for data collection in research are reliable. The reliability of the pre-test was tested by means of the Cronbach's Alpha calculation. The calculations refer to the level of knowledge of the experimental and control groups before the treatment phase. The intention was to ensure that the sample taken was the same, hence the reliability of the test.

The statistical analysis of the reliability test results are tabulated and discussed hereafter:

Summary for scale: Mean=4.22296 Std.Dv.=2.19009 Val Cronbach alpha: .712207 Standardized alpha: .684623 Average inter-item corr.: .129031					
variable	Mean if deleted	Var. if deleted	StDv. if deleted	Itm-Totl Correl.	Alpha if deleted
Q1.1.b	3.257677	4.567781	2.137237	0.241273	0.706188
Q1.1.c	4.169559	4.349086	2.085446	0.416339	0.691766
Q1.1.d	4.212283	4.669221	2.160838	0.248252	0.708951
Q1.1.e	4.221629	4.775980	2.185402	0.079946	0.715094
Q1.1.f	3.401869	4.061465	2.015308	0.376554	0.690037
Q2.a	3.576769	3.782157	1.944777	0.419020	0.684737
Q3.a.	3.692924	3.644022	1.908932	0.470722	0.675920
Q3.b	3.813084	3.583220	1.892940	0.518264	0.666946
Q3.c	3.967957	3.742631	1.934588	0.508447	0.669474
Q1.a	4.049399	4.036278	2.009049	0.401076	0.686700
Q1.d	4.213618	4.726063	2.173951	0.130874	0.713078
Q2.a	4.170895	4.657043	2.158018	0.087260	0.716959
Q3.a	4.090788	4.266791	2.065621	0.292012	0.700529
Q3.b	4.221629	4.778651	2.186013	0.063198	0.715296
Q1.a	4.061415	4.236549	2.058288	0.275948	0.703116

**Table: 8.62: Cronbach's Alpha variables**

A value that equals 0,7 indicate statistical significance. The Cronbach Alpha value for the reliability of the test is 0,712207. Therefore the value calculated reveals that the test was reliable because it gave a figure which is more than 0,7 (Nunnally & Bernstein, 1994: 294).

Therefore the conclusion drawn from the observation is that the two groups were at the same level and none of the groups were at an advantage prior to the treatment phase. This is evident from the scores obtained during the pre-test phase of the research in the two groups.

### **8.5.2. Presentation of the pre-test scores: Experimental group**

The learning gain scores (Pre-test) of the experimental group are tabulated hereunder:

Experimental Group	Pre-Test Scores				
	School A	School B	School C	School D	School E
Learner per school					
1	9	4	20	11	21
2	18	3	10	4	13
3	14	10	20	4	14
4	15	5	11	11	11
5	13	9	20	16	13
6	14	19	8	33	5
7	13	5	4	34	16
8	14	15	15	6	9
9	10	10	4	16	5
10	13	18	13	19	8
11	21	8	25	11	9
12	9	28	9	19	2
13	13	3	13	9	16
14	15	2	10	11	14
15	21	3	6	20	11
16	19	2	15	26	8
17	20	5	18	11	15
18	15	8	14	2	13
19	25	8	14	14	16
20	20	3	16	24	20
21	10	6	33	4	25
22	14	2	6	5	3
23	29	15	13	14	10
24	14	3	15	6	20
25	14	3	18	6	11
26	13	3	5	3	9
27	23	5	9	11	5
28	15	5	15	6	10
29	18	6	16	8	9
30	10	3	53	10	5
31	13	5	13	2	21
32	28	5	15	18	20
33	6	2	13	15	9
34	9	2	25	11	16
35	19	5	14	15	10
36	13	2	11	9	15
37	31	16	11	21	16
38	7	6	13	2	10
39	13	19	20	13	9
40	14	3	14	11	6
41	10	6	13	25	11
42	23	5	11	20	13
43	4	2	15	5	21
44	16	2	10	10	10
45	18	2	3	8	10
46	14	2	9	4	19

47	10	6	15	5	28
48	12	3	6	21	10
49	6	3	14	9	11
50	12	5	10	15	2
51	12	4	2	13	19
52	18	6	5	19	23
53	14	6	8	9	14
54	10	8	8	8	13
55	8	4	15	20	10
56	16	6	6	15	20
57	14	10	8	11	9
58	12	12	9	2	11
59	12	6	15	9	8
60	16	8	10	19	13
61	18	14	11	20	14
62	8	8	11	9	8
63	6	12	13	2	10
64	10	8	6	4	8
65	10	14	6	6	5
66	12	12	30	9	18
67	4	12	11	11	21
68	16	10	15	26	6
69	18	8	6	11	25
70	14	6	10	15	16
71	12	8	25	11	14
72	14	6	10	4	23
73	10	12	12	21	6
74	16	8	14	16	10
75	18	6	12	8	14

**Table: 8.63. Pre-test learning gain scores (Experimental Group)**

### 8.5.3. Presentation of the pre-test scores: Control group

The learning gain scores (Pre-test) of the control group are tabulated below:

Control Group Learner per school	Pre-Test Scores				
	School A	School B	School C	School D	School E
1	15	20	13	5	9
2	9	13	5	3	39
3	2	10	13	3	25
4	2	8	3	20	10
5	14	2	3	5	10
6	4	13	9	28	25

7	4	6	21	19	11
8	4	3	15	19	29
9	4	8	8	11	9
10	6	15	5	4	27
11	2	5	11	9	34
12	16	14	11	9	36
13	12	9	18	14	30
14	2	2	6	9	9
15	4	10	14	11	20
16	3	10	13	3	8
17	7	9	6	6	35
18	8	6	19	4	18
19	8	13	9	15	14
20	7	11	10	9	6
21	5	9	11	11	9
22	5	6	18	6	4
23	2	13	9	4	6
24	4	10	8	8	7
25	15	6	21	10	24
26	12	5	11	5	19
27	4	4	14	19	9
28	3	13	8	9	13
29	7	10	6	13	11
30	4	5	2	2	12
31	12	10	8	8	10
32	4	24	2	10	30
33	6	13	30	13	10
34	5	9	10	9	15
35	6	9	18	9	9
36	6	9	9	15	15
37	6	4	18	3	9
38	7	6	16	15	27
39	7	5	15	14	8
40	8	6	11	6	14
41	7	5	14	30	31
42	6	5	15	9	15
43	7	5	19	16	12
44	6	9	8	19	14
45	8	9	5	14	16
46	10	14	5	6	17
47	6	9	11	10	12
48	4	4	11	3	13
49	2	6	10	26	16
50	8	2	10	9	18
51	6	5	13	5	9
52	10	11	14	5	10
53	2	15	9	9	15
54	10	13	15	9	12
55	12	11	18	4	19
56	10	2	18	4	21

57	8	9	11	18	12
58	14	18	14	13	11
59	12	12	4	14	10
60	14	10	5	13	9
61	10	20	15	4	15
62	8	18	16	10	17
63	12	16	3	9	13
64	14	16	13	5	14
65	10	14	45	11	12
66	12	8	8	5	15
67	12	6	16	9	14
68	10	10	9	4	13
69	15	12	6	4	15
70	16	8	8	11	18
71	14	6	14	34	19
72	12	16	8	9	20
73	10	12	12	21	14
74	8	18	10	11	21
75	16	14	14	3	22

**Table: 8.64. Pre-test learning gain scores (Control group)**

**8.5.4. Analysis of scores (Pre-test)**

The pre-test results of the learning gain scores were analysed statistically by means of the SAS programme. The p- value for both groups as shown on the subsequent table is 0,174559 and the d- value is 0,10. According to Ellis and Steyn (2003: 51) these values are small and signify that the two groups (experimental and control) were at the same level before the treatment phase. The two values, p and d, verify the Cronbach's Alpha values discussed above.

Pre test

Variable	Mean	Mean	t-value	df	p	Valid N	Valid N	Std.Dev.	Std.Dev.	F-ratio	p
	CON	EXP				CON	EXP	CON	EXP	Variances	Variance
Pre-test	11.18933	11.85067	-1.35899	748	0.174559	375	375	6.635176	6.691769	1.017132	0.8696

**Table: 8.65. Summary on statistical analysis of pre-test**

### 8.5.5. Discussion of the post-test scores: Control group

After the two groups were subjected to the pre-test, the experimental group was taken for intervention in the Science Centre. Thereafter the post-test was administered to the two groups. The learning gain scores were recorded and analysed statistically. The post-test results of the control group are tabulated hereunder:

Control Group	Post-Test				
	Learner per school	School A	School B	School C	School D
1	14	8	15	2	11
2	8	14	4	1	41
3	8	8	12	3	21
4	3	6	2	16	8
5	6	9	3	3	11
6	3	14	5	34	20
7	3	3	18	25	9
8	6	3	16	16	24
9	5	9	7	15	7
10	9	10	5	1	31
11	4	6	12	8	33
12	12	9	9	6	38
13	9	10	18	11	30
14	2	3	8	9	7
15	3	6	10	12	21
16	6	7	13	3	10
17	9	10	3	5	38
18	8	13	21	6	16
19	7	13	7	18	14
20	5	9	8	7	4
21	4	11	12	14	9
22	3	6	21	3	2
23	5	9	7	2	5
24	3	7	8	6	6
25	18	8	19	9	20
26	9	8	9	3	17
27	3	5	15	22	5
28	5	5	8	6	11
29	9	12	4	11	12
30	6	5	5	2	12
31	13	12	6	5	8
32	7	3	2	8	33
33	6	4	42	15	8
34	4	2	13	8	12

