LEARNING CONSERVATION OF MATTER IN PHASE CHANGES

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ABSTRACT

Learners regard Chemistry as one of their most difficult courses at secondary and undergraduate levels, because they have to link several modes of representing matter and their interactions. *Phase changes* is one of the topics that learners of Chemistry experience problems with. On microscopic level phase changes can be explained in terms of the particulate nature of matter. During a phase change the outward appearance of a substance change, while the substance itself remains the same. In order to learn this concept, learners performed experiments on conservation of mass in an empirical study.

The empirical study was conducted amongst 46 Grade 10 learners of Kgabutle High School in the Bojanala region, in the North-West Province, South Africa, following the Curriculum Statement for Physical Sciences.

The investigation was done with the aid of a questionnaire. This was followed by an intervention that consisted of guided inquiry lessons aimed at enhancing the learners' understanding of conservation of matter in phase changes. Constructivist learning principles were implemented in the lessons. The effectiveness of the intervention was determined by administering the same questionnaire as pre- and posttest and calculation of normalized learning gains.

The results of the empirical study were used to identify alternative conceptions and other problems that hampered learners' understanding, such as language and in-depth knowledge about the kinetic molecular theory.

Constructivist principles of learning are recommended to be used to enhance learners' understanding of conversation of matter in phase changes.

OPSOMMING

Leerders ervaar Chemie as een van die moeilikste vakke op sekondêre en tersiêre vlak, aangesien hulle verskillende voorstellings van materie en hul interaksies bymekaar moet bring. Faseveranderings is een van die onderwerpe waarmee Chemie leerders sukkel. Op mikroskopiese vlak word faseveranderings in terme van die deeltjie-aard van materie verklaar. Gedurende faseveranderings verander die uitwendige voorkoms van 'n stof, maar die stof self bly dieselfde. Om hierdie begrip te leer het leerders as deel van die empiriese studie eksperimente oor die behoud van materie gedoen.

Die empiriese studie was uitgevoer met 46 Graad 10 leerders van die Kgabutle Hoërskool in die Bojanala gebied van die Noord-wes provinsie, Suid-Afrika. Die leerders volg die Kurrikulumverklaring vir Fisiese Wetenskappe.

Die ondersoek is gedoen met behulp van 'n vraelys. Dit was opgevolg deur 'n intervensie wat bestaan het uit lesse van begeleide ondersoeke met die doel dat leerders behoud van materie in faseveranderings beter sal verstaan. Die lesse was saamgestel volgens beginsels van konstruktiwistiese leer. Die effektiwiteit van die intervensie is bepaal deur dieselfde vraelys as voor- en natoets te gee en genormaliseerde leerwinste uit die resultate te bereken.

Die resultate van die empiriese studie was gebruik om alternatiewe begrippe en ander leerprobleme wat leer benadeel te identifiseer, soos taal en in-diepte kennis van die kinetiese molekulêre teorie.

Die implementering van beginsels van konstruktiwistiese leer word aanbeveel om leerders 'n beter begrip te gee van behoud van materie en faseveranderings.

CONTENTS

CHAPTER 3: THE THEORY OF CONSTRUCTIVISM

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY

CHAPTER 5: ANALYSIS OF RESULTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

PROBLEM ANALYSIS AND RESEARCH DESIGN

1.1 PROBLEM ANALYSIS AND MOTIVATION

The purpose of this research project is to address the problems that learners experience when learning about one of the six knowledge areas of Physical Sciences in South African schools. This knowledge area is called Matter and Materials and is an integration between Physics and Chemistry (National Curriculum Statement, 2003:11).

According to Mackay *et al.* (2005:95), Physical Sciences focus on investigating physical and chemical phenomena through scientific inquiry. By applying scientific models, theories and laws, it also seeks to explain and predict events in our environment. The area Matter and Materials is based on the kinetic molecular theory and the particulate model of matter. This theory and model help us to have a deeper understanding of particle arrangement of gases, solids, liquids and plasmas. In addition, the theory helps us to obtain scientific knowledge about properties of materials and how particles make up a substance (Mackay *et al.*, 2005:95).

Renstrom *et al.* (1990:555) emphasise that science learners need to have a clear understanding of matter, namely, that all things are made of smaller particles that move around continuously, attracting each other when they are far apart and repelling when squeezed into one another. Stephens (1996:1) agrees that in order to lessen learners' misconceptions about physical change, the educator has to give learners time to logically explore what they know about matter. Kabapinar *et al.* (2004:649) found that learners with a good grasp of the particulate model of matter understand conservation of mass and use the model to explain various solubility phenomena. Piaget and Inhelder (1974) studied children's understanding of conservation of matter and found that understanding of conservation takes place at the concrete operational stage (7 – 11 years).

Kyle *et al.* (1989:2) believe that as children develop, educators need to construct meaning regarding how and why things behave as they do. It is believed that from the moment of birth, infants generate views of their new environment. Even before starting formal education, children begin to construct sets of ideas, expectations and explanations about their daily experiences. Through the difference of explanations given in every day life and scientific frameworks, the following words are used largely in literature to address learners' problems: misconceptions, alternative conceptions or alternative frameworks

The child tends to attach what he sees to any situation that is appropriate, reinforcing misconceptions. Examples of misconceptions are that learners believe that a molten material weighs less than the same material in its solid state and that a gas weighs less than the same substance in its liquid or solid form (Stavy, 1990:501). In order to conserve matter, a learner should be able to follow a substance from one form to the other (Renstrom *et al.*, 1990:555). These problems regarding the learning of science should be attended to in the teaching of science.

Vermeulen (1997:10) defines a teaching strategy as a broad action for teaching activities with a view of achieving an aim. A teaching strategy must account for the main components of didactic situations, namely the learner, educator and content. Choosing a relevant teaching strategy is very difficult, because learners differ according to their respective intelligence. Therefore, it is proper and reasonable enough to have a combination of teaching strategies to serve the multiple intelligence levels of learners. Such intelligence is visual, verbal, mathematical, kinesthetic, interpersonal and intrapersonal intelligence. Harrison and Treagust (2001:47-52) discuss a variety of theoretical perspectives to explain conceptual change and argue that multiple interpretive perspectives yield the most fruitful explanation.

In view of the research surveyed above and the implementation of the new National Curriculum Statement for the FET band this year in Grade 10, it is necessary to investigate what learning problems Grade 10 learners in a typical rural South African school have with regard to conservation of matter in phase changes. The results should inform effective teaching of chemistry in the FET band.

1.2 AIM OF THE STUDY

The aim of the study is to improve learning of conservation of matter in phase changes by implementation of constructivist learning principles.

1.3 POPULATION

Forty-six (46) registered Grade 10 Physical Science learners of Kgabutle High School in Lesetlheng village (Saulspoort) in the North-West Province (Bojanala West region) of South Africa participated in the study. The group has been introduced to the National Curriculum Statement and Outcomes Based Education.

1.4 SPECIFIC OBJECTIVES FOR THIS STUDY

The objectives of the study are to:

1. identify Grade 10 learners' alternative conceptions regarding phase changes and compare them with those found in science education literature; and.
2 investigate the effect of contemporary learning strategies on a group of Grade 10 learners' understanding of conservation of matter in phase changes.

1.5 HYPOTHESES

With reference to the objectives for the study, the hypotheses are:

1. Grade 10 learners hold alternative conceptions regarding phase changes.
2. Implementation of constructivist learning principles result in acceptable learning gains.

1.6 METHOD OF RESEARCH

1.6.1 Literature study

A literature study was conducted to gain background knowledge on learners' alternative conceptions on the conservation of matter and phase changes, as well as contemporary teaching strategies.

Relevant literature was assembled from local and international journals, encyclopaedias, natural science textbooks, government publications (e.g. NCS – National Curriculum Statement) and electronic database providers such as EBSCOHOST.

1.6.2 Empirical study

A questionnaire (pre- and posttest) was compiled to determine the learners' knowledge and understanding of phase changes before and after the intervention. In the intervention, the educator and learners were involved in performing experiments whereby intensive investigation on conservation of matter in phase changes should result in a deeper understanding of the content. The efficiency of the intervention was tested by means of statistical comparison of the pre- and posttest results.

1.7 VALUE OF STUDY

The study hopes to:

- Improve learners' understanding of chemistry from the viewpoint of conservation of matter; and
- make recommendations for the effective use of contemporary learning strategies in South African science classrooms.

1.8 DEFINITION OF CONCEPTS

1.8.1 Matter

Matter is often defined as anything that has mass and occupies space (Compton, 1993:223). Matter is described in terms of its state (e.g. solid, liquid or gas state) and its properties, such as mass, inertia, density, melting point, hardness, crystal form, mechanical strength or chemical properties.

1.8.2 Phase changes

Atkins and Beran (1990:3) classify properties of matter as either physical or chemical. Physical properties include the physical state of the substance, which determines whether the substance is a gas, liquid or solid. For a change of state (i.e. a phase change), temperature plays a vital role, as it determines the melting, boiling, freezing, vaporisation and condensation points of substances.

1.8.3 Law of conservation of matter

Kotz and Treichel (1996:60) state that Antoine Lavoisier (1743 – 1794) carried out a series of experiments in which the reactant were carefully weighed before a chemical reaction and the products were carefully weighed afterward. Lavoisier concluded that the law of conservation of matter holds during chemical reactions. The law states that matter can neither be created nor destroyed, but can be changed from one form to the other.

1.9 CONTENTS OF SCRIPT

Chapter 1: Introduction

Chapter 2: Scientific and alternative conceptions

Chapter 3: The theory of constructivism

Chapter 4: Research design and methodology

Chapter 5: Analysis of results

Chapter 6: Conclusion and recommendations

CHAPTER 2

SCIENTIFIC AND ALTERNATIVE CONCEPTIONS

2.1 INTRODUCTION

This chapter reports on a literature survey conducted to determine learners' problems and alternative conceptions about phase changes. Difficulties that learners experience with understanding phase change are due to a confusion of the macroscopic and microscopic levels of particle properties (Crespo & Pozo, 2004:1325-1327). During a phase change (or change of state of matter), the outward appearance of a substance changes, while the substance remains the same. A rigid solid can be observed to change into a liquid that takes the shape of the container. An evaporating liquid seems to disappear into the air. Although learners can observe these changes in physical properties, they should know that the building blocks (atoms or molecules) remain the same. The observable changes are simply due to changes in their configuration and energy.

Two knowledge domains that underpin learners' understanding of physical changes (such as phase changes) are the principle of conservation of matter and the particulate nature of matter (Liu & Lesniak, 2005; Nakhleh & Samarapungavan, 1999). Although the study focuses on the domain of conservation of matter, the particulate model forms the explanatory framework for physical and chemical changes. Therefore, both of these two domains are attended to in the literature study, as well as in the empirical study.

In this chapter learners' problems regarding phase changes are studied in the theoretical framework of the scientific view of the nature of matter (paragraphs 2.2 to 2.4). Paragraphs 2.5 to 2.8 give a literature review of learners' problems with regard to this scientific view.

2.2 THE PARTICULATE NATURE OF MATTER

The kinetic molecular theory describes the behaviour of matter on the molecular level (Kotz & Purcell, 1991:479). It is a scientific theory that is used to explain physical and chemical changes in terms of the actions of unseen entities (called atoms and molecules) that constitute matter. The particulate nature of matter can be perceived as a subset of the kinetic molecular theory of matter (Nakhleh & Samarapungavan, 1999:779).

2.2.1 Atoms, elements and compounds

All matter is composed of different kinds of atoms (Kotz & Purcell, 1991:43). Matter that is composed of only one kind of atom is an element. A compound is a substance that contains atoms of more than one element (Bodner & Pardue, 1995:54).

An element is a substance that cannot be broken down into anything simpler by chemical means (Lewis & Waller, 1992:43). Particles of an element cannot be broken down into smaller pieces; therefore such particles will form building blocks for all particles of compounds. Elements can be organised into a periodic table in which elements with similar chemical properties are placed in vertical columns or groups (Bodner & Pardue, 1995:48).

Elements are divided into metals, non-metals and semi-metals due to their differences with regard to chemical and physical properties (Bodner & Pardue, 1995:48-52). More than 75% of the known elements are metals, while 15% (that are clustered in the upper right-hand corner of the periodic table) are non-metals. Along the dividing line between these two categories are a handful of semi-metals. Examples of metals (represented in symbols) are: Li, Be, Na, Mg and K and examples of non-metals (represented in symbols) are He, C, N, O and F. Examples of semi-metals (represented in symbols) are B, Si, Ge, As and Sb. The only element that can be classified as a metal and a non-metal is hydrogen (H).

An atom is the smallest particle of an element that retains the chemical properties of the element (Kotz & Purcell, 1991:43). An atom consists of three primary constituents, namely electrons, protons and neutrons. All atoms of the same element have the same number of protons in the nucleus. An atom has no net electric charge. The number of negatively charged electrons around the nucleus equals the number of positively charged protons in the nucleus.

Elements combine to produce compounds (Lewis & Waller, 1992:43). The chemical combination of elements is called synthesis. The smallest unit of a compound that retains the chemical characteristics of the compound is a molecule (Kotz & Purcell, 1991:70). Compounds are divided into ionic compounds or salts and covalent compounds (Bodner & Pardue, 1995:54). Since a compound is a specific combination of elements, it can be broken down by using chemical techniques (Atkins & Beran, 1990:6). Compounds therefore differ from mixtures, which can be separated by using physical techniques.

2.2.2 States of matter

Atkins and Beran (1990:3) state that a physical property of a substance is a characteristic that we observe or measure without changing the identity of a substance. Physical properties of a substance include its colour, melting and boiling points, odour, hardness and density. Physical properties are either extensive or intensive. An extensive property is a property that depends on the amount of matter present, such as mass, length or volume. An intensive property is a property that does not depend on how much matter is present, such as boiling point, melting point, or density (Regular Chemistry Notes; 2001).

The state (or phase) of matter is a physical property. Four states of matter occur in nature, namely the solid, liquid, gas and plasma state. These states are discussed in the following paragraphs.

The solid state

Solid is a phase of matter in which substances have both definite shape and volume (Kotz & Treichel, 1996:16). The molecules that are found in a solid are arranged in regular, repeating patterns that are held firmly in place, but that can vibrate within a limited area. As the molecules are bound together, the order of their arrangement is called a crystal. This arrangement helps the intermolecular forces to overcome the disruptive thermal energies of the molecules (Atkins & Beran, 1990:4). Figure 2.1 shows a model of a solid state. The lines indicate strong bonds between the particles.

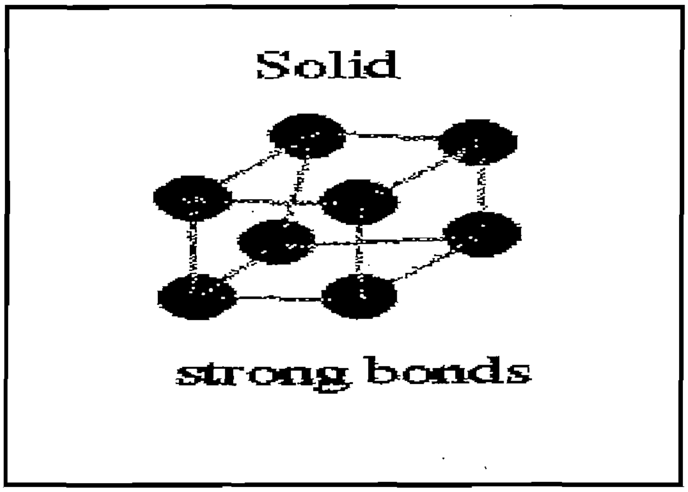


Figure 2.1: Model of the solid state

Solids have the greatest density and cannot flow freely as compared to liquids and gases. Diffusion does not occur in solids because particles are closely packed and strongly bound together with no empty space for particles to move through (GCSE-K53, 2007). Examples of common solids at room temperature include brass, granite, quartz as well as the elements of copper, titanium, vanadium and silicon (Atkins & Beran, 1990:4).

When the temperature of a solid is raised, the solid undergoes a state of melting and becomes a liquid (Atkins & Beran, 1990:4).

The liquid state

Figure 2.2 below shows bonds of a liquid. Liquid is a phase of matter in which the substance has no definite shape, but does have a definite volume (Kotz & Treichel, 1996:16). For example, a pint of water changes its shape when it is poured from a glass into a bowl, but its volume remains the same, therefore the volume is conserved (Atkins & Beran, 1990:3).

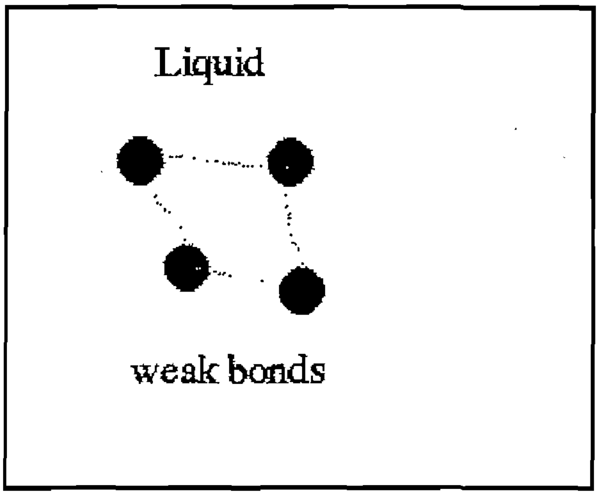


Figure 2.2: Model of the liquid state

A liquid is kept from flying apart by attractive forces between the molecules, for example, Van der Waals' forces (Atkins & Beran, 1990:3). A liquid has a greater density than gases have due to the attractive forces between their particles. Spaces between liquids are not readily compressed (GCSE-K53, 2007). Liquids' particles move in all directions but less frequently as compared to gases. With an increase in temperature the particles move faster as they gain kinetic energy.

Common substances that are liquids at room temperature include benzene and water, while gallium and cesium melt down to liquid at body temperature, which is 37^0 C (Atkins & Beran, 1990:3).

The gas state

In Figure 2.3 below, particles of gases are displayed. The gas state is the phase of matter in which a substance has no definite shape and has a volume that is determined only by the size of its container (Kotz & Treichel, 1996:16).

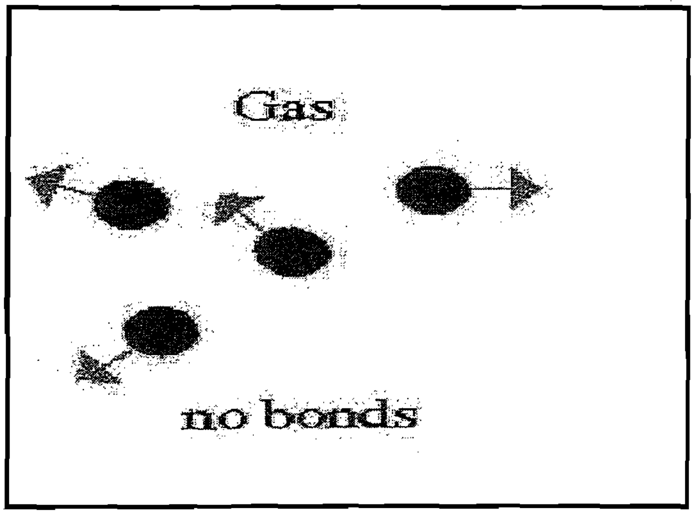


Figure 2.3: Gas state

A gas is defined as a fluid in the form of matter that fills any container that it occupies and can be easily compressed into a much smaller volume. Molecules in gases are so far apart that the attractive forces between them are insignificant (Kotz & Treichel, 1996:16).

Common gases that are found in the atmosphere are nitrogen and oxygen (Kotz & Treichel, 1996:16). Border and Pardue (1995:113) named the following examples of elements and compounds that are gases at room temperature: helium (He), neon (Ne), argon (Ar), hydrogen cyanide (HCN), hydrogen sulphide (H_2S), boron trifluoride (BF_3) and dichlorodifluoromethane (CF_2Cl_2).

Kotz and Treichel (1996:17) emphasise that gases are also fluids. As the temperature of liquids is raised, liquids evaporate to form gases. Intermolecular forces between gas particles are so small and weak that the net effect of the many molecules striking the container walls is observed as pressure. When the temperature of a gas is increased, the particles move faster due to the gain in kinetic energy. Gases have a very low density because of the space between their particles. When compared to solids and liquids in density, solids have a greater density than liquids and gases.

Diffusion in gases is much faster compared to liquids and solids. In solids, diffusion is negligible due to the close packing of the particles. As the temperature increases, the rate of diffusion also increases due to the increase of kinetic energy of particles (GCSE-K53, 2007).

The plasma state

Plasma is defined as a gas-like phase of matter that consists of charged particles. The source of energy from the sun and other stars is due to the reaction of the charged particles (Kotz & Treichel, 1996:140). Figure 2.4 shows a distribution of charges (electrons and protons) in plasma state.