35	5	6	23	9	9
36	8	6	10	11	11
37	9	2	15	3	7
38	6	10	14	13	27
39	9	7	16	10	6
40	10	7	9	5	10
41	6	3	16	27	34
42	7	2	18	5	11
43	5	4	22	8	9
44	9	7	5	20	5
45	8	5	6	16	7
46	6	9	8	11	11
47	9	7	9	7	9
48	4	5	7	2	5
49	5	4	11	33	2
50	6	4	9	7	11
51	5	3	15	5	4
52	9	12	12	6	6
53	3	12	7	8	11
54	9	13	13	11	9
55	11	8	23	3	13
56	12	3	20	4	17
57	5	7	9	20	6
58	18	13	9	13	12
59	9	12	3	18	10
60	6	9	2	14	8
61	7	12	7	6	11
62	6	16	11	7	12
63	15	12	1	9	11
64	12	18	4	3	14
65	8	12	38	9	11
66	7	7	5	6	15
67	9	8	12	7	10
68	8	7	9	2	9
69	8	9	3	1	12
70	17	7	5	9	18
71	16	2	11	33	21
72	12	16	9	5	12
73	8	13	5	19	5
74	8	10	7	15	4
75	19	13	6	6	14

**Table: 8.66: Post-test learning gain scores (Control group)**

The  $d$  – value of the learning gain score is 0,18 a figure too small to denote any statistical significance (Ellis & Steyn, 2003: 51). This value implies that there is no change in the control group as there was no treatment on the group. The table is given hereunder:

In CONTROL

T-test for Dependent Samples (Pre_post)								
Marked differences are significant at $p < .05000$								
Include condition: v3='CON'								
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Post-test	9.99467	6.939384						
Pre-test	11.18933	6.635176	375	-1.19467	3.427160	-6.75038	374	0.000000

$\alpha=0.18$

**Table: 8.67: Mean and d-values for the control group**

### 8.5.6. Discussion of the post-test scores: Experimental group

The following table enlists the learning gain of the experimental group:

Experimental Group	Post-Test				
Learner per school	School A	School B	School C	School D	School E
1	33	17	35	39	49
2	52	25	28	20	29
3	42	22	43	25	26
4	51	17	37	42	28
5	29	19	49	38	34
6	24	35	33	65	20
7	36	33	36	72	36
8	39	56	40	18	12
9	42	22	29	46	18
10	56	39	55	52	19
11	54	45	49	33	25
12	26	55	36	45	19
13	36	19	44	9	39
14	38	17	45	21	39
15	41	16	25	46	39
16	50	28	16	56	24
17	49	31	22	29	29
18	41	29	48	22	33
19	68	38	12	48	56
20	52	39	30	46	42
21	12	25	55	18	54
22	38	29	18	25	27
23	51	45	13	52	19
24	33	39	43	26	33
25	36	33	55	19	24
26	45	35	33	23	18
27	56	39	29	15	14

28	46	42	35	19	22
29	45	46	35	14	19
30	22	48	88	22	22
31	39	17	18	12	54
32	52	18	41	25	42
33	18	19	44	30	19
34	9	20	59	34	35
35	26	42	42	46	22
36	25	35	33	36	36
37	42	36	34	49	49
38	31	38	36	25	22
39	25	40	45	49	22
40	25	29	35	42	26
41	26	29	48	52	39
42	31	38	33	49	25
43	16	37	56	39	45
44	29	29	45	25	22
45	33	27	19	43	19
46	33	29	40	24	23
47	25	33	54	26	56
48	29	48	34	49	29
49	36	49	10	25	28
50	36	29	24	39	26
51	34	28	16	39	33
52	52	29	35	49	53
53	63	32	39	42	52
54	42	29	41	15	41
55	19	32	39	56	46
56	39	33	42	62	25
57	48	31	44	31	9
58	42	41	58	21	25
59	25	38	52	24	28
60	43	39	45	35	45
61	45	45	44	46	28
62	21	21	38	21	41
63	18	39	46	6	40
64	19	35	29	16	58
65	25	39	13	25	26
66	23	33	49	15	39
67	18	42	19	29	59
68	39	39	39	62	25
69	45	39	24	42	69
70	42	24	36	39	36
71	49	29	62	25	23
72	48	38	48	49	52
73	42	34	36	48	50
74	45	36	29	49	24
75	52	34	39	33	35

**Table: 8.68: Post-test learning gain (Experimental group)**

The calculated d- value for the post-test of the experimental group is 3,5. According to Ellis and Steyn (2003: 51) the ranges  $d = 0,12$  is a small value which shows no statistical significance and  $d = 0,5$  is a medium value that signifies a statistically visible change or impact. However a d value that equals 0, 8 is large and denote statistical significance. The value of 3,5 is larger than 0,8 which means that the treatment or intervention of the experimental group was significant as it yielded a positive shift on the post-test results.

In EXP

T-test for Dependent Samples (Pre_post)								
Marked differences are significant at $p < .05000$								
Include condition: v3='EXP'								
Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df	p
Post-test	35.06933	12.79185						
Pre-test	11.85067	6.69177	375	23.21867	10.05520	44.71590	374	0.00

$d=3.5$

**Table:8.69: Mean and d-values for the experimental group**

The breakdown on the performance per item of the post-test questions is tabulated and discussed in the subsequent subsection.

### 8.5.7. Breakdown and Analysis of the questions (Post-test entries: Experimental group)

Section	Question	Description	No. of correct entries
1. Mechanics	1.	Steel balls on tracks	
	1.1.a		300
	1.1.b		325
	1.1.c		180
	1.1.d		178
	1.1.e		125

	1.1.f		125
	<b>2.</b>	<b>Feathers in 2 glass columns</b>	
	2.a		
	<b>3.</b>	<b>Linear air track</b>	
	3.a		315
	3.b(i)		123
	3.b(ii)		310
	3.c		225
<b>2. Electricity &amp; magnetism</b>	<b>1</b>	<b>Zn - Cu electric circuit</b>	
	1.a		208
	1.b		205
	1.c		104
	1.d		102
	<b>2.</b>	<b>Forks in magnetic field</b>	
	2.a		318
	2.b		216
	2.c		194
	<b>3.</b>	<b>Magnet &amp; rotating disc</b>	
	3.a		220
	3.b		98
<b>3. Optics</b>	<b>1</b>	<b>Real object vs. number of images on different planes</b>	
	1.a		336
	1.b		280
	1.c		265

**Table 8.70: Breakdown of correct entries on post-test (Experimental group)**

### **8.5.8. Discussion on breakdown of results**

The problems identified with the responses to Section 1, (mechanics), is that learners could not draw the corresponding acceleration–time graph from the velocity–time graph. The other challenge was the understanding of the linear air track.

Prior to the Science Centre visit, learners associated the reading on the ammeter (Section 2) to a number of possibilities. Some said it was due to the weight of the two boys (Question 1.b). Others attributed the difference in the ammeter reading to the pressure and the size of the arms of the two boys performing the experiment. Lack of conceptual knowledge was therefore a problem.

The problem on the same question was the lack of conceptual knowledge. This was evident when learners could not describe and give examples of electrolytes.

### **8.5.9. Conclusion**

The conclusion can therefore be drawn from the results that the Science Centre is effective as a means of science learning. It further means that science centres impact on the cognitive development as well as the affective and psychomotoric skills of learners or visitors. This is evident from the results obtained from the post test scores of the experimental group and the responses obtained to the items of the questionnaire. Therefore a science centre is a suitable tool for developing learners in a holistic manner.

The next section tabulates the biographic information of teachers whose learners participated in this study. However the biography is only of teachers whose learners constituted the experimental group of the study.

## 8.6. TEACHERS' DEMOGRAPHIC INFORMATION

The demographic information of teachers is discussed hereunder in terms of the statistical frequency table per item.

### 8.6.1. Name of school (*Item 1*)

The results indicate that there were two teachers who were engaged in the FET-band teaching grades 10 to 12. There was only one school where a teacher was in charge of the phase. The issue of the distribution of the work load seemed to have been considered in the allocation of the number of classes and learners per teacher at a school.

v1	Frequency	Percent	Cumulative Frequency	Cumulative Percent
1	2	22.22	2	22.22
2	2	22.22	4	44.44
3	1	11.11	5	55.56
4	2	22.22	7	77.78
5	2	22.22	9	100.00

**Table 8.71. Analysis of item 1 of Teachers' Biography**

### 8.6.2. Name of province (*Item 2*)

As it was mentioned in Section 7.5.1 of this study the experimental group consisted of the learners of the five high schools in Ikageng in the NorthWest province. The statistical results revealed that 100,0 % of the teachers participating in this study were members of the local schools.

### 8.6.3. Gender (*Item 3*)

Males constituted two thirds of the total population of this study. Perhaps this is due to the fact that the the FET-band is dominated by males and/or that more males than females opt for science education careers.

v3	Frequency	Percent	Frequency	Percent
1	6	66.67	6	66.67
2	3	33.33	9	100.00

**Table 8.72. Analysis of item 3 of Teachers' Biography**

**8.6.4. Teaching experience in years (Item 4)**

The results revealed that teachers in the five high schools were fairly experienced in the classroom. There were only 11,0 % of the teachers who had a minimum of 4 years experience in teaching. A larger number (44,0 %) had between 7 and 10 years of teaching experience. An equal distribution of 22,0 % each had been exposed to the classroom for 11 – 14 years and more than 15 years.

v4	Frequency	Percent	Frequency	Percent
2	1	11.11	1	11.11
3	4	44.44	5	55.56
4	2	22.22	7	77.78
5	2	22.22	9	100.00

**Table 8.73. Analysis of item 4 of Teachers' Biography**

**8.6.5. Grades currently teaching (Item 5)**

The study focused on the holistic development of Physical Sciences learners who were in grades 10 – 12 at the five identified schools. Therefore the teachers were also teaching the same grades during the period of the study. The statistical results are presented in the following table:

	Grade 10	Grade 11 & 12	Grade 12	Grades 10 - 12
Number of teachers teaching grade(s)	4	1	1	3

**Table 8.74: Distribution of grades taught by teachers**

#### **8.6.6. Experience in science teaching (Item 6)**

Responses to item 6 indicated that the experience in science teaching of the teachers ranges from 4 years to 10 years.