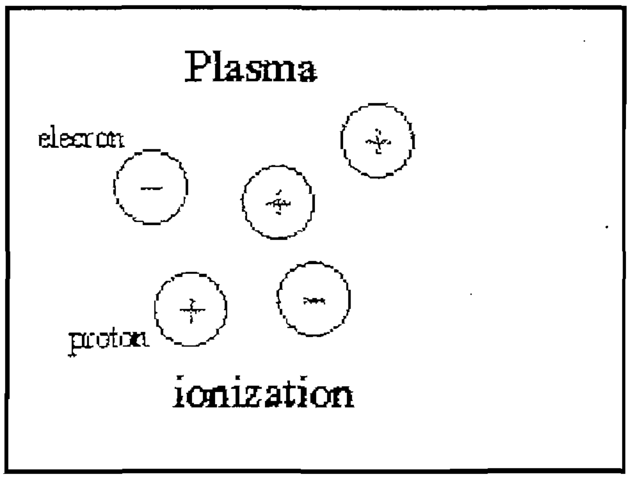


Figure 2.4: Model of the plasma state

Plasma is found in nuclear power plants that are used to generate large amounts of electricity worldwide. Some of these plasma particles have very long half-lives that can be up to tens of thousands of years. These particles can be dangerous in high concentrations (Kotz & Treichel, 1996:140).

2.3 PHASE CHANGES

2.3.1 The difference between physical and chemical change

A phase change is a physical change. The major difference between a physical change and chemical change is that physical changes are reversible, while chemical changes are not. In a chemical reaction the original substance is changed completely (Atkins & Beran, 1990:4). It is also important to note that when a reversibility of a chemical reaction is observed, it cannot be explained as phase change, as the temperature fluctuates. Chemical reactions will continue until all the reactants are exhausted, while the concentrations of all species in a reaction mixture will be equal, for example, $3H_2 + N_2 \rightarrow 2NH_3$.

A physical change can take place without changing the substance into a different substance. Physical changes can be used to separate mixtures, for example, distillation can separate liquids based on different boiling points as is used in oil or alcohol distillation (Regular Chemistry Notes, 2001).

One interesting property of a physical change is solubility, which is the ability to dissolve in solution. The property depends on several factors, temperature being a major one. The greater the temperature, the easier the substance will dissolve (Regular Chemistry notes, 2001).

Examples of physical changes in our laboratories (GCSE – KS3, 2007):

(1) $I_2(s) \quad \leftrightarrow \quad I_2(g)$

At room temperature bottles of solid iodine show crystals forming at the top of the bottle. When temperature of $I_2(s)$ is increased, it changes its state to a gas.

(2) $CO_2(s) \leftrightarrow CO_2(g)$

Solid carbon dioxide (dry ice) is formed when cooling the gas down to less than -78^{0}C. On warming, it changes directly to a very cold gas, condensing any water vapour to a mist.

Chemical change is the formation of one substance from other substances (Atkins & Beran, 1990:4). In our everyday lives we can observe chemical change in our kitchens when food is cooked and the different substances that contribute to its flavour and aroma. In industry, the extraction of metals from their ores makes use of chemical change. In laboratories, the chemical change can be referred to as chemical reactions whereby one substance responds or reacts to the presence of another. Such influences can be brought by a sudden change of temperature, pressure or concentration and other external factors. Even the passing of an electric current through liquids such as matter substances can bring about a chemical change. The process is called electrolysis (Atkins & Beran, 1990:4).

Chemical change can also be referred to as a change in which one or more substances are converted into different substances, such as a chemical reaction of a metal to rust, flammability, decomposing and fermentation. Reactants or beginning substances are converted into products, which are end substances.

Example: Iron + Sulphur → Iron sulphate

The most observable signs of chemical change are bubbling whereby gases are involved, formation of precipitates that involves insoluble solids, colour change and when heat is taken up or lost.

Physical and chemical changes take place simultaneously in some chemical reactions. A laboratory example is (GCSE – KS3, 2007):

$NH_4Cl(s) \leftrightarrow NH_3(g) + HCl(g)$ (Chemical and physical change)

When white solid ammonium chloride is heated strongly in a test tube, it decomposes into two colourless gases that are ammonia and hydrogen chloride. On cooling, the reaction is reversed to ammonium chloride.

2.3.2 Processes of phase changes

Atkins and Beran (1990:3) summarise changes of state as indicated in Table 2.6.3

Table 2.1: Changes of states

Initial state	Phase change	Final state
Solid	Melting (or fusion) $\rightleftharpoons$ Freezing	Liquid
Liquid	Vaporisation $\rightleftharpoons$ Condensation	Vapour
Solid	Sublimation $\rightleftharpoons$ Deposition	Vapour

In a phase change, temperature plays a vital role, as it indicates the melting, boiling and freezing points or vaporisation and condensation of the substances (Mabalane, 2006:34).

Evaporation and condensation

Lewis and Waller (1992:8) define evaporation as the state where liquids change into their specific gases over a range of temperatures. Evaporation can be recognised by the gas bubbles coming from the liquid.

Substances with high vapour pressure (like gasoline and hot water) vaporise more readily than substances with low vapour pressure. Increase in temperature increases the vapour pressure, because the molecules in the heated liquid move faster. Through this movement, particles that are on the surface of the liquid will easily evaporate, as they are least bound as compared to the ones at the bottom of the container (Atkins & Beran, 1990:374).
Birk (1994:420) emphasises that for molecules to undergo evaporation, they should be in a position of overcoming the intermolecular forces of attraction and moving in the right direction, with a high kinetic energy. The average kinetic energy of the remaining liquid molecules will definitely decrease as evaporation proceeds, unless energy is supplied continuously to the system.

The return of gas-phase molecules to the liquid phase is called condensation. The situation is more favourable in a closed container, because the gaseous molecules cannot diffuse completely away from the liquid. Evaporation and condensation continue at rates that depend on the temperature and the number of molecules. When the rate of evaporation is equal to the rate of condensation, a state of equilibrium will be reached (Birk, 1994:424).

Freezing and melting points

Kotz and Purcell (1991:581) define freezing as the process whereby a pure solvent's few molecules cluster together to form a tiny amount of solid. During clustering, as long as the heat of fusion is removed, more molecules will move to the surface of the solid to intensify solidification. The reverse process is that when the heat of fusion is not removed, the opposing process of melting can come into equilibrium with freezing.

Conservation of molecules will be observed as the number of molecules moving from solid to liquid is the same as the number moving from liquid to solid in the given time. However, in order to keep the two processes balanced (solid → liquid and liquid → solid) in terms of the number of molecules, the temperature must be lowered to slow down movement from solid to liquid and prevent sublimation.

2.4 LAW OF CONSERVATION OF MATTER

The law of conservation of matter (or the law of conservation of mass) was discovered by Antoine Laurent Lavoisier (1743-94) around 1785. Lavoisier was not the first to accept this law as true or to teach it, but he is credited as its discoverer after he had performed a convincing number of experiments. Lavoisier showed that matter can neither be created nor destroyed. For example, 10 grams of reactant will end up being 10 grams of product when the reaction is complete (Kotz & Treichel, 1996:159). Lavasoir wrote a textbook in which the principle of the conservation of matter was applied for the first time.

Most of the experiments done by Lavoisier were done in closed vessels. He discovered that the weight of matter remained constant during chemical reactions such as combustion. Part of his work was shared with the Englishman Joseph Priestley (1733 – 1804). During the Reign of Terror of the French Revolution, Lavoisier came under suspicion and died by guillotine on May 8, 1794 (Kotz & Purcell, 1991:105).

During the 18th century the law of conservation of matter became part of Dalton's atomic theory. Atoms of different elements combine in simple whole numbers to form compounds. As stated earlier, atoms cannot be created or destroyed. Matter is consequently conserved (Bodner & Pardue, 1995:46). This means that if 1000 atoms of a particular element react, the product will have 1000 atoms. For example, 2 atoms of aluminum and 3 diatomic molecules of Br_2 produce 1 molecule of Al_2Br_6,
$2Al\,(s) + 3Br_2\,(l) \rightarrow Al_2Br_6\,(s)$ (Kotz & Treichel, *1996:160*).

2.5 ALTERNATIVE CONCEPTIONS ABOUT MATTER

2.5.1 Introduction

Our senses suggest that matter is continuous, for example, the air that surrounds us feels like a continuous fluid, because we do not feel bombarded by individual particles (Bodner & Pardue, 1995:46). In addition, the water we drink is referred to as being a continuous fluid, as it can be divided into halves again and again up to a point where it is impossible to divide it further.

Crespo and Pozo (2004:1325) indicate that to learn science is more than just replacing our everyday knowledge by knowledge that is more acceptable from a scientific point of view. Two difficult concepts that were researched by Crespo and Pozo (2004:1327) were that learners fail to explain situations involving two different states of matter within the same material. An ice cube melting in water and the expansion of an iron bar through heat were the most difficult to grasp. It is important that the kinetic theory should be used to ensure the understanding of expansion and changes of states. By using this theory, an appropriate explanation about movement and interrelationships between the temperature and density of matter should be reached.

In the early 1980s there was an explosion in research about learners' learning of science concepts. Science education researchers explored learners' (and in some instances adults') ideas about concepts and events in science. A general conclusion was that researchers labelled their findings as learner misconceptions, naïve science, alternative theories or children science. Researchers made us aware that learners hold ideas about science that are significantly different from what scientists believe. Alternative conceptions are highly resistant to change, even with successful instruction or correct performance on tests. Outside the science classroom, learners are more likely to explain natural events in their own way to fellow learners and do not use correct scientific conceptions (Meyer, 2007:3).

2.5.2 Alternative conceptions regarding the properties of matter

Under the properties of matter, the following alternative conceptions have been identified by Anon, 1998:6:

- Gases are not matter because most are invisible. For the learners to be clear regarding these alternative conceptions, the educator could use nitric oxide. Nitric oxide is a colourless gas, but when it mixes with oxygen in the air, it forms the brown gas NO_2.
- Air and oxygen are the same gas. To clarify this misconception, the educator should simply differentiate the two through definitions.
- Air is the mixture of gases that surrounds the earth and we directly breathe it in in everyday life, while oxygen is a gas present in the air that is an element, is without colour, taste or smell and is necessary for all forms of life on earth.

In an investigation on learners aged between 14 and 16 years, Renstrom *et al.* (1990:558) encountered the alternative conception that matter is perceived to be a homogeneous substance, i.e. it is seen as a continuum. A continuum is something that is without parts and is the same from beginning to end. The idea of empty space between particles in matter is related to issues of size and number of particles in matter (Meyer, 2007:7). In order for learners to understand a particulate view of matter, they should be in a position to accept that there is empty space between and within these particles.

Renstrom *et al.* (1990:558) also report that learners believe that any substance has only one state. They reason that if a substance can be changed to another state of matter, it will be impossible to recognise the identity of the substance. Learners were therefore not able to support the statement that says "any substance has something that is typical". An example of this alternative conception is that learners regarded "hot air" and "cold air" as two different substances. When learners were asked to comment on a substance with small particles (i.e. crushed), they believed that the substance could not be reversed to form a whole, for example in the case of wax or ice. This result proved that the conservation of matter was not taken into consideration by learners (Renstrom *et al.*, 1990:560).