#### **8.6.7. Qualification in Physical Sciences (Item 7)**

Teachers who participated in this study met the basic requirements as stipulated by the Department of Education. The entry level of a teacher is suggested to be matric and a three year teacher training diploma (M+3). However, there is growing concern that the entry level should be raised to matric and an additional four years of training (M+4) (DoE, 2003).

The indication was that 33,0 % of the teacher population countrywide were still on the lowest level of the requirement, a point of concern to the Department of Education.

#### **8.6.8. Level/nature of qualifications (Item 8)**

Of the teachers who participated in this study 33,0 % were holding either a Secondary Teachers Diploma or University Education Diploma, while 56 % were holding a Higher Education Diploma, or an Advanced Certificate in Education which is a minimum requirement according to the Department of Education. Only one (11,0 %) was holding a Degree in Education.

v8	Frequency	Percent	Frequency	Percent
1	3	33.33	3	33.33
2	5	55.56	8	88.89
3	1	11.11	9	100.00

**Table 8.75: Analysis of item 8 of Teachers' Biography**

### 8.6.9. Visit to the Science Centre (*Item 9*)

The schools that participated in this study were in the catchment area of the Science Centre. However, only 78,0 % of the teachers had visited the Potchefstroom Science Centre prior to the study. An investigation further revealed that the 22,0 % that had not visited the Science Centre teach grade 10s and lower grades. This is discussed in the next chapter (Chapter 9).

v9	Frequency	Percent	Frequency	Percent
1	7	77.78	7	77.78
2	2	22.22	9	100.00

**Table 8.76: Analysis of item 9 of Teachers' Biography**

### 8.6.10. Which science centre have you visited? (*Item 10*)

Teachers who indicated that they were in the Science Centre before, identified the Potchefstroom Science Centre as the centre they had visited.

In the next section the responses on the questionnaires by teachers are discussed. The researcher aimed at getting feed-back from teachers about the development of their learners after intervention. Teachers' reflections on the questionnaire are presented hereunder.

## 8.7. TEACHERS' QUESTIONNAIRE

The teachers' convictions and observations are presented per item according to the statistical frequency tables.

### 8.7.1. Shift in academic achievement (*Item 1*)

Teachers responded that after the intervention they had noticed a positive change in their learners' academic performance. The teachers' reports on learners' academic achievement correlate with learners' responses on *items 1, 4, 18, 22, 28 and 33* of the learners' questionnaire. The items cited refer to the cognitive development of learners through the interaction with exhibits. The items ranged from learners' understanding, to improvement of scientific knowledge.

v1	Frequency	Percent	Frequency	Percent
1	6	66.67	6	66.67
2	1	11.11	7	77.78
3	2	22.22	9	100.00

**Table 8.77: Analysis of item 1 of Teachers' Questionnaire**

### 8.7.2. Motivated to pursue studies in science (*Item 2*)

From *items 26 and 27* of learners' questionnaire 90,0 % and 94,0 % of the respondents agreed that the Science Centre had played a role in motivating them to pursue studies in science. In relation to this, 77,0 % of the teachers agreed that there had been an interest in pursuing science related careers as a result of the visit to the Science Centre.

v2	Frequency	Percent	Frequency	Percent
1	3	33.33	3	33.33
2	2	22.22	5	55.56
3	4	44.44	9	100.00

**Table 8.78: Analysis of item 2 of Teachers' Questionnaire**

### 8.7.3. Improvement in physical skills (*Item 3*)

Of the teachers 88,0 % reported to have witnessed an improvement in the learners' practical skills after the visit to the Science Centre. This is in agreement with the results of the related items in the learners' questionnaire (*Items 7, 19, 29 and 32*). The learners responded positively in these items in that the percentage ranges from 92 – 93 %.

v3	Frequency	Percent	Frequency	Percent
1	4	44.44	4	44.44
2	1	11.11	5	55.56
3	4	44.44	9	100.00

**Table 8.79: Analysis of item 3 of Teachers' Questionnaire**

#### 8.7.4. Change in attitude (Item 4)

The one aspect that critical affects learning and knowledge acquisition according to literature, is the affective domain (Chapter 4, 5 and 6 of this study). The responses of the teachers reflected that the Science Centre had the ability to change learners' attitude. All teachers confirmed that a positive shift in attitude was observed amongst their learners. As was reported, above 96,0 % of the learners had confirmed that they had experienced a change in attitude due to the Science Centre visit (Items 3 and 16 of learners' questionnaire).

v4	Frequency	Percent	Frequency	Percent
1	4	44.44	4	44.44
3	5	55.56	9	100.00

**Table 8.80: Analysis of item 4 of Teachers' Questionnaire**

It was stated in Chapter 6 of this study that learners who show *enjoyment of the learning experience*, learn better, they learn more and remember longer because they find pleasure in the learning experience. Klopfer (1971: 578) assert that Physical Sciences provide learners with opportunities to find pleasure in learning, that include discovering new relationships, explanations, generalizations and discussions. This aspect is helpful to teachers, peers, parents and other stakeholders in the education of a learner because learners who enjoy their learning experience in science will express their feelings either in words or in actions.

**8.7.5. Science Centre helped to promote independent thinking (Item 5)**

When asked to express their convictions about conducting experiments on their own after the visit to the Science Centre, 95,0 % of the learners affirmed the situation (item 7 of learners' questionnaire). On the other hand 67,0 % of the teachers noted independent work amongst the learners since their learners visited the Science Centre.

v5	Frequency	Percent	Frequency	Percent
1	1	11.11	1	11.11
2	3	33.33	4	44.44
3	5	55.56	9	100.00

**Table 8.81: Analysis of item 3 of Teachers' Questionnaire**

**8.7.6. Application of knowledge in everyday life (Item 6)**

The ability to apply acquired knowledge in every day life situations is a sign that one has acquired conceptual knowledge and hence meaningful learning (see Chapter 4 of this study). In their responses 66,0 % of the teachers agreed to have observed this change in their learners as a result of the impact of the Science Centre. Of the teachers 33,0 % agreed with reservations to the statement. This item correlates with *item 31* of the learners' questionnaire where 94,0 % of the learners attested to the ability to relate new knowledge to everyday life situations.

v6	Frequency	Percent	Frequency	Percent
1	2	22.22	2	22.22
2	3	33.33	5	55.56
3	4	44.44	9	100.00

**Table 8.82: Analysis of item 3 of Teachers' Questionnaire**

**8.7.7. Planning of scientific inquiry (Item 7)**

Item 5 of learners' questionnaire probed whether science centres could lead learners to acquire the skills of investigating. According to the frequency table of the learners' responses, 93,0 % confirmed that the Science Centre had helped them acquire the skill.

The table hereunder confirms the learners’ response as all teachers agreed to have identified such a skill amongst the learners.

v7	Frequency	Percent	Frequency	Percent
1	2	22.22	2	22.22
3	7	77.78	9	100.00

**Table 8.83: Analysis of item 3 of Teachers’ Questionnaire**

One teacher commented that his learners did further research and that they even started to debate about the latest scientific inquiry. The National Curriculum Statement (DoE, 2005) states that learners’ tasks should focus on the ability to use scientific processes and inquiry skills to solve problems in a variety of scientific and technological contexts (Learning Outcome 1). In this graded assessment learners sharpen their motor skills whilst they also gain cognitively (Sherphard & Britsch, 2001: 120). This is in accordance with Chapter 6 of this study.

According to Klopfer (1971: 577) a learner who displays acceptance to the process of *scientific inquiry* has a particular way of thinking and will follow scientific methods to perform scientific processes. Learners who show this kind of attitude towards scientific inquiry commit themselves to the subject.

### **8.7.8. Learners can assume leading roles in practical work (Item 8)**

In the survey 89,0 % of the teachers agreed that the Science Centre instilled leadership capability in learners. This item probed the effect science centres have on the affective domain in learners. When learners are motivated they will assume leading roles when they participate in performing tasks. They will also become interested in participating when tasks are to be carried out.

### **8.7.9. Reflection on experiences in the Science Centre (Item 9)**

The following comment was received from a participating teacher: *“when treating a science concept they (learners) will always reflect on their experiences encountered in the Science Centre. This is done by comparing the relevance of the concept to what they have learnt from the Science Centre”*.

The responses of the teachers on this item reflected that 89,0 % noted the impact the Science Centre had on learners' development.

### **8.7.10. Connection between science and the world (Item 10)**

This item was included to test the consistency with which teachers responded to the items. There is a relation between this item and item 6. Two thirds of the teachers agreed in item 6 that their learners could apply the knowledge gained from the Science Centre in everyday life. In this item, 89,0 % said that their learners, since their visit to the Science Centre could see the connection between science and the real world.

There is consistency in the responses to the two items. The two items also relate to item 3 of the learners' questionnaire. In their responses 95,0 % of the learners agreed that the Science Centre played a role in helping them to identify the connection between science and the real world.

### **8.7.11. Benefits brought by Science Centre (Item 11)**

*“Just before they visited the Science Centre learners lacked interest in science because they only learnt about things they did not see. But when they saw and interacted with the apparatus (exhibits) they started to realize the wonder of science. Learners are now proud to have chosen physical science as a subject”*. These are the words cited by one teacher on his questionnaire. This comment reflected more on the practical and affective domains of learning.

The analysis of the response to this item is done with reference to learners' item 32 – 34 on a table hereunder.

<b>Learning Domain</b>	<b>Learners %</b>	<b>Teachers %</b>
Psychomotoric	96	44
Cognitive	92	22
Affective	65	33

**Table 8.84: Comparison of learners' and teachers' responses**

Top of the list of benefits the Science Centre is, according to both teachers and learners, the opportunity granted to perform practical work/experiments on your own. This observation confirms the statements found in the literature, that practical work is essential in science teaching and learning (see Chapters 4, 5 and 6).

In the experimental group 96,0 % of the learners said that they would visit the Science Centre again because of the opportunity to perform experiments on their own. In the corresponding question 44,0 % of the teachers stated that the highest benefit of the Science Centre was the opportunity of doing practical work. The reasons, from the teachers' perspective, why this was so important varied from lack of resources at schools to inadequate or inappropriate strategies to conduct practical work (Rapule, 2005).

Teachers and learners held contrasting views with regard to the cognitive benefits of the Science Centre. In the experimental group of learners 92,0 % appreciated the scientific knowledge presented in the Science Centre, as opposed to 22,0 % of the teachers. This is not surprising in that teachers seemed to have understood that the factors that impact on cognitive development of learners were of affective nature (see Chapters 4, 5 and 6). Like Krathwohl *et al.*, (1964: 24), Sherphard and Britsch (2001: 121) consider the affective domain of Bloom's Taxonomy to be crucial in learning. They assert that in Physical Sciences learners should be assessed on their attitude towards science as factors of affective nature impacts on learners' progress. These factors are vital to learning as

they affect learners' interest, motivation and the will to participate in learning (Hamilton & Ghatala, 1994: 85).

Therefore if there is *willingness* (affective aspect) to learn, learners will pay attention and the cognitive as well as the psychomotoric skills will be active and in the receptive mode (Toh, 1991: 90, Koballa *et al.*, 1990: 370).

The percentage representation of the affective domain as shown in the frequency table (see Table 8.84) reflected 65,0 % for learners and 33,0 % for teachers.

The conclusions drawn from the teachers' responses to the questionnaire are given hereunder.

#### **8.7.12. Conclusion**

Judging from the teachers responses it becomes evident that the Science Centre has the capacity to develop learners in a holistic manner. This judgement is based on the following facts:

(1) The items of the teachers' questionnaire cover the three learning domains. More specifically, the questionnaires were assessing the impact science centres have on the holistic development of Physical Sciences learners (see Chapter 6 of this study). Of the responses, more than 66,0 % replied positively. As a result the responses affirm the hypothesis (see Section 1.3), and this contributes to the achievement of the objective(s) (see Section 1.2.2) and hence the aim of the study (see Section 1.2.1): *assessing the impact science centres have on the holistic development of learners*.

(2) Teachers' and learners' responses on related items, were consistent. This fact proved the reliability of the instruments used in this study. Therefore the instruments used in this study tested what they were intended to. The questionnaires revealed the role played by

the Science Centre in the development of cognitive, affective and psychomotoric domains of learning of science learners.

### **8.8. INTERVIEWS**

The interviews conducted with the teachers and learners who participated in this study were recorded on the video. Teachers were requested to reflect on the three learning domains that form the core focus of this study. The interviews supported the outcomes of the learners' and teachers' questionnaires.

### **8.9. CONCLUSION**

The next chapter seeks to give conclusions of the study by outlining the researcher's view on developing learners a in holistic manner (the first objective of this study). The chapter also addresses, from the information gathered in the empirical study, learning problems on which the Science Centre could have an effect. This outcome is in line with the second objective of this study. The chapter further seeks to address the third objective by suggesting effective ways for empowering science centres.

The chapter rounds off the discussion by recommending studies for further research.

## CHAPTER 9

### CONCLUSION AND RECOMMENDATIONS

*Great is the art of beginning, but greater is the art of ending (Lazarus Long)*

#### 9.1. INTRODUCTION

This chapter aims at presenting the concluding remarks and recommendations of the study based on the literature study (Chapters 1, 2, 3, 4, 5 & 6) and the empirical findings presented and discussed in the previous chapter (Chapter 8). The chapter will therefore address these by firstly focusing on the statistical results of the empirical survey conducted and presented in the previous chapter. In this chapter, by way of concluding, the statistical analysis together with the relevant literature and experience sought by the researcher (from interaction with respondents), is used to propose recommendations for further research in this field.

The conclusions as well as recommendations based of this study address the research hypothesis (*Science Centres impact positively on learners' holistic development in the Physical Sciences*) and the three objectives of the study (see Section 1.2.2), namely:

- (a) To determine the extent to which science centres contribute to the (i) cognitive; ii) affective and (iii) the psycho-motoric development of Physical Sciences' learners.
- (b) To identify problems associated with the learning of Physical Sciences by learners in a holistic manner, within the context of science centres.
- (c) To propose effective way(s) to empower science centres to be more effective in the development of a learner's physical science knowledge, with regard to the cognitive, affective and the psycho-motoric domains.

The envisaged conclusions and recommendations of the study will hence address the aim of the study; *investigating the impact science centres have on the learning of physical science in a holistic manner* (see Section 1.2.2).

## **9.2. STATISTICAL RESULTS AND ANALYSIS**

The initial stage of collecting data for this study was to identify the *learners' demographic information*. The important observation made in this part of data collection was that grade 10 learners did not participate significantly in the National Science Week activities (see Appendix 2: *items 8 & 9*). This fact is discussed in Section 9.6.

The second part of data collection entailed *information on learning* at various schools, particularly of the experimental group (see Appendix 3). It was observed that practical work was not done at schools, in spite of the fact that the teachers knew how important it was for the learning of Physical Sciences (see Appendix 3: *items 1, 2 & 4*).

Learners then completed the questionnaire (see Appendix 4) about their experiences in the Science Centre after the intervention phase of the experimental group. Learners reflected on the benefits brought about by the Science Centre in terms of the three learning domains, the cognitive, affective and psychomotoric skills.

The experimental as well as the control group were subjected to the pre- and post tests (see Appendix 1). The reliability of the test was verified by means of the Cronbach alpha statistical software (see Section 8.5.1 & Table 8.62). The academic performance of the two groups was measured before and after the visit of the experimental group to the Science Centre. The results proved that the experimental group performed better after the exposure to the Science Centre. The breakdown of results also proved the same fact (Table 8.12).

The last part of the data collection focused on the teachers' view about the role played by the Science Centre. Teachers' responses on the questionnaire (see Appendix 6) and interviews corresponded well with the learners' answers.

Data were collected and analysed so as to address the three objectives of this study (stated in Sections 1.2.2 & 9.1 of this study).

In section 9.3 the condensed findings of this study is summarised. This also illustrates how the results relate to the three objectives and hence the goal of this study.

### **9.3. CONDENSED FINDINGS**

The conclusions of the researcher about the contribution of the Science Centre in developing learners in a holistic manner are categorised according to the objectives (a), (b) and (c) of this study (see Sections 1.2.2 & 9.1). The first conclusion encompasses objective (a) which relates to the three learning/educational objectives classified by Bloom (1964) and Klopfer (1971), which form the core of this study:

#### **9.3.1. Cognitive**

The learners' responses to the questionnaire (see Section 8.4 & Appendix 4) and the learning gain scores obtained from the empirical study (Chapter 8) reveal that learners gained knowledge of facts, of principles and theories and insight into the application of knowledge in different situations by exposure to the Science Centre.

As discussed in Chapter 6, Dochy and McDowell (1997: 280) assert that the successful functioning of an assessment tool should seek to find specific skills in learners. These skills include the cognitive competencies such as problem solving, critical thinking, conducting observations, data analysis, assessing, generating ideas, evaluating and creating new things. Careful consideration of the skills mentioned above gives an indication that the skills cut across the various levels of the cognitive domain as set out

by Bloom and his collaborators (Bloom *et al.*, 1964: 21, Krathwohl *et al.*, 1954: 24). It is important that these listed skills are developed in the teaching and learning of Physical Sciences because without demonstrating evidence of competence in these skills, it is argued that learners cannot claim to understand related concepts. And sadly, without understanding of related science concepts, there is no meaningful learning (Ausubel *et al.*, 1968: 288, Hudson, 1994: 97).

Items 5, 7, 8, 9, 15, 30 and 31 of the learners' questionnaire (see Appendix 4) about the Science Centre focused on the cognitive competencies achieved through the interaction between learners and exhibits. The analysis indicated that the Science Centre has the capacity to empower learners with the said competencies.

Schunk (2000: 171) contends that these cognitive competencies are enhanced effectively when the context is learner centred. Therefore science centres place themselves at the fore-front of the constructivist approach of learning as learners (visitors) take charge of their own learning (see Chapter 4 of this study). In order to enhance cognitive skills optimally, learners should be allowed to design their own investigations. This strategy is in line with the principle of constructivism as it advocates for learners to be placed on the centre stage of their own learning. In the learning process learners are given freedom of interpretation.

To start a learning task in a learning context, such as a science centre for example, there must be a question or questions that stimulate or challenge their thought processes and interest so as to set their minds in a curious state (see Chapter 3). Learners will then most probably engage in cooperative learning and will start to reason and debate issues (Hudson, 1994: 71) (see Chapter 6).

From the learners' performance and researcher's observations, it is clear that the Science Centre does not limit/restrict itself to the lower order of cognitive development. It stretches the visitors' minds to evaluate, analyse and investigate phenomena. These are

the competencies of high order thinking according to the Taxonomy of Learning (Krathwohl *et al.*, 1954: 24).

### **9.3.2. Affective**

The competencies that encompass the affective domain of learning include: interest, attitude, intrinsic motivation, self-efficacy and preferences. In the questionnaire (Appendix 4) items 2, 3, 11, 13, 16, 21, 23, 25, 26, 27, 34 and 35 (recorded and discussed in Chapter 8) probed learners' conviction on affective issues. The responses show a positive change in attitude and interest as a result of exposure to the Science Centre. Teachers confirmed the learners' responses as they reported a significant change in learners' attitude, interest and motivation to pursue science related careers (*Items 2, 4, 8 & 11*).

It was mentioned in Chapters 2, 3, 4 and 6 of this study that components of the affective domain are the most crucial as they impact on the other two. Bjorklund (2005: 121) and Spear (1978: 2) hold the view that loss of interest in learners impact on the encoding process (Chapter 3) of the knowledge acquisition (Chapter 2). This viewpoint is supported by Klopfer (1971) in that he contends that learners are more proficient in cognitive operations like problem solving when they enjoy what they are doing. Affective traits, as they are called, are internal states that have a bearing on what learners are likely to pay attention to (see Chapters 3 & 6 of this study).