2.5.3 Learners' alternative conceptions regarding phase change

Stephens (1996:1) indicates that in order to lessen learners' alternative conceptions on physical change, an educator has to give learners room and time to logically explore what they know about matter. Learners have problems to relate appearance and density, as there are other characteristics of matter. They only understand that matter has mass, volume and density. They find it difficult to understand that mass is conserved during a phase change, e.g. melting of ice to liquid. Due to the fact that ice floats, learners deduced that ice does not have mass. As was seen in the discussion of the solid state, particles of solids have no motion. Particles are arranged in regularly repeated patterns and can vibrate within a limited area.

Meyer (2007:4) reports that young learners believe that things just disappear when they are dissolved. Even when learners gain more instruction in chemistry, it was found that a large proportion of learners in the 15-year age group still demonstrated misconceptions about dissolving. In connection with phase change, learners were most likely to believe that particles exist in solids and a solid could be continually broken into smaller and smaller bits until you get particles. Furthermore, learners were not likely to believe that liquids and gases are composed of particles

Anon (1998:6) states that phase changes such as melting/freezing and boiling/condensation are often understood only in terms of water. Laboratory experiments have shown that many substances can undergo the above change of states. For example, dinitrogen trioxide (N_2O_3) condenses to a deep blue liquid that freezes at -100^0 C to a pale blue solid (Atkins & Beran, 1990:751).

With regard to physical and chemical change, there is confusion in learners between atoms and molecules, leading to the following misconceptions (Smith *et al.*, 2006:3):

- Water molecules become solid and heavier when frozen.
- Molecules of water become molecules of oxygen and hydrogen when water boils.
- The number of particles is not conserved during physical changes.
- Matter can disappear with repeated division, e.g. in dissolving and evaporation.

2.5.4 Difficulties involved in learning about conservation of matter

Learners must understand the conservation of matter in order to explain physical or chemical changes (Gomez *et al.*, 1995:78). When matter undergoes a change such as a phase change, the microscopic structure of the substance does not change and thus conserves its identity. For example, the water molecule H_2O retains its structure when changing from ice to water.

Conservation of matter is a core idea of understanding both physical and chemical changes. This can be achieved only when learners have a good understanding of an atomistic conception of matter (Gomez *et al.*, 1995:78). From a scientific point of view, during physical change and on obeying the law of conservation, the substance is still the same. For example, in the form of a solid, the external appearance of water will be ice and in the form of liquid it will be water. All molecules involved in the two states are the ones belonging to water. The conclusion is that the initial and final matter is water (Driver *et al.*, 1998:147).

Physical changes such as phase changes differ from chemical changes. In a chemical change, a chemical reaction takes place and a new substance is formed. A reorganisation and distribution takes place in the microscopic structure, while conservation of matter is still experienced (Driver *et al.*, 1998:147).

Learners experience problems with conservation of matter during the transition between different phases, for example, a transition from liquid to gaseous phase (Renstrom *et al.*, 1990:556).

Learners also experience problems in explaining what happens to sugar when it dissolves in water. Responses to this question suggested that the mass of the solution would be the same as the original mass of the water, because sugar does not do anything to water. Regarding the issue of mass and volume, learners responded in terms of whether the level of water will go up when sugar is added, therefore equating mass with volume. Conservation of matter entails that when sugar granules dissolve, they fill spaces between the molecules of water to form one solution, while the total mass remains unchanged (Driver *et al.,* 1998:155).

2.6 SUMMARY OF ALTERNATIVE CONCEPTIONS REGARDING PHASE CHANGE.

From the literature review follows that learners may reveal the following alternative conceptions regarding phase changes:

- Mass is not conserved during phase change (Stephens, 1996:1).
- A molten material weighs less than the same material in its solid state. Similarly, a gas weighs less than the same substance in its liquid or solid form (Stavy, 1990:501).
- Due to the fact that ice floats, learners deduced that ice did not have mass (Stephens, 1996:1).
- Gases are not matter because they are invisible.(Anon, 1998:6).
- Air and oxygen are the same gas (Anon, 1998:6).
- Particles of solids have no motion (Anon, 1998:6).
- Phase changes such as melting/condensation/freezing and boiling are understood in terms of water (Anon, 1998:6).
- Bonds between oxygen and hydrogen atoms break during boiling (Smith *et al.,* 2006:3).
- Water molecules become solid and heavier when frozen (Smith *et al.,* 2006:3).
- Relative particle spacing amongst solids, liquids and gases are incorrectly perceived and not generally related to the densities of the states. (Hapkiewicz, 1999:26).

2.7 FACTORS THAT MAY CAUSE ALTERNATIVE CONCEPTIONS

Tsai (2004:1733) did research on the misconceptions of Grade 11 and 12 science learners. The research revealed that science conceptions can be a result of learning approaches, which then have a negative influence on the learning outcome. Many of the problems of learning science are brought about by memorisation, which leads to rote learning. In order to counteract these conceptions, the educator should practise approaches to learning that will ensure better learning outcomes.

Alternative conceptions can also be due to misrepresentation of particles in sketches. An example is where no differentiation is made between atoms and molecules (Anon, 1990:6). The educator should differentiate between atoms and molecules by using the atomic theory of matter.

Purdie *et al.* (1996) (as quoted by Tsai (2004:1735) mention culture as one of the factors that influence learners to have alternative conceptions. The following countries are likely to have the same conceptions, as they share a similar culture, norms and standards, namely: Taiwan, China and Hong Kong. According to Eklund-Myrskog (1997, 1998) (as quoted by Tsai (2004:1735), the educational context also confuses learners so that they are unable to relate what they have learnt in one field to other fields.

One of the major problems experienced by learners in the learning of science is that there are many formulae, definitions and laws that need to be understood and used wisely when solving exercises and real-life situations. Learners indicated that all the factors mentioned above are abstract to them. It seems that they lack good strategies to recall them effectively; hence alternative conceptions are held (Tsai, 2004:1738).

One of the reasons leading to misconceptions is that learners are not exposed to ontology or metaphysics (Smith *et al.,* 2006:3). For example, according to the Aristotelian view, substances exist in only one state (water is a liquid and oxygen is a gas). Learners experience problems to differentiate between intermolecular and intra-molecular bonds, for example, they think that bonds between hydrogen and oxygen atoms break during boiling.

Driver *et al.* (1998:130) investigated the particular nature of matter in the gaseous phase and learners' preconceptions. They divided their work into different categories. In the first category gas is composed of invisible particles. Here they found that 64% of the students responded by saying that air is made up of particles. This percentage verified that 36% of the class has alternative conceptions with regard to this aspect. In the second category, gas particles are evenly scattered in any enclosed space. Here the learners were forced to demonstrate that they have overcome the concept of continuity of matter and have to address the behaviour of individual particles. The results were that one out of six learners believed that the particles were not scattered but were only concentrated in some part of a confined space in an enclosed container (Driver *et al.,* 1998:130).

Category 3 was concerned with the empty space between the particles in gas. The findings were that 45% of the learners agreed that there is an empty space between particles, 16% were unsure until such time the particles were pressed. The remaining 39% reasoned that there was no space between particles and that particles were closely packed (Driver *et al.,* 1998:130).

During an investigation where salt was divided into smaller and smaller particles, learners concluded that these "small atoms" are made of the same substance. With this information, it was easy to explain to learners about the smallest constituents of matter. Learners also referred to matter as an aggregate of particles. These particles were believed to be divisible or having an atom-like character but no size (Renstrom *et al.*, 1990:561).

2.8 CATEGORIES OF LEARNERS' ALTERNATIVE CONCEPTIONS

Nakhleh and Samarapungavan (1999:784) identify the following categories of learners' alternative conceptions.

- Category arising from initial, spontaneous descriptions:
  This category explains the macroscopic and microscopic properties. For example, macroscopic descriptions deal with properties such as taste, function, visual properties, texture, shape and size, while microscopic properties deal with molecules and atoms.
- Category arising from interviewer-constrained description of composition:
  This category describes statements that deal with macro-continuous, macro-particulate, macro-description and micro-particulate.
- Category arising from explanation of properties (fluidity and malleability):
  This category explains the phenomenon based on macro-description, macro-intrinsic, macro-state, macro-force, macro-composition, macro-compression, non-explanation, macro-particulate and micro-particulate-description.
- Category arising from explanation of processes (phase transitions and dissolving):
  This category explains perceptions based on macro-process, macro-process heat, micro-process and micro-process heat.

Nakhleh and Samarapungavan (1999) found that the understanding of the particulate nature of matter by young children (ages 7 to 10) showed different developmental levels. They categorised the learners' understanding about the macroscopic and microscopic properties of the state of matter, phase changes and dissolving into three explanatory frameworks, namely:

- Macro-continuous: Matter is perceived purely macroscopic with no underlying structure.
- Macro-particulate: Learners still think on the macroscopic level, but begin to view some forms of matter as being composed of some sort of tiny particles and explain some phenomena (e.g. dissolving) in terms of particles.

- Micro-particulate: All matter is made up of tiny invisible particles, called atoms, or molecules. Phenomena such as phase changes and dissolving are explained in terms of the motion and arrangement of these particles.

2.9 SUMMARY OF CHAPTER

This chapter discussed the scientific view of the physical properties of matter, the particle nature of matter and the conservation of matter. This served as a theoretical framework for a survey of learners' alternative conceptions and other problems regarding phase changes. In Chemistry textbooks, phase changes are discussed and explained in terms of the particulate model of matter and the law of conservation of matter. Learners' alternative conceptions regarding phase changes relate to deficiencies in their knowledge of these two core domains.

The importance of the research on alternative conceptions is to help science learners to overcome fundamental learning problems about matter. However, Meyer (2007:4) indicates that recent literature showed that these alternative conceptions are resistant to change. Most of the researchers attempt to address how to overcome misconceptions, but on the way the researcher end up focusing on new problems.

The next chapter provides a literature study of the constructivist theory. According to this learning theory, educators should take learners' alternative conceptions into account for effective learning of science concepts.

CHAPTER 3

THEORY OF CONSTRUCTIVISM

3.1 INTRODUCTION

This chapter reviews learning theories and teaching strategies that may be applied in the empirical study to enhance learners' understanding of conservation of matter in phase changes. The emphasis is on constructivism as teaching-learning theory. In the empirical study constructivist principles will be applied in the teaching of grade 10 science learners introduced to the National Curriculum Statement. The intention is to develop their knowledge and address their alternative conceptions regarding matter and its conservation.

Teaching strategies must account for the main components of the didactic situations, which are the learners, educator and the content. Vermeulen (1997:10) defines a teaching strategy as a broad action for teaching activities with a view to achieving an aim. It must be emphasised that there are different teaching strategies that can be chosen to fit the backgrounds and culture of the educator and learners.