Unlike cognitive and psychomotoric skills, affective traits are difficult to measure (Thurstone & Chave, 1970: 24). However the responses to the questionnaire (both learners' and teachers') and the video footage show learners' excitement, interest and *will* to engage in meaningful learning tasks in the Science Centre.

### 9.3.3. Psychomotoric skills

Items 7, 19, 20, 29 and 32 of the learners' questionnaire (Appendix 4) and items 3 and 11 of the teachers' questionnaire (Appendix 6) probed into the psychomotor skills acquired by learners. The statistical analysis of the results indicated that the Science Centre has the capacity to empower visitors with practical skills.

According to literature, these skills involve the ability to carry out and coordinate a wide range of physical tasks. The psychomotoric skills involve the haptic memory, that is, the ability to hold knowledge from the physical world through interaction with material/apparatus in the short term memory (Adams, 1976: 256). In the process the muscles are coordinated by the brain to perform various tasks.

The observation and learners' responses from the questionnaire revealed that hands on interactivity enhance learning. On the other hand minds-on interactivity change behaviour towards learning and instil more confidence in learners. Learners become confident in practical skills because the psychomotor skills are permanently retained in the long term memory and become automatic due to interaction with exhibits (Knapp, 1963 quoted by Hudson, 1994: 103).

Hudson (1994: 104) asserts that psychomotoric skills become permanent because they are acquired by doing. Therefore if learners are accorded the opportunity to be minds-on and hands-on with exhibits they are sure to acquire these skills. Evidence from the observation and statistical analysis prove that the Science Centre renders itself useful for the task.

The subsequent section seeks to address the second objective (objective b) of the study: *To identify problems associated with the learning of Physical Sciences in a holistic manner within the context of the Science Centre.*

#### 9.4. LEARNING PROBLEMS ASSOCIATED WITH SCIENCE CENTRES

In engaging visitors hands-on, minds-on and affectively, science centres use two methods of interaction with exhibits. A science centre can opt for either the experience-based approach or the information-based approach (Ansbacher, 2005: 2). In the experience-based approach authentic objects, images or phenomena are made accessible to the visitors for exploration and inquiry. The primary goal of this approach is to engage visitors in interaction with exhibits by showing the sequence of the exhibit back and forth. The approach challenges the visitors to form a hypothesis while observing and their thinking is what connects one step of the sequence to the next. In this case labels and other forms of visible tags attached to the exhibits are used to support the engagement (Ansbacher, 2005: 2).

In the information-based approach, the primary goal is to present information verbally through labels and other media while the physical exhibit serves as an attractor to the label or an illustrative example for the label. In this approach the emphasis is laid on acquisition of information and scientific knowledge through interaction with exhibits. In this approach observation and hypothesis formulation occurs throughout the interaction as in the other approach but is enhanced by the acquisition of psychomotoric skills. As visitors are minds-on and hands-on during the interaction phase, thinking takes place where visitors work at understanding the information.

According to Dewey (1933) quoted by Ansbacher (2005, 2) information is an undigested burden unless it is understood. Therefore information becomes knowledge only as its material is comprehended. *The common problem associated with learning in a science centre therefore is that thinking is optional.* Because of this fact visitors may be exposed to information but make no effort to understand it.

The other problem associated with learning in a science centre is visual imparity due to overcrowding. Knowledge construction as discussed in Section 2.3 entails the interaction of a learner and the world/phenomenon around the learner. This self-constructed

knowledge is then brought to a learning context and is related to the relevant learning experience (Novodvorsky, 1997: 242; White, 1988: 117). Therefore it means that if there is visual disparity between the learner (visitor) in the Science Centre and the exhibit (phenomenon) that will impact negatively on successful construction of knowledge.

This fact is further supported in Section 3.8.3 in that research has proved that human beings remember information best when it is visually encoded. This could be because the capacity of the visual memory is unlimited. When information is visually encoded it is easily retrieved. The consolidation of the picturesque is enhanced by elaborate exposure to the stimuli. That is, when learners are exposed for a considerable amount of time to the scientific resources the visual memory will be improved. If the visual memory (iconic memory) is improved it directly relates to the encoding and retrieval process (Adams, 1976: 243, Smith & Jones, 1989: 8, Eysenck & Keane, 1995: 125).

Therefore it becomes imperative that it is more profitable if visitors to a Science Centre are exposed frequently and not once for a longer time span. The periods of visits depend on the visitors' concentration span. The periodical visits (according to the researcher's view) are in line with the principle of chunking and processing of information (Johnstone, 1997: 262, White, 1988: 32). Overloading of information is detrimental to the cognitive development of learners. It is for this reason that the researcher recommends a reflection session after the visit to the Science Centre (refer to Section 9.6).

In the next section the researcher proposes the recommendations for the effective operation of a Science Centre. This is done to address the third objective of this study: *to propose effective ways to empower science centres to develop learners' in a holistic manner.*

## **9.5. RECOMMENDATIONS: Effective ways of empowering Science Centres**

The Department of Science and Technology has raised concerns about the day to day running of science centres (DST, 2004: 2, Nursall, 2003: 381). Among the concerns is

the fact that science centres do not achieve their intended objective(s). Based on the results of the empirical study and observations during the treatment phase of the experimental group, the researcher proposes the following as a guide to an effective science centre visit:

- ❖ Divide learners into small groups of not more than five.

When learners work in large groups some members of a group become spectators and the level of contribution is minimised. The greatest challenge with large groups is control as it is indicated on the video that learners become very excited and spontaneous in the Science Centre environment and therefore spontaneously start discussing their predictions and interpretations about the experiment.

Large groups tend to obscure vision to the exhibits and members of the group will not be able to observe the processes and outcomes of the experiment. In support of this view Hodson (1998: 39) contends that conceptual change, hence conceptual development is made possible when learners understand the limitations of their current views and recognize the need to replace them. Therefore learners will understand their limitations if they personally interact with exhibits in the science centre and confront their pre-conceived ideas as they establish scientific concepts in the process. This fact addresses the contribution of science centres in developing the cognitive domain of learners. This cannot be achieved if there is impaired visual perception due to too many in a group attending to an experiment.

- ❖ Make use of a tour guide facilitator (Refer to video)

Although the Potchefstroom Science Centre and other science centres have been designed such that they are user friendly, that is, visitors should be able to tour the centre on their own and interact with exhibits individually, it became evident that a tour guide is necessary to assist school groups. However the guide should NOT assume the role of a

traditional teacher where he/she steals the show and position him/herself at the centre of the encounter.

The role of a guide should be to probe learners with questions based on their predictions and answers/explanations that they provide. This is very helpful in soliciting learners' alternative conceptions and the origin of these conceptions. Because the setting and environment in the Science Centre is learner-led, learner-centred and voluntarily (Wellington, 1990: 2480), learners are free to express their opinions and convictions about phenomena thereby revealing possible alternative conceptions.

Therefore it is essential that tour guides should have a good level of scientific knowledge and understanding of learning processes of children. They should equally importantly have the skill to ask and probe different levels of questions, that is, the ability of varying the order of questions from low to high order of thinking as recommended by the cognitive domain of learning in Bloom's Taxonomy of learning objectives. Probing varying levels of questions benefit learners in that according to Anderson *et al.* (2001: 40), learners acquire different types of knowledge, from factual to metacognition, as discussed in Section 2.6 of this study.

On the other hand the context of learning should be kept informal and learner-centred. Learners must be in control of the learning so that the guide will only come in if and when needs arise. The guide should also briefly explain to visitors the lay-out of the exhibits as per carrying out experiments as discussed below.

#### ❖ Exhibits.

The exhibits in the Potchefstroom Science Centre are displayed such that on one side of the exhibit is a written instruction of what and how to go about the execution of the experiment. A question is stated. Visitors are expected to predict what the outcome of the experiment would be. Learners (visitors) are expected to read the instructions and

follow the constructivist approach of conducting experiments, that is, the POE model: Predict, Observe and Explain model (White & Gunstone, 1993: 58).

The POE model of experimental/practical work is based on the classical model of research where learners state a hypothesis and give reasons to support their hypothesis. Crouch *et al.* (2004: 836) assert that involving learners by having them predict the outcome of the experiment is a simple step towards increasing learners' engagement and improving learning from practical work. Thereafter relevant data is gathered during the observation phase and results are discussed. Finally learners explain the possibility of any discrepancies between their predictions and observations (Kearney *et al.* 2003: 13; Kearney, 2003: 589).

Learners then compare their explanations with the provided explanation sheet attached to the other side of the exhibit. If in doubt or expressing dissatisfaction, learners may at will repeat the experiment and this may result in further discussions because learners shall have identified the discrepancies in their explanations and the scientific explanation provided.

As the exhibits in the Potchefstroom Science Centre focus on the National Curriculum Statement (NCS, 2003) and General Sciences curricula, it is important that learners should relate experiments to the relevant sections treated at school. Accompanying teachers should also be aware of the links with what they teach.

From the evidence gathered during the treatment phase of the experimental group, the researcher realised that the model adopted by the Potchefstroom Science Centre is successful and that it creates an environment where learners engage in discussions throughout the visit and most importantly encourages co-operative learning (refer to DVDs). This fact came out explicitly during the prediction and explanation phase where members of the same smaller group are further divided and discuss in pairs. This was brought up by diversity of ideas among members about phenomena but later reconciled after the discussion phase.

The activity of carrying out experiments addressed objective (a) (refer to Section 1.2.2) of this study as it strengthens the cognitive, affective and the psychomotoric skills of learners.

❖ Visits.

*Length of visit*

The vision and mission of the Department of Science and Technology is to “*create a prosperous society that derives enduring and equitable benefits from science and technology*” and “*develop, coordinate and manage a national system of innovation that will bring about maximum human resource capital, sustainable economic growth and improved quality of life for all*” (DST, 2004: 3). It is a fact that the vision and mission of the department are “loaded statements”. Therefore it is practically impossible for the nation to realise the envisaged vision of the DST if learners are to visit a science centre only once in their schooling career.

The subjects of this study elected for the experimental group visited the Potchefstroom Science Centre at least on three occasions in a period of six months (see Table 7.2) and the evidence is that the practical skills of handling apparatus and conducting experiments was improved over time (refer to Appendix 4: items 7, 19, 20, 29 of learners questionnaires part 2).

It is discussed in Section 2.2.1 of this study that acquisition of scientific knowledge is constructed in the mind of a learner by means of a self-regulated mental mechanism and the development of the capacity to construct knowledge is a life-long process (Beilin, 1971: 98). By adopting scientific knowledge an individual goes through a process of conceptual change and replaces structures that emerged from everyday experience with scientific conceptions.(Kempa, 1988: 22) quoted by Rapule (2005: 78). These knowledge structures incorporate a large body of routines that allow an agent to overcome limitations of his/her cognitive capacities (Hewson *et al.*, 1998: 201; Posner *et al.*, 1982: 212; Smock, 1981: 53).

Considering the preceding facts to this paragraph and the nature of learners' alternative conceptions and the fact that learners bring the alternative conceptions with to the learning encounter, compounds to the researcher's view that there should be follow up visits by learners to the Science Centre(s). The follow-up visits will undoubtedly impact positively on the memory structures of learners. According to Bjorklund (2005: 121) and Hamilton and Ghatala (1994: 81) the elements of the sensory memory (iconic, echoic and haptic memory), the working memory and the long term memory holds on to the occurrence if it is exposed over and over again. The practice thereof eventually becomes automatic.

❖ Reflection phase.

After a science centre tour it is recommended to let learners convene at a lecture hall where they (the learners) should reflect on their visit. This is done so as to engage learners in a discussion phase where they interact and formalize issues. The platform also serves as a clarity seeking session and most importantly give visitors an opportunity to express their general impression about the exhibits and hence the centre for improvement purposes.

This practice in the researcher's opinion has two benefits: (1) it will help learners to consolidate and modify their scientific knowledge structures about the day spent in the science centre through discussion (co-operative learning) and (2) the practice will help to sustain science centres as they will be continuously assessed by its own beneficiaries (visitors), a concern for DST and the ministry of science and technology.

The latter also seeks to address the Department of Science and Technology concern, that science centres are not assessed (DST, 2004).

Learners' reflection on the day spent at the Science Centre may be extended to schools where related experiments may further be conducted. This practice will involve teachers in discussions and in turn assist in the facilitation of the problem solving process.

❖ Information-based vs. experience based approach.

The Potchefstroom Science Centre entertains its visitors by blending the *experience-based* with the *information-based* approach. However, the information to the exhibits (instructions and explanations) is structured such that they embed the constructivist theory, the POE model (White & Gunstone, 1993: 53). Visitors/learners read the instructions of what to do before interacting with exhibits and are requested to predict the outcome of the experiment. The prediction phase is then followed by the observation phase and then by the explanation phase.

To further curb this problem, as observed from the sample participating in this study, constant reflection is provided as learners continuously engage in cooperative learning and after the visit they convene to reflect as a larger group as discussed in the subsequent section (Section 9.6). The scenario of continuous interaction between learners is made possible by the fact that the learning encounter is not taking place in an exam orientated and highly structured system of school (classroom) but it is taking place in a relaxed and conducive environment (science centre) (Stocklmayer and Gilbert, 2002: 143).

❖ Visual imparity.

To curb this problem one has to ensure that the science centre visits are well structured and coordinated. This means that the type and capacity of the science centre has to be taken into account (*limited service or full service science centre*) so as to determine the number of visitors per given time. This will help in establishing small groups for the duration of the visit and maximise the possibility for cooperative learning.

One of the main reasons why human beings forget is as a result of unorganized material (*displays*). In the case of a science centre it is crucial that the displays/exhibits are arranged in a coherent fashion. It means that a concerted effort must be made to ensure that exhibits under same/similar concept are adjacent to one another and one build upon the next.

The findings of the study prompted the researcher to propose further research based and as an outcome of this study. The ideas are presented hereunder.

#### **9.6. RECOMMENDATIONS: Further research**

The experimental group that participated in this study came from the catchment area of the Potchefstroom Science Centre. The furthest school is less than 10 km from the Science Centre. However the rate at which the grade 10's of the local schools visit the science centre is minimal (see Appendix 2: Item 8 of the learners' demographic information). It will therefore be interesting to probe into the problems compounding this trend.

This study focused on the FET-Band, therefore the researcher recommends that a similar study be undertaken to involve and expose the GET-Band learners in science centres. The intended study should also focus on the effect science centres have in drawing/attracting learners into the science, engineering and technology stream for career studies. The study should be done so as to address the demand and challenge posed by the Department of Science and Technology (DST). The Department of Science and Technology envisages drawing learners into science related careers and hoping to use science centres to achieve that goal.

The GET-Band learners will be ideal for this study because they are on the brink of choosing the subject groups at grade 10. The influence science centres have on learners' choice will be measured and observed by the change in intake to the science streams at schools (Chapter 5 of this study).

It is recommended that the findings of the proposed study be coupled with the concept that science centres are seen as context for life-long learning.

It is often observed that parents accompany their children to the science centre during unstructured visits. The researcher recommends that the study be undertaken to evaluate

the role parents play in influencing learners to follow science related careers. The study will also address DST's concern about the role parents' play or should play in the science centres.

Some science centres have tour guides/explainers to help clarify uncertainties to visitors. The role of these tour guides should be clearly spelt-out. The science centre is a context which is free from structured classroom operations. Learners interact or should interact freely. If the visit is reduced to an extension of the classroom, then the fun and excitement is taken away. Learners are supposed to discover and inquire on their own in the science centre. It is for this reason that the Potchefstroom Science Centre opt for the POE-model in engaging visitors. This model is embedded in the constructivist theory of learning.

If visitors are told what to do they tend to rely and depend on the guide for answers and tend to "switch-off". No real learning takes place. Therefore the researcher recommends that the role of guides or facilitators in science centres be fully explored.

## **9.7. CONCLUSION**

From the outcomes of the study reported in the thesis it is evident that science centres are valuable resources. Following the video evidence it is clear that science centres have a high degree of effectiveness in changing attitudes (refer to data analysis and video), and this impacts positively on the acquisition of knowledge and conceptual change. In other words, the results obtained from this study proved that science centres can and should be used as agents to develop learners (visitors) in a holistic manner.

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Appendix 1

LEARNING GAIN TEST

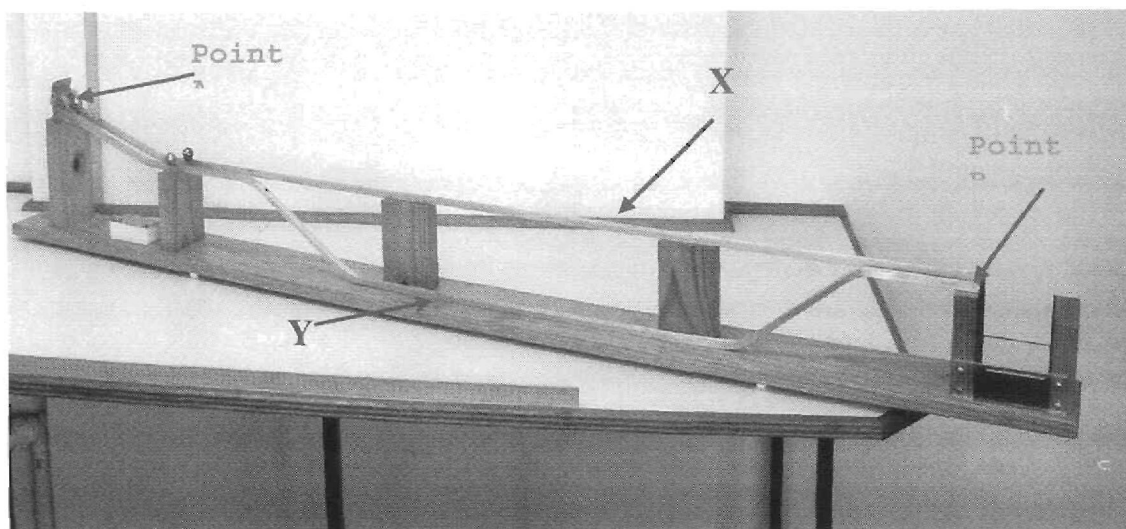
Name: \_\_\_\_\_

Name of School: \_\_\_\_\_

SECTION 1: MECHANICS [50]

QUESTION 1

1.1. The picture below shows two rails with two identical steel balls. The balls are released simultaneously from the same height (Point A). One ball runs on path X and the other on path Y as shown.



(a) What is the total distance (in metres) traveled by each ball on its path? (2)

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(b) Which ball will reach point B first when the two balls are released simultaneously from point A? Explain your choice. (3)

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(c) Draw a rough velocity-time graph that describes the motion of the two balls on the same set of axis. Label your graphs X for ball X and Y for ball Y. (8)

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(d) Interpret the type of motion of the two balls by completing the table below. State where on the path did each ball experience acceleration, deceleration or was moving at constant velocity. (8)

Ball	Acceleration	Deceleration	Constant velocity
X			
Y			

(e) From the velocity-time graphs you have drawn, by deduction draw the acceleration-time graph on the same set of axis for the motion of the two balls. Label your graphs X and Y respectively. (8)

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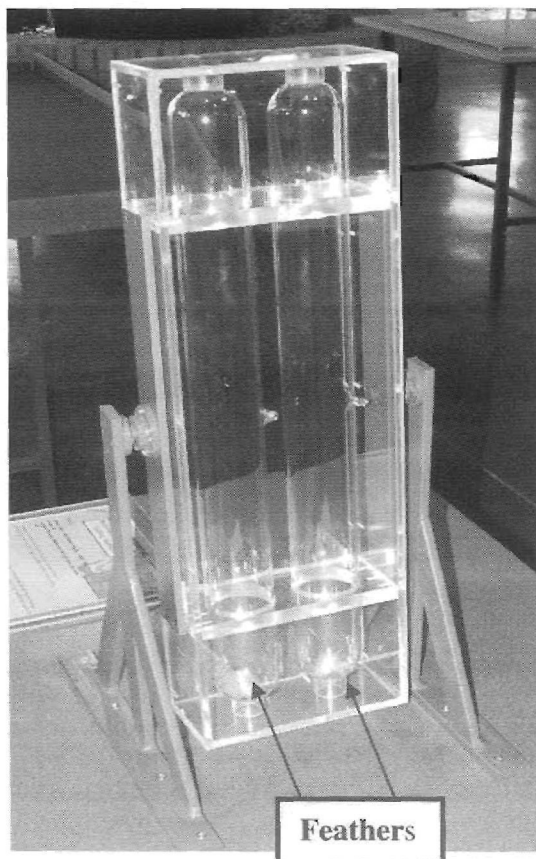
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2. Two identical glass columns each with a feather inside are suddenly inverted. It is observed that in one of the glass columns, when suddenly inverted, the feather falls much quicker than in the other.