Choosing a relevant teaching strategy that will cater for all learners in a class is very difficult, because learners differ according to their respective intelligence. Therefore, it is proper and reasonable to have a combination of teaching strategies so as to serve the multiple intelligence levels of the learners. Intelligence variables include visual, verbal, mathematical, kinesthetic, rhythmic, interpersonal and intrapersonal intelligence (Vermeulen, 1997:11).

In this chapter, constructivism as a learning and teaching strategy will be discussed. Specific reference will be made to its effectiveness to help the researcher achieve his goal and aim. The chapter starts with an overview on what constructivism is and how it was developed by different educational theorists, types of constructivism, constructivist principles of learning, constructivist principles of teaching practice and guided discovery.

3.2 WHAT IS CONSTRUCTIVISM?

Constructivism emphasises the importance of the knowledge, beliefs and skills that a learner brings to the learning experience. It is regarded as the philosophy of learning that encourages learners' need to build their own understanding of new ideas. The theory is about knowledge and learning. It describes what knowing is and how learners come to know (Epstein, 2002:4). Constructive approaches enhance the understanding of one's mental process and learning. Constructivism highlights the importance of understanding the knowledge construction process so that learners can be aware of the influences that shape their thinking (Woolfolk, 1995:483).

Huitt (2003:1) regards constructivism as an approach based on a combination of research in teaching and learning within cognitive psychology and social psychology. A consequence is that an individual learner must be actively involved and apply his/her knowledge and skills as much as possible. Epstein (2002:4) defines constructivism as a combination of prior learning, gathering of new information and readiness to learn. Readiness to learn means that instruction must be concerned with the experiences and contexts that make learners willing and able to learn (Huitt, 2003:2). For example, a toddler's social understanding, development of language, physical experiences and emotional development are acquired simultaneously and are of benefit to him for the rest of his life.

Constructivism is also concerned with the spiral organisation of the learning content, meaning that the instruction must be structured so that it can be easily grasped by the learner. Instruction should be designed to facilitate extrapolation and fill in the gaps (Huitt, 2003:2). Educators' philosophical beliefs about how children learn guide their teaching approaches.

Six fundamental characteristics of constructivism have been identified by Barrows (1996) as quoted by Gijbels *et al.* (2006:216), namely,

1. Learning needs to be student-centered
2. Learning has to occur in small groups under the guidance of the educator.
3. The tutor is a facilitator or guide who plays an important role in the preparation of learners' education.
4. During learning, learners will always encounter learning problems and such problems will be used as a tool to achieve the required knowledge.
5. New information is acquired through self-directed learning

3.3 DEVELOPMENT OF THE THEORY OF CONSTRUCTIVISM

Epstein (2002:1) identifies John Dewey, Jean Piaget, Lev Vygotsky and Jerome **Bruner** as important people who contributed to the theory of constructivism. John Dewey (1933-1998) is regarded as the philosophical power of this approach, while Ausubel (1968), Piaget (1972) and Vygotsky (1934) are considered as chief theorists among the cognitive constructionists (Huitt, 2003:1).

According to John Dewey, education depends on action. Dewey defined the mind as a means of transforming, recognising, reshaping accepted meanings and values. His central idea was that a learner's knowledge is gained from experiences. He combined knowledge and ideas as coming from where learners have to draw their experiences. Learners are encouraged to give proper meaning to their daily experiences. Daily experience is positively brought forward by a social environment whereby learners share ideas, analyse content and create a conducive environment for themselves (Epstein, 2002:4).

Jean Piaget's interest was in the way that children think. He indicated that in order to understand an aspect, one has to discover it. Through discovery, proper learning will take place. Children have to go through stages of understanding so that they can accept better ways of understanding. Piaget believed that logical reasoning will be developed if the child goes through the various reconstructions that an individual's thinking goes through

(Epstein, 2002:4). Piaget (1971), as quoted by Wong *et al.* (2006:124) made a huge contribution to cognitive constructivism (refer to paragraph 3.4.1).

Lev Vygotsky believed that children learn concepts from their everyday experiences. In addition, he indicated that children should be guided by adults and be influenced positively by their peers (Epstein 2002:4). Vygotsky was responsible for the theory of social constructivism (refer to paragraph 3.4.2). Donald *et al.* (2002:103) refer to socially constructed knowledge as a type of knowledge that is not fixed but shaped and reconstructed in different social contexts and at different times. For example, language as a tool of social interaction shapes the way individuals think and present themselves to the public.

Jerome Bruner was interested in learners' current knowledge. He indicated that learning is an active, social process in which a learner constructed new ideas or concepts based on known knowledge. He encouraged educators to give learners more time so that they can explore and discover principles by themselves. In conclusion, Bruner emphasised that a curriculum should be organised in a spiral manner so that learners continually build upon what they already know (Epstein, 2002:4).

3.4 TYPES OF CONSTRUCTIVISM

Epstein (2002:4) identifies two types of constructivism, namely cognitive and social constructivism. Although critical or radical constructivism is also a type of constructivism (Wong *et al.*, 2006:124), it is not relevant for this study. A brief discussion of cognitive and social constructivism follows.

3.4.1 Cognitive constructivism

Cognitive constructivism is based on the work done by the developmental psychologist Jean Piaget, who divided his work into major parts known as "ages" and "stages". Ages were used to explain what learners can and cannot understand at different ages. Stages defined what learners learn and develop at different stages with reference to cognitive abilities.

According to cognitive constructivism, the role of the educator and classroom environment are important aspects, as they prepare learners for learning (Epstein, 2002:4). Piaget argued that meaningful learning requires learners to construct rather than receive knowledge (Wong *et al.*, 2006:124). Cognitive development indicates that learners should be given information that will draw out their potential so that they build their knowledge through experience and create mental images (Epstein, 2002:4). Seen from this perspective the educator's role is to assist learners to modify their views, findings and experiences to be in line with fellow learners.

Multiple representations of content help learners to have different methods to apply to different complex situations. When learners us only one way of understanding complex content, they often get confused when they encounter situations that need a multiple approach. Richard Spiro and his colleague (1991) as quoted by Woolfolk (1995:483) suggest that revisiting the same material at different times, in rearranged contexts, for different purposes and from different conceptual perspectives, are essential for attaining the goals of advanced knowledge acquisition.

3.4.2 Social constructivism

The work of Vygotsky is similar to that of Piaget, although he placed more emphasis on the social context of learning. This theory encourages learners to grasp concepts and ideas from their educators and fellow learners so as to promote understanding. The difference between the two theories is that in cognitive constructivism (Piaget's theory), the educator plays a bigger role in learning (Epstein, 2002:4). In social constructivism, the educator should be active and at all times be involved in learners' learning. The educator may guide learners as they approach problems, encourage them to work in groups and give them advice with regard to learning (Epstein, 2002:4). It is believed that constructivist teaching helps learners to internalise, reshape or transform new information (Mahaye & Jacobs, 2008:168).

Kabapinar *et al.* (2004:636) also argue that social constructivism has important implications for the role of the educator and content presentation during learning and teaching. In addition, it is the responsibility of the educator to ensure that the language used to teach science should be on the level of understanding of learners. Learners should be helped to recognise the limitations of their explanations and apply their thoughts and ideas.

Social constructivism also helps learners to consult with their educators as much as they need so that they can be familiar with the problematic situations that they meet in their everyday lives. This strategy helps the educator to introduce ideas on the social plane of the classroom and to support learners in coming to an understanding of shared ideas. Control of the classroom by the educator, the manner in which he or she writes on the blackboard, drawings and gestures can all enhance the understanding of concepts. This strategy enables the educator to support learners in explaining concepts through questioning (Kabapinar *et al.*, 2004:636).

Constructivist learning promotes social negotiation (Woolfolk, 1995:482). This type of approach indicates that cultural experiences and interactions with others in a social setting mediate each individual's construction of meaning. With Vygotsky's belief that higher mental processes develop through social interaction, constructivists conquered. Through collaboration in learning, learners develop skills and abilities to establish and defend their own positions, while respecting the positions of others. For further promotion of social negotiation, learners must talk and listen to each other as much as possible (Woolfolk, 1995:482).

Due to the idea that learning should be meaningful and useful in their own lives, the skills leant by learners are more important than the content of what they learn (Mahaye & Jacobs, 2008:171). The target of the learning content is to empower learners to become lifelong learners; to represent a shift from a product-orientated curriculum to a process-orientated curriculum. Educators are encouraged to provide learners with the type of skills that will enable them to become well-rounded human beings that are able to apply the knowledge and skills they have acquired to the benefit of their families, communities and country.

Spector (1993:9) as quoted by Mahaye and Jacobs (2008: 169) identifies the following as the characteristics of socio-constructivist learning content:

- Content information is reduced, since new research produces new information.
- The emphasis is on holistic concepts.
- Content is more trans-disciplinary as compared to disciplinary boundaries.
- At all times, the content should be organised around themes, current issues and how to solve real-life problems.
- Through socio-constructivist learning content, science is portrayed as a dynamic discipline.
- Learning is seen as scientific enquiry whereby meanings are constructed, because a scientist is regarded as someone that is empowered to look for answers and solutions to the problems of society.
- Through strategies such as co-operative learning strategy applied by the educator, it will be reasonably clear that socio-constructivism requires a learner-centered approach to teaching. In this case, learners need to be liberated and the activities and work in the classroom needs to be relevant to the lives of the learners.
- Learners are encouraged to work in groups so that they can be given the opportunity to seek out information, discuss and analyse, understand and relate it to their existing.

3.5 CONSTRUCTIVIST PRINCIPLES OF LEARNING

3.5.1 The principles of learning

Fardanesh (2006:3) indicates that the constructivist approach is based on epistemological and psychological aspects of constructivist learning. Therefore, a successful learning process does not rely on predetermined designed steps but on some principles. Fardanesh (2006:3) outlines these principles as follows:

- Include learning in related and authentic contexts.
- Include learning in social experiences.
- Induce having perspective in the learning process.
- Provide the experience of the process of knowledge creation.
- Induce consciousness of the process of knowledge construction.
- Provide experience and appreciate different perspectives.
- Induce the use of different presentation modes.

Epstein (2002:3) identified nine constructivist principles, namely:

Principle 1: Learning is an active process in which the learner uses sensory input and constructs meaning from it.
Principle 2: People learn to learn as they learn.
Principle 3: Physical actions and hands-on experience may be necessary for learning.
Principle 4: Learning involves language.
Principle 5: Learning is a social activity.
Principle 6: Learning is contextual.
Principle 7: One needs knowledge to learn.
Principle 8: Learning is not instantaneous, it takes time to learn.
Principle 9: The key component to learning is motivation.

This list of Epstein's (2002:3) nine principles is more comprehensive and includes those of Fardanesh (2006:3). Thefore, these nine principles are discussed in the following paragraph (3.5.2).