(a) Under which conditions is the one feather expected to fall quicker? (3)

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3. (a) State the principle of conservation of momentum (3)

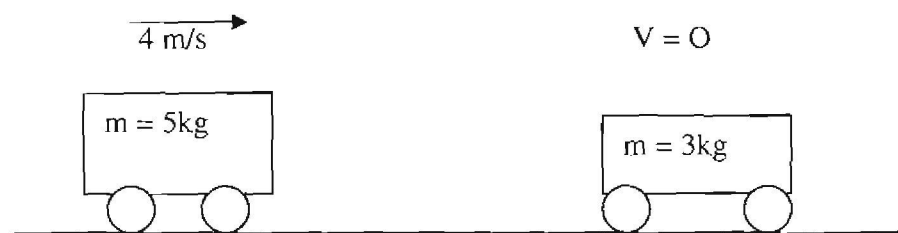
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(b) Trolley A of mass 5 kg travels at 4 m/s collides with a stationary trolley B of mass 3 kg as shown in the diagram. The two trolleys are traveling on the **linear air track** such that there is no friction between the track and the trolleys.



b(i) What is a linear air track? (1)

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After collision the two trolleys move off as a unit. Calculate the velocity of the trolleys after collision. (5)

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(c) Was the collision elastic or inelastic? Prove by means of calculations (5)

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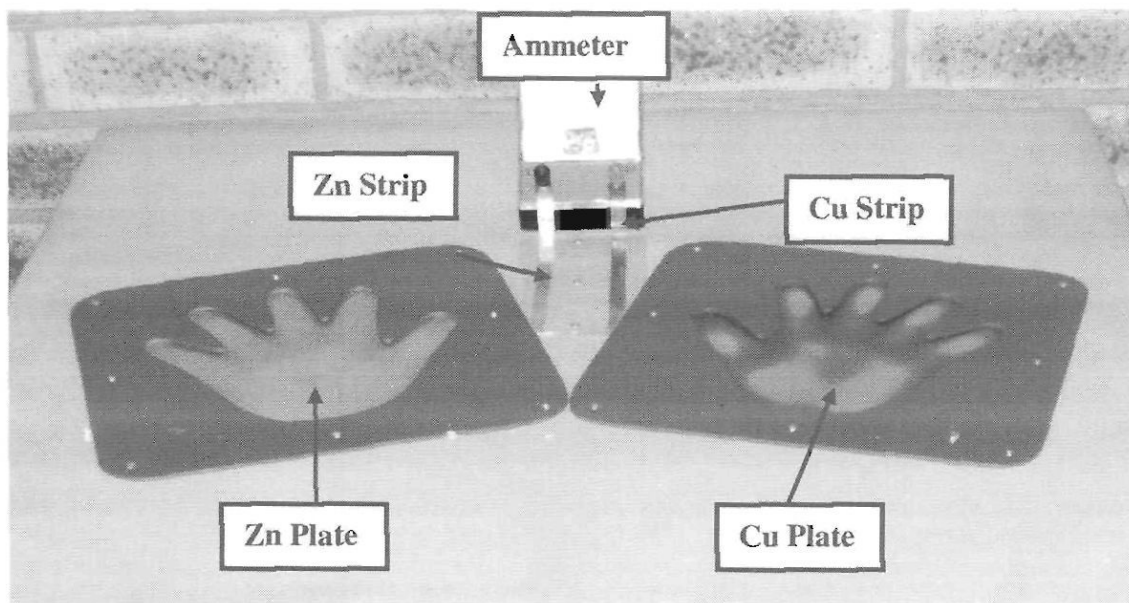
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## SECTION 2: ELECTRICITY [24]

1. The picture below shows a circuit diagram with copper strip and a zinc strip connected to the ammeter in series. The copper strip is connected to the copper plate and the zinc strip is connected to the zinc plate.



Thabo, a grade 10 learner place his hands on the copper and zinc plates and observe that there is a reading on the ammeter. Siphso, also a grade 10 learner, does the same experiment and realizes that the ammeter registers a higher reading than with Thabo.

(a) What causes the ammeter to register a reading when the hands are placed on the plates? (2)

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(b) What may be the cause for the difference in the ammeter reading with the two boys, Thabo and Siphho? (4)

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(c) What is an electrolyte? (2)

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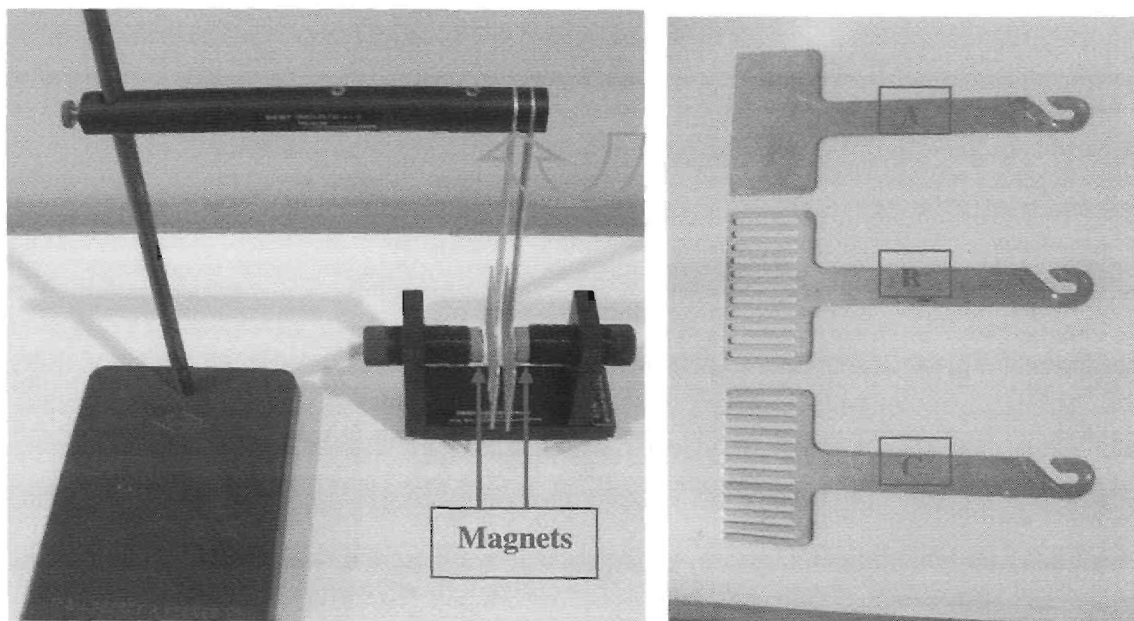
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(d) Mention one use of an electrolyte in everyday life. (2)

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2. The picture below shows opposite poles of a magnet placed 1 cm apart. Three aluminium forks are suspended such that they can freely swing between the magnets. Fork A is solid aluminium plate, B has openings but the lower part is enclosed as shown. The difference between fork B and C is that C is not enclosed.



(a) If the three forks are released simultaneously from the same position, the order of complete swings from most to least will be: (2)

*Circle the correct letter of the option*

	Forks
<b>A</b>	A B C
<b>B</b>	B C A
<b>C</b>	C B A
<b>D</b>	C A B

(b) Draw the magnetic field lines between the poles of the bar magnet. (2)

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(c) Why do the forks not swing for the same duration/length of time? . (3)

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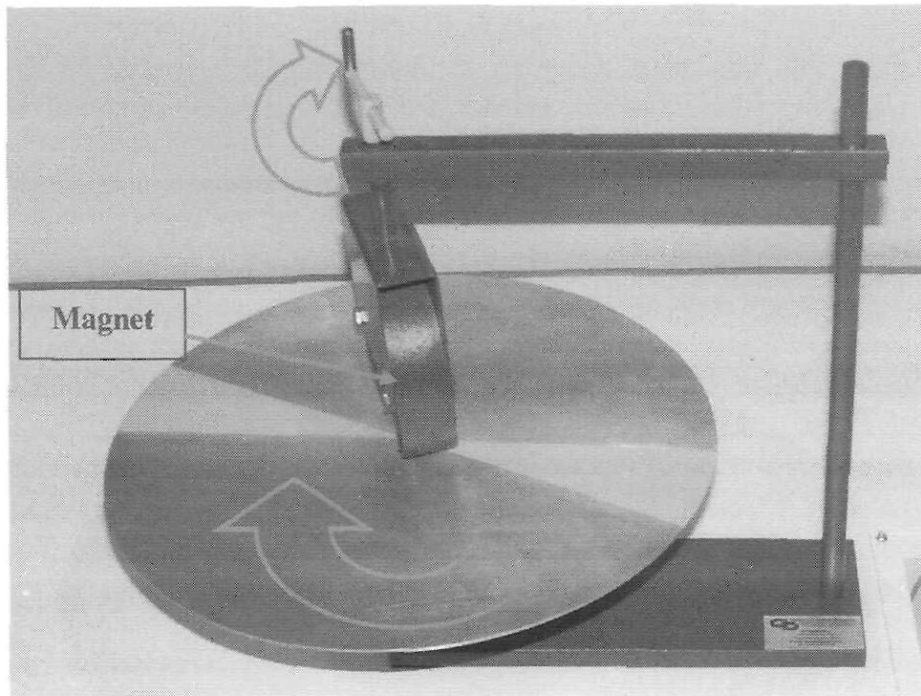
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3. The photo below shows a magnet placed close to (but not touching) an aluminium disc mounted on a screw such that the disc can rotate freely. It is observed that when the magnet is rotated, the aluminium disc rotate as well.



(a) What causes the disc to rotate? (3)

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(b) Name the two laws associated with the phenomenon to describe the action demonstrated by the magnet and the disc above? (4)

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**SECTION 3: OPTICS [6]**

**Multiple choice questions: Circle the letter of the correct option, eg. A**

(a) If you stand before a flat plane mirror, how many images of yourself are you going to see? (2)

- A. 0      B. 1      C. 2      D. 3      E. 4

(b) Three flat mirrors are held at right angles to each other. If an object is held to the mirrors, how many images are you likely to see? (2)

- A. 0      B. 1      C. 2      D. 3      E. 4

(c) Now if you hold an object close to two mirrors held at  $60^\circ$  to each other, how many images of the object will you see? (2)

- A. 1      B. 2      C. 3      D. 4      E. 5

**Appendix 2**

**QUESTIONNAIRE TO LEARNERS**

**SECTION A: GENERAL INFORMATION**

**Read the following statements and give answers as accurate as you possibly can without help from friends. The answers to the questionnaire are confidential and will be administered as such.**

**COMPLETE OR MAKE A CROSS ON THE APPROPRIATE BLOCK!!**

1. Name of your school:

1	2	3	4	5
A	B	C	D	E

2. Name of province where your school is situated:

1	2
NW	FS

3. Gender:

1	2
Male	Female

4. Age in years:

1	2	3	4	5
15	16	17	18	19

5. Present grade:

1	2	3
Grade 10	Grade 11	Grade 12

6. Number of years in the grade:

1	2	3
1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>

7. What is your most recent mark/symbol in the Physical Sciences examination?

1	2	3	4	5	6	7
A	B	C	D	E	F	G
80 +	70 - 79	60 - 69	50 - 59	40 - 49	30 - 39	< 30

8. I have visited the Potchefstroom science centre before.

1	2	3	4	5
NEVER	ONCE	TWICE	THREE TIMES	MORE THAN THREE TIMES

9. I have been to the Potchefstroom science centre during the National Science Week.

1	2
YES	NO

10. I have been to other science centre(s) before.

1	2
YES	NO

If yes, name the science centre(s) you have visited.

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11. I have attended a science road show conducted at my school before.

1	2
YES	NO

If yes, name the person(s) who conducted the science show at your school.

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**Appendix 3**

**SECTION B: INFORMATION ON LEARNING AT SCHOOL**

**Part 1**

**Respond to the items of the questionnaire by marking with an X on the appropriate block. Remember there is no right or wrong answers to the statements; choose the block that best describes your situation.**

*KEY: Choose 1: If you totally agree with the statement*

*Choose 2: If you agree with reservations*

*Choose 3: If you agree*

*Choose 4: If you disagree with the statement, or*

*Choose 5: If you totally disagree with the statement.*

**Please motivate your answers in the spaces provided.**

1. At our school we as learners conduct experimental work regularly

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

State how frequently (if applicable)

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2. I am confident in carrying out experiments on my own.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Give details of the experiment you conducted on your own briefly:

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3. I can easily follow instructions stipulated on the book to carry out experiments at school

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Example of such experiment:

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4. I understand the science involved better when my teacher demonstrates an experiment to the class.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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5. I can easily handle apparatus when conducting experiments.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

List the apparatus you have recently handled in experiments at your school:

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*Choose a suitable option*

6. I consider the contribution of practical work/experiments in learning science as

Very important	1
Important	2
Not important	3

**Appendix 4**

**SECTION B: INFORMATION ON SCIENCE CENTRE LEARNING AND ENVIRONMENT**

**Respond to the items of the questionnaire by marking with an X on the appropriate block. Remember there is no right or wrong answers to the statements; choose the block that best describes your situation.**

1. It was my experience that after a visit to the science centre, I understood science better.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Give an example of the experiment you understood better after the visit.

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2. The atmosphere/environment in the science centre stimulates or promotes my scientific thinking.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Which exhibit/experiment did stimulate you most?:

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3. I like Physical Sciences more after the visit to the science centre

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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4. I have learned new things in the science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Which new things have you learnt? Example:

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5. I have learned how to investigate things in a science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Give an example of something you have investigated:

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6. The experiments I have conducted in the science centre demand/require understanding.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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7. The science centre gave me the opportunity to learn by doing experiments on my own.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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8. In the science centre I have learnt to identify a problem.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Give an example of the problem you identified:

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9. In the science centre I have learned to find answers to problems.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

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10. The science centre helped me to analyze problems.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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11. I could easily collaborate (work) with my peers/friends in the science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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*Choose the appropriate option*

12. Working in a small group of 2 – 5 in science experiments in the science centre is

Pleasant	1
Impossible	2
Not recommended	3

13. It is boring in the science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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14. I did not learn anything in the science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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15. I think that the experiments in the science centre will help me to become creative in science.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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16. Because of the experiments conducted in the science centre I developed a positive attitude towards Physical Sciences.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

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17. The visits to the science centre taught me to concentrate while doing science.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

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18. The visits to the science centre have developed my understanding in science.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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19. The visits to the science centre have developed my skills to handle apparatus.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Which exhibit did you handle and interacted with most?

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20. Before the visit to the science centre I had problems to execute experiments on my own.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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21. I have enjoyed the visit to the science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Will you invite your friend to the science centre?

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22. I see a science centre as a place for learning science.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

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23. A science centre is a place for entertainment.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

What entertained you the most?

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24. The experiments in a science centre captured my interest for the entire visit to the science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Which exhibit/experiment kept your attention in the science centre?

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25. A visit to the science centre is worthwhile.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate your answer:

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26. The visit to the science centre motivated me to pursue my studies after grade 12 in science.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Which field of science would you study after grade 12

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27. I would like to work in an environment such as a science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Would you like to be an engineer/scientist or an actor?

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28. The visit to the science centre has improved my scientific knowledge.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Motivate:

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29. I see a science centre as a place where I can sharpen my handling skills in apparatus

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Which skills have you gained by visiting the science centre?

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30. I could easily relate the experiments that I conducted in the science centre with the science we study at school.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Supply an example of such a relation:

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31. The experiments in the science centre relate to my everyday life experience

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Supply an example of an experiment that you have performed/seen that relates to your everyday life:

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**Rank the following (32 – 34) in order of importance.**

32. I consider visiting the science centre again because:

	1	2	3
It offers me an opportunity for doing practical work on my own	Very important	Important	Not important

33. I will visit the science centre again because:

	1	2	3
I gain scientific knowledge	Very important	Important	Not important

34. I will visit the science centre again because:

	1	2	3
I enjoy/love the environment in it	Very important	Important	Not important

35. I will not visit the science centre again

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Why?

**Appendix 5**

**SECTION A: BIOGRAPHICAL INFORMATION ON TEACHERS**

**Read the following statements and give answers as accurate as you possibly can. It is vital to give your own response rather than your friends. The answers to the questionnaire are confidential and will be administered as such.**

**MAKE A CROSS ON THE APPROPRIATE BLOCK!!**

1. Name of your school:

1	2	3	4	5
A	B	C	D	E

6	7	8	9	10
F	G	H	I	J

2. Name of province where your school is situated:

1	2
NW	FS

3. Gender:

1	2
Male	Female

4. Teaching experience in years:

1	2	3	4	5
0 - 3	4 - 6	7 - 10	11 - 14	> 15

5. Grades that you are currently teaching:

1	2	3
Grade 10	Grade 11	Grade 12

6. Experience in teaching Natural or Physical Sciences (in years):

1	2	3	4	5
0 - 3	4 - 6	7 - 10	11 - 14	> 15

7. Highest qualification in science:

1	2	3	4	5
M + 3	M + 4	M + 5	M + 6	OTHER

8. State qualification and level to which Physical Sciences (Physics and/or Chemistry was studied).

<b>Qualifications</b>	
<b>Level</b>	

9. Have you ever visited a science centre?

1	2
YES	NO

10. If yes, which one(s):

1	2	3	4	5
NWPOTCH	SCI-BONO	TUT	MITTAL	OTHER

## Appendix 6

### SECTION B: FEEDBACK ON LEARNERS' DEVELOPMENT

Please respond to the items of the questionnaire by marking with an X on the appropriate block. Remember there is no right or wrong answers; choose the block that best describes your situation.

KEY: Choose 1: If you totally agree with the statement

Choose 2: If you agree with reservations

Choose 3: If you agree

Choose 4: If you disagree with the statement, or

Choose 5: If you totally disagree with the statement.

If you want to express an opinion or more information on the specific item, kindly do so on the spaces provided.

1. I have recognized a positive shift in academic performance on my learners after a visit to the science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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2. Since the visit to the science centre, my learners are motivated to pursue studies in science related careers.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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3. The work done at the science centre has improved the physical skills of learners.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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4. There is a major difference on my learners' attitude towards science before and after the visit to the science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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5. The science centre has helped learners to think more independently

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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6. My learners can apply the knowledge gained from the science centre in everyday situation.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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7. My learners are now able to, after the visit to the SC, to plan a scientific inquiry better

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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8. My learners feel motivated to assume leading roles in practical work.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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9. After a visit to a science centre my learners often reflect on their experiences in the science centre.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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10. The visit to the science centre has helped my learners to see the connection between science and the world they live in.

1	2	3	4	5
TOTALLY AGREE	AGREE WITH RESERVATIONS	AGREE	DISAGREE	TOTALLY DISAGREE

Comment:

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11. Of the benefits brought by the science centre in your learners, which would you regard as the most striking?

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