3.5.2 Discussion of the principles

Principle 1: *Learning is an active process in which the learner uses sensory input and constructs meaning from it*

The first principle simply means that a learner should use all his senses to learn actively. Bransford *et al.* (2000:89) indicate that the constructivist view of learning is promoted by an active process of learning. Passive learning is observed when learners are involved in reading books, attending regular lectures as well as on-line presentation by lecturers. In turn, constructivist teaching involves active group discussions, hands-on activities and interactive games.

Donald *et al.* (2002:100) emphasise that through constructivism knowledge is not passively received but actively constructed, that is, it is built up and developed to higher levels of knowledge by every learner. As human beings are active agents in their knowledge development, they are shaped by both nature and nurture. For learners to be involved in experiences, activities and discussions, they need to understand both the social and physical environment they find themselves in. Learners play an active role in building understanding and making sense of information (Woolfolk, 1995:481).

Prawat (1992:357), as quoted by Woolfolk (1995:481), agrees that constructivism involves dramatic changes in the focus of teaching, putting the learners' own efforts to understand at the centre of the educational enterprise. Consequently, learning is learner-centered. Through constructivism learners are able to solve problems on their own, become be creative, discover on their own and become accurate thinkers.

In addition, constructivist learning requires active teaching methods that will enhance learners to construct knowledge for themselves. Learners should solve problems with maximal freedom to explore. Bruner (1961), as quoted by Mayer (2003:8), encourages learners to discover and not to memorise what the educator says. Pure discovery methods mean that learners receive problems to solve with little or no guidance from the educator. According to the guided discovery method, however, a learner is requested to solve a problem while the educator provides hints, direction, coaching and feedback so that the learner is kept on track. Lastly, in expository methods, a learner is simply given the problem along with the correct answer (Mayer, 2003:8).

Moston (1972:117), as quoted by Reichert (2005:2), outlines ten cognitive operations that usually take place as the learner engages in active learning, namely, recognising, analysing, synthesising, comparing and contrasting, drawing conclusions, hypothesizing, memorizing, inquiring, inventing and discovering. As the learner is undergoing these cognitive operations, he or she will acquire an understanding of the subject matter.

It is further indicated that discovery-learning cannot take place if the answers were given, because learners' minds will not be challenged to work on their own. Some of the drawbacks related to this teaching method are that it controls and manipulates learning behaviour and could therefore be abused. It is designed or work effectively for individuals rather than groups (Reichert, 2005:2).

Principle 2: *People learn to learn as they learn*

Learners will realise that through learning they can achieve a lot in life and they will have a better education (Donald *et al.*, 2002:116). Constructivism through learner-centered learning allows learners to be responsible for their own learning. They should play an active role to achieve high-level outcomes, such as application and creation (Donald *et al.*, 2002:116).

Principle 3: *Physical actions and hands-on experience may be necessary for learning*

Learners should be given activities that will keep their mind and hands busy during the process of learning (Trowbridge *et al.*, 2004:183).

Advantages of hands-on experience are that:

- Learners become directly engaged at all times, while educators help them in planning and performing investigations (Trowbridge *et al.*, 2004:183).
- Learners' expectancy level increases because they believe that they can accomplish a task on their own. From one investigation to the other, learners' accuracy and investigative talents will be nourished. The more freedom learners have to use their academic talents, the more opportunities they will have to develop others, such as creative, social, organising and planning talent (Trowbridge *et al.*, 2004:184).
- Learners are allowed to learn at their own pace and use relevant contexts (Vermeulen, 1997:71). As learners have different abilities it is important that one must acknowledge that they are unique. Learners should be exposed to different experiences in different contexts. In this way self-activity helps learners to perceive the purpose of the lesson as they are involved in practical applications of what they are learning.

Learners use their own initiative, exercise their imagination and think for themselves as the process of learning continues (Vermeulen, 1997:72). In most cases, learners are faced with situations and they simply have to use their own judgment to fulfil the given task. When learners are given a self-activity, they acquire knowledge and develop skills simultaneously. Such skills include writing skills, listening skills and communicating skills.

Development of good habits of work and discussing their work are also enhanced (Vermeulen, 1997:72). Learners tend to derive enjoyment and satisfaction from their work as they achieve what is expected from them. It is important to learn from our mistakes so that we can correct them ourselves; therefore learners also learn from their mistakes.

Principle 4: *Learning involves language*

This principle simply means that learning should take place in the language that the learner understands (Donald *et al.,* 2002:114).

Through constructivism, learners are helped to develop and refine their use of language in all its forms, such as speaking, reading and writing. Language is said to be a central tool in the teaching and learning process. Learners are encouraged to be involved in discussions, reflections, debates and interaction problem solving (Donald et *al.*, 2002:114).

Gass and Mackey (2000:28) indicates that human learning require a specific social nature and is a process by which children grow into the intellectual life of those around them. One of the most important findings is that children learn basic language and grasp basic words from those they interact with.

Development is a prerequisite for learning and if a child's mental functions have not matured to the extent that he is capable of learning, no instruction will be useful. It is important that a learner should basically learn in the language he or she understands Vygotsky (1978:35).

Gordon (1994:41) emphasises that language has a central and unique role in learning, both in and outside school. When children learn language, they engage in many foundations of learning itself. Learning language and learning through language are processes that take place simultaneously, because language is the essential condition of knowing and the process by which experience becomes knowledge.

Donald *et al.* (2002:116) indicate that language development can be enhanced if the learner is confident. Learners that are not confident in their ability to use language will not interact easily. Lack of language interaction will lead to learners' confidence being held back.

Principle 5: *Learning is a social activity*

Learners should interact with their educators, peers and society at large to enhance continuous learning. Constructivist learning should be relevant to learners so that they can use their initiative to build up their knowledge with the help of the educator's guidance and learners' collaboration. The traditional educator-centered approach is said to be not constructivist, because learners' points of view and suppositions are often neglected (Taylor & Francis, 2007:281).

Constructivism is designed in such a way to educate learners to analyse and solve problems efficiently. Learners are encouraged to engage in arguments, discussions and debates so as to stress learning as an active and cumulative construction of knowledge. By so doing, both the learner and the educator will be in a situation whereby ideas are exchanged without fear. Constructivism promotes co-operative learning that enhances social interaction between learners. Learning is said to be goal-oriented, since constructivist materials and resources are targeted towards solutions (Gijbels *et al.*, 2006:219).

Principle 6: *Learning is contextual*

Multiple representations of content help learners to have different methods to apply to different complex situations. When learners use only one way of understanding complex content, they often become confused when they encounter situations that need a multiple approach. Richard Spiro and his colleague (1991), as quoted by Woolfolk (1995:483), suggests that revisiting the same material at different times, in rearranged contexts, for different purposes and from different conceptual perspectives, are essential for attaining the goals of advanced knowledge acquisition.

Principle 7: *One needs knowledge to learn.*

New knowledge is easy to be absorbed and understood when there is rich existing knowledge to build on. When the learner has a wide range of information he will develop an interest in further learning. A scaffold is defined as a temporary structure that is erected around a building to support it until it has been completed. In the teaching and learning context, the educator needs to understand knowledge structures around the topic and how that will be implemented into the lesson. An educator may explain, demonstrate, ask questions and ask learners to reflect in order to set a strong scaffold throughout the lesson (Trowbridge *et al.,* 2004:184).

According to Appleton and Asoko (1996), as quoted by Wong *et al.* (2006:124), the learning environment reflected by the cognitive constructivism approach encourages educators to become aware of the preconceptions held by learners. From this angle the educator will be in a position to challenge the initial view of the learners and help them to become aware of alternative views. By so doing, the educator will provide opportunities for learners to try out new ideas in a non-threatening atmosphere.

Principle 8: *Learning is not instantaneous, it takes time to learn.*

The theory indicates that for continuous learning, we need to revisit ideas, try them out, play with them and use these ideas to confirm their practicality (Gijbels *et al.,* 2006:224).

Meaningful learning takes place when rich and relevant examples are made available to the learners so that they can integrate their former and recent learning experiences (Gijbels *et al.,* 2006:224).

Principle 9: *The key component to learning is motivation.*

Constructivism emphasises that education is about using knowledge and not acquiring it (Gijbels *et al.,* 2006:224). One form of encouragement is to provide regular and positive feedback to learners as often as possible. Encouragement is important when learners are struggling or when learners are about to begin a challenging activity. Learning should be made meaningful to learners by connecting schoolwork to learners' personal lives (Hanson, 1998:29).

Wolters and Rosenthal (2000:802) indicate that learners will be motivated if they feel safe, secure and that they belong. Educators should encourage learner thinking, facilitate learner collaboration and nurture learner autonomy. Learners with a strong learning goal are less likely to allow motivational problems, such as boredom, distractions and difficult tasks from completing their required schoolwork.

3.6 CONSTRUCTIVIST PRINCIPLES OF TEACHING PRACTICE

Donald *et al.* (2002:107) discuss and outline constructivist principles of practice applicable to teaching and learning. The principles are said to be overlapping and interacting, meaning that not one principle will operate on its own. Outcomes Based Education (OBE) is said to be learner-centered, encourages learners to be active and fits the constructivist principles closely. Through good understanding of these principles, one may become an effective, creative and productive educator within the OBE framework.

Donald *et al.* (2002:109) discuss the principles of practice as follows:

1. Promoting content as well as process

This principle encourages the educator and the learner to be actively involved during learning and teaching. Learning areas are structured according to key concepts and relationships, for example: the relationship between Mathematics and Physical Science helps the learner to use relevant theorems across learning areas with understanding.

2. Creating opportunities for action

Educators are encouraged to create opportunities for active engagement by the learners. They should involve all learners at all times so that they do not lose touch of what is expected of them.

3. Connecting

The educator should try to link the previous lesson with the current lesson to instill a proper follow-up from the learners. Bruner (1983:183), as quoted by Donald *et al.* (2002:109), indicates that the learner has to interact between the familiar and unfamiliar and figure out how to use what is already known in order to go beyond it.

Taylor and Francis (2007:281), as quoted by Brooks and Brooks (1993), argue that constructivist teaching could be defined as teaching that applies the following guiding principles:

- Posing problems of emerging relevance to learners;
- structuring concepts from whole to parts;
- valuing learners' points of view and addressing learners' suppositions; and.
- assessing learners' learning in context

Brooks and Brooks (1993), as quoted by Woolfolk (1995:487), identify the following constructivist teaching practices. The constructivist educator:

- Encourages learner autonomy and initiative;
- uses raw data and primary sources, along with manipulative, interactive and physical materials;
- uses cognitive terminology such as classify, analyse, predict and create;
- enquires about learners' understanding of concepts before sharing their own understanding of concepts;

- allows learner responses to drive lessons, shift instructional strategies and alter content;
- encourages learners to engage in dialogue, both with the educator and with one another;
- encourages learners' inquiry by asking thoughtful, open-ended questions and encourages learners to ask questions;
- seeks elaboration of learners' initial responses;
- engages learners in experiences that might rectify contradictions to their initial hypotheses and that will yield discussion;
- allows a waiting time after posing questions; and
- provides time for learners to discover relationships and create metaphors.

The main purpose of the constructivist theory is to make learners think for themselves and not to wait for the educator to lead them to the next level of learning. According to Epstein (2002:4), the constructivist educator:

- Sets up problems and continually assesses and monitors learners' exploration;
- guides the direction of learners' enquiry and new patterns of thinking;
- encourages learners and support them; and
- makes provision for learners' point of view and by so doing places learners in a position to express their own ideas in their own words

3.7 CONSTRUCTIVIST CLASSROOM

A constructivist classroom is the type of classroom that is molded to draw out learners' potential. In traditional classrooms learners used to sit in rows facing one direction, which was the chalkboard. A constructivist classroom allows learners to sit in groups and share information as much as possible. A very positive social environment, such as mutual respect between the educator and a learner and amongst learners themselves, will enhance learning and teaching. The learning process is more recognised than the product of learning. The constructivist classroom provides learners with a platform to attach their own meanings and make their own decisions about learning (Epstein, 2002:4).

Biggs (1996), as quoted by Wong *et al.* (2006:125), indicates that even if it is evident that cultural differences play a vital role in our education, the principles of good teaching are culturally independent. It has also been proven that a change to a cognitive constructivist teaching approach has led to higher-order cognitive strategies and learning outcomes. Learners tend to achieve more in a learning environment that they find accommodative. Five important indicators that are related to an effective constructive learning environment are as follows: personal relevance, uncertainty, critical voice, shared control and learner negotiation.

According to Wong *et al.* (2006:125), learners in Hong Kong secondary schools prefer their Chemistry classes to be more personally relevant and to allow them more say, to share more control and to negotiate more with their educators. However, it is also imperative to note that each child is unique; therefore the educator must start where the child is.

3.8 GUIDED DISCOVERY-LEARNING

Guided discovery learning is said to be very important to learning, as it connects with learners' previous understanding. Learners are not expected to discover everything for themselves; therefore guided discovery needs to be planned well. For it to be effective, it needs to challenge learners to discover key elements of the content. Guided discovery promotes exploring, searching, trying things out, discussions, reflections and arguing things with their peers (Bruner, 1990:183).

Mayer (2003:2) encourages educators who wish to have active learning in their classes to use constructivist methods of instruction that focus on discovery-learning. In discovery-learning learners are free to work in an environment with little or no guidance. Evidence has shown that effective methods for promoting constructivist learning involve cognitive activity rather than behavioural activity; instructional guidance rather than pure discovery; and lastly, curricular-focus rather than unstructured exploration.

Discovery or inquiry is words or terms that are used interchangeably by many educators. However, discovery occurs when an individual is mainly involved in using his/her mental processes to mediate some concept or principle. The processes of discovery include the following skills: observing, classifying, measuring, predicting, inferring and other related skills. Inquiry is well observed in the middle school where learners are being prepared to progress to high school education. Through inquiry, a learner tends to act more like a maturing adult, because they will be requested to define problems, formulate hypotheses, design experiments and explain their observations (Trowbridge *et al.*, 2004:182).

The following reasons have been widely discussed to support the usage of and advantages of discovery- and inquiry-teaching (Trowbridge *et al.*, 2004:183).

- Intellectual potency: In this case a learner learns and develops her/his mind only by using it to think.
- Intrinsic rather than extrinsic motivation: Due to an understanding of what is to be done, a learner receives a satisfying intellectual thrill rather than an extrinsic reward.
- Learning the heuristics of discovery: Learners should be given a platform to learn the techniques of discovery so that they can slowly learn how to organise and conduct investigations.
- Conservation of memory: Trowbridge *et al.* (2004:183) indicate that one of the greatest benefits of the discovery approach is that it aids better memory retention. They further emphasise that concepts that a learner has reasoned out are better remembered as compared to those taught in class.

These four justifications are considered to be important, because they stress that learners use their cognitive mental processes to work out the meanings of things they encounter in their daily environment.

Through guided discovery learners feel that they are psychologically secure, because from time to time they are open to new experiences. Learners develop a strong self-esteem that helps them to take chances and explore, to tolerate minor failure relatively well and become more creative. Greater involvement by learners enhances learners to obtain more insights and develop their self-concept (Trowbridge *et al.,* 2004:183).

In most instances, learners discover knowledge without guidance and during the process they develop their own understanding. However, the role of giving instruction is to provide a suitable environment to work on. A basic characteristic of guided discovery is convergent thinking. Reichert (2005:2) indicates that an instructor should devise a series of questions that guide the learner step by step logically and that will help a learner to end up making discoveries that will lead to a single goal.

3.9 CO-OPERATIVE LEARNING

3.9.1 Promoting co-operative learning

Co-operative learning acts as an active agent of mediation between learners and it also promotes co-operation in social terms. Co-operative learning is said to take place in many forms, e.g. between pairs of learners or larger groups. Tasks given to learners can be specific, such as solving a particular problem or when related to a larger task, learners could be requested to make a presentation that might involve planning and organising (Donald *et al.*, 2002:114).

It is easy to control a large class by means of a co-operative learning strategy. This strategy involves learners in small task groups where active participation of all members is required for success. Learners work in a group to attain a common outcome. It is important and beneficial to allow small groups so that members can contribute equally. There should be a group leader that will account for the success of the group and present their work as agreed upon (Donald *et al.,* 2002:114).

Skills that are needed mostly for co-operative learning are communication, trust-building, leadership and conflict management. Learners should learn to accept that they may have differing viewpoints and at the same time should reach a common goal. Co-operative learning helps learners to achieve common goals, such as engaging in activities, sharing, and joint problem solving (Donald *et al.,* 2002:114).

3.9.2 Benefits and disadvantages of co-operative learning

Learners will easily learn from their peers and they also learn to share information amongst themselves. As a group of learners finish tasks at their own pace, all learners in a group will end up mastering the material at least at the same time. The social skills of the learners are enhanced, for instance leadership and communicating skills. Such skills are also important for real-life situations, for instance in the workplace. Interdependence is also practised whereby learners believe and realise that they are together and therefore have to care about one another's learning. Individual accountability is rotated amongst members, as each will be given a role to play. Each member will also have a chance to offer his opinion about the given task (Donald *et al.*, 2002:114).

Learners identified the following problems during grouping (Taylor & Francis, 2007:281):

- Some learners dominate the group;
- other learners do not co-operate;
- sitting arrangements;
- noise;
- group grading is not fair;
- limited time for discussions; and
- difficulty for the educator to monitor the whole class.

3.10 SUMMARY OF CHAPTER

Chapter 3 discussed constructivism as an appropriate theory to address learners' difficulties in science. A short summary of what it entails and its benefits are, is given.

Constructivism is regarded as the umbrella term of learning perspectives, with the understanding that knowledge should be actively constructed by the learner (Gijbels *et al.*, 2006:214). To learn science involves active and qualitative reorganisation of knowledge structures (Tsai, 2004:1746). Redish (2003:30) emphasises that it is important that existing knowledge should be used as a connection in building core knowledge for an individual.

Woolfolk (1995:484) indicates that in a constructivist approach, the educator and the learner make decisions about the content, activities and approaches. The working together of these two parties does not mean that educators have no goal. Educators encourage learners to use primary sources, formulate hypotheses and engage in class activities. Learners are helped to handle multiple points of view and be effective readers and active writers. According to Gijbels *et al.* (2006:213), learners' perceptions are said to affect the results of their learning. Instructional practices are developed and implemented to help learners communicate, think, reason effectively and make correct judgments about the information they receive. Learners develop skills by working collaboratively in diverse teams as well as by solving complex problems.

Constructivism as a strategy is highly recommended, as it can help learners to be engaged in deeper learning about science (Tsai, 2004:1746). In addition, the strategy helps educators to change learners' unfruitful conceptions of learning science, such as memorization without understanding. Through this strategy learners will be in a position to construct more appropriate conceptions of learning. Learners will also be encouraged to interpret science phenomena in a deeper scientific view. According to Romesin (2006:91) the constructive approach asks for an open and less dogmatic approach to science in order to generate the flexibility that is needed to cope with today's progress of science.

Vakalisa *et al.* (2008:14) indicate that the introduction of the New Curriculum Statement in South Africa gave educators the freedom to select relevant learning content from the learning areas. Educators are expected to teach the content in a way that learners attain identified learning outcomes as specified by the National Department of Education. Such reforms in education have encouraged a change from the traditional educator-centered, transmission-oriented learning environment to a more learner-centered approach (Wong *et al.*, 2006:124). The reason for the need of such changes is that the environment found in a constructivist approach encourages more confident, creative, independent, problem-solving and life-long learners.

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

4.1 INTRODUCTION

The empirical study aimed at determining Grade 10 learners' conceptual problems when learning about phase changes (paragraph 1.1). The kinetic molecular theory and law of conservation of matter are two fundamental domains of chemistry that underpin a study of physical and chemical changes (Chapter 2). Research (see chapter 2) has shown that many learners experience difficulties with understanding these two domains and applying them in the context of phase changes. A questionnaire was compiled to probe these difficulties. An intervention based on constructivist principles (Chapter 3) was compiled. Learning problems with the experimental approach of the intervention was observed. The effectiveness of the intervention in remedying learners' alternative conceptions regarding phase changes was determined by the calculation of learning gains.

The intervention focused on applications of the law of conservation of matter in order to enhance learners' understanding of phase changes. The particulate nature of matter was the theoretical framework for explanation of the results obtained in the intervention.

A detailed overview of the research design and methodology of the empirical study is reported in this chapter. The research design includes discussions of the type of research study and the population (paragraph 4.2.1), while the methodology describes the development and structure of the questionnaire, intervention, processing and interpretation of the results (paragraphs 4.3 to 4.8).

4.2 RESEARCH DESIGN

4.2.1 Population

Tuckman (1994:237) defines population as a target group used in a questionnaire or interview study that a researcher is interested in gaining information and drawing conclusions from. The population helps the researcher to establish boundary conditions that specify who shall be included in or excluded from the empirical study. It is further indicated that if the population is broadly defined like "all learners" in the school, external validity or generality will be maximized. However, a narrow population may facilitate the selection of a suitable sample but restrict conclusions and generalisations to the specific population used.

Forty six (46) Physical Sciences Grade 10 National Curriculum Statement learners participated in this study. The school is situated in Rustenburg in the Moses Kotane Area Project Office. This group of learners is the second to study Physical Sciences since its introduction in 2006 in the FET band.

The empirical study is a case study (paragraph 4.2.2) that used a quantitative and qualitative research method (4.2.3).

4.2.2 Case study

Dul and Holk (2008:40) identify a case study as one of the several ways of doing social science research. Other ways include experiments, surveys, multiple histories and analysis of archival information. The case study method involves an in-depth investigation of a single instance.

Leedy and Ormrod (2005:135) emphasise that a case study is suitable for learning more about a little known or poorly understood situation. The weakness of a case study is that when only one single case is involved, we cannot be sure that the findings can be generalised to other situations. In the empirical study reported here, the research results obtained with a typical rural South African class were compared to findings of similar studies elsewhere in the world.

The following advantages of case studies have been very beneficial to researchers (Dul and Holk, 2008:43):

- Case studies provide a systematic way of looking at events, collecting data, analysing information and reporting results.
- Through this process a researcher could gain a sharpened understanding of why the instance happened as it did, and what might become important to look at more extensively in future research.
- The case study is taken as an empirical inquiry that investigates a phenomenon within its real-life context.

Dul and Holk (2008:43) emphasise that a case study can be based on any combination of qualitative and quantitative evidence and can rely on multiple sources of evidence and benefits.

4.2.3 Quantitative and qualitative research

The case study reported here used quantitative and qualitative research. The term quantitative research is most often used in the social sciences in contrast to qualitative research (Shunk, 2008:5).

According to Leedy and Ormrod (2005:94), quantitative research is used to answer questions about relationships among measured variables with the purpose of explaining, predicting and controlling phenomena. This type of approach is sometimes called the traditional, experimental or positivist approach.

Quantitative research is the systematic scientific investigation of quantitative properties and phenomena and their relationships. The most important objective of quantitative research is to develop and employ mathematical models, theories or hypotheses pertaining natural phenomena. The process of measurement is central to quantitative research because it provides the fundamental connection between empirical observation and mathematical or quantitative expression (Shunk, 2000:5). In this study learning gains were calculated from the pre- and posttest results.

The quantitative results were complemented by a qualitative analysis of the motivations that the learners gave for their answers, as well as the answers that the groups wrote down on the worksheets during the intervention. Qualitative research is typically used to probe into the complex nature of phenomena (Leedy & Ormrod, 2005:94). The learning of science is an example of a phenomenon of complex nature. While the items of the questionnaire used in this study investigated the improvement of learners' understanding of the content, the qualitative study focused on difficulties that they experienced with learning the content.

4.3 RESEARCH METHODOLOGY

The empirical study comprised of a pre-test, intervention and posttest. A questionnaire was compiled to serve two purposes, namely as:

- Diagnostic assessment instrument to determine learners' initial alternative conceptions; and
- pre- and posttest for an intervention that aimed to enhance their understanding of the concepts under investigation.

The purpose, structure and composition of the questionnaire are discussed in paragraph 4.4. The questionnaire is attached as Appendix A.

In the intervention the learners were given a chance to perform some experiments so that they could attain a better understanding of the law of conservation of matter as applied in phase changes. Worksheets were used to guide their experimentation and reasoning. The intervention was based on an activity-learning approach that applied constructivist principles. An example of the activities that formed part of the intervention is given in Appendix B.

4.4 RESEARCH INSTRUMENT

4.4.1 A questionnaire as research instrument

Research instruments are used to gauge some quality or ability of your subjects. The main purpose of the instrument is to elicit the data in the research. An instrument can, for instance, be a physical measurement device, a psychological test or a performance checklist (Tuckman, 1994:239).

Vockell (1983:78) defines a questionnaire as a device that enables the respondent to answer questions. The respondent will be requested to directly supply his/her answers as well as motivations to a set of questions. The answers given by the learners are directly determined by the nature of questions and reactions to these questions. The questionnaire should be compiled so that the language is clear and easily understood by the learners.

Motlhabane (2003:85) summarises the following advantages of using a questionnaire as research instrument, as reported in literature:

- Questionnaires are said to be economical for both the sender and respondent, especially with respect to time and effort.
- They have a great potential when properly used.
- When constructed skillfully, the investigator may ask anybody to administer it.
- They are fairly easy to plan and administer.
- It helps in focusing the respondent's attention on all the significant items.

Motlhabane (2003:86) further refers to the following disadvantages of questionnaires:

- If the respondent misinterprets the question, little can be done to rectify the misinterpretation.
- Low response is a concern in analysing the questionnaire.

- Respondents may not feel happy about airing their views.
- They may not reveal a true picture of opinions and feelings.
- When respondents feel their options are not included, loss of rapport can be identified.

It is important for the researcher to know and understand what the answers from the learners actually mean (Vockell (1983:78). All the questions in this case study were structured. Learners were requested to select correct options from the given alternatives so that all learners could answer within the same framework. The most common disadvantage about a structured format is that alternatives might look similar and that might confuse respondents and they end up losing interest. However, to counteract that problem, the researcher gave learners a chance to motivate their answers so as to draw out their interest, as was suggested by Vockell (1983:78).

In this study the questionnaire was administered to the learners as pre- and posttest, before and after an intervention.

4.4.2 Pre-test

Redish (2003:148) indicates that a pre-test is used to get to know learners' thinking about a given issue. A pre-test should be a straightforward assessment. In this study a pre-test was used in the form of a questionnaire. The class did not receive any treatment in the form of revision or other related actions. The class of 46 learners wrote the same test and their responses were analysed to assess their pre-knowledge and alternative conceptions. Due to unsatisfactory results in the pre-test, an intervention was introduced to all. The class was not divided into an experimental and control group.

4.4.3 Intervention

An intervention is used as a platform to fill gaps and to address areas of uncertainty and ambiguity. In this study, learners were given time to perform a series of experiments so as to address misconceptions and problems related to the content in the pre-test. During the intervention constructivist principles were applied in order to help learners to improve their physical science content relating to conservation of matter and phase changes (Appendix B, lessons 1, 2 and 3).

Since practical work was done, the following constructivist principles were focused on in the intervention (refer to the numbers given to the principles in section 3.5.2):

- Principle 1: Learning is an active process in which a learner uses sensory input and constructs meaning out of it.
- Principle 3: Physical actions and hands-on experience may be necessary for learning.
- Principle 5: Learning is a social activity.
- Principle 9: A key component to learning is motivation.

During the intervention, learners worked in groups and filled out worksheets. These worksheets were analysed by the researcher to determine qualitatively how the learners interpreted their experimental results and related it to the scientific theory.

4.4.4 Posttest

Posttest results indicate whether the intervention has enhanced the pre-test results. To determine the effectiveness of the intervention, learning gains were calculated. The importance of a posttest is that it may cause certain ideas presented during intervention to fall into place (Vockell, 1983:163). It may also show what deficiencies in learners' knowledge remained.

4.5 DATA COLLECTION

Data collection is a process of collecting valid and reliable information on the variables relevant to the research problem. Full details of the data collected should be processed with appropriate techniques and procedures (McMillian & Schumacher, 1989:241). The steps taken in a data analysis strategy may differ according to the type of data and the nature of the research, e.g. whether that is qualitative or quantitative. Data collection and analysis is an interactive process whereby the researcher moves repeatedly back and forth through the data (collecting – analysing – collecting – analysing data) rather than in a simple, linear direction (Vithal & Jansen, 1997:29).

In this study, data was mainly collected from questionnaires. Before analysis, data requires validating, verifying and recording. In this study, the questionnaire data was read into the computer and checked for incomplete, inaccurate, inconsistent or irrelevant data. Learner's motivations given for responses in the pre- and posttests were studied. Responses of different learners were compared and analysed to point out improvements during the intervention.

4.5.1 Validity

Validity is defined as the extent to which an instrument measures what it intends to measure (Macmillan & Schumacher, 1989:241). The following are types of validity, content, construct, criterion-related, predictive and concurrent. The study was interested in the learners' understanding of the content. Additionally, the learners had to motivate their answers. This enhanced the validity of the results. Their motivations would indicate if they understood a question correctly and answered accordingly.

4.5.2 Reliability

Macmillan and Schumacher (1989:242) define reliability as the degree of consistency/stability of results over time on different occasions of data collection. It is further indicated that reliable data collection instruments minimise the influence of results negatively. Many variables or sources can contribute to unreliable measurements.

Macmillan and Schumacher (1989:242) identified factors that affect reliability as follows: heterogeneity, number of items in instrument, range of score obtained, level of difficulty of instrument and similarity of subjects. In this study, reliability was mostly affected by the difficulty of the instrument in the form of content. The number of variables was minimised by using the same group of learners and the same questionnaire in the pre- and posttest, while the same educator compiled and presented all the activities of the intervention.

In this study the reliability of the results obtained with the questionnaire was strengthened by the qualitative analysis of their motivations as well as their worksheet responses.

4.6 STRUCTURE OF THE QUESTIONNAIRE

In order to achieve the first objective of the study (paragraph 1.3), the questionnaire was compiled as pre-test to identify learners' misconceptions regarding phase changes. The same questionnaire was used as posttest to determine the effect of the implementation of constructivist principles in the intervention. The intervention aimed at remedying the misconceptions by means of experiments on conservation of mass.

Questions assessed learners' understanding of two aspects related to phase changes, namely the particulate nature of matter (Question 1) and the law of conservation of matter (Question 2). Items on the particulate nature of matter related to the states of matter, while items on the law of conservation of matter focused mainly on physical changes. One example of a chemical change was included, namely item 2.4.

Learners were requested to follow the instructions given in the questionnaire. For each item, the learners were requested to indicate whether the given statement is TRUE or FALSE. They were also given the option of UNSURE. The learners were also requested to motivate their responses.

The scientific response to each item, as well as possible alternative conceptions that could be expected, are as follows:

Question 1: Particulate nature of matter and states of matter

1.1 *All material objects (solid, liquid and gases) consist of particles.*

Scientific view: According to the particulate nature of matter, particles are the building blocks of matter, irrespective of the state.

Possible alternative conception: Gases or solids do not consist of particles.

1.2 *Ice molecules differ from water molecules.*

Scientific view: The particles of a substance in different phases are identical, e.g. ice (solid) and water (liquid) molecules are the same. The difference in state of matter is not due to change of the particles themselves, but due to differences in motion and forces between them.

Possible alternative conception: Ice molecules are solid, and heavier than water molecules.

1.3 *Spaces exist between particles (atoms or molecules) in a solid.*

Scientific view: Although particles of solids are close to one another, there are spaces between them.

Possible alternative conception: No spaces exist between particles of a solid.

1.4 *Particles of hot water move faster than particles of cold water.*

Scientific view: Kinetic energy possessed by particles of hot water will cause the particles to move faster. The higher the temperature the faster is the average speed of the water molecules (until it boils).

Possible alternative conception: Hot and cold water differs due to differences of the particles themselves, and not their average speed.

1.5 *Particles in a liquid move faster than particles in a solid.*

Scientific view: In a solid the particles only vibrate, while the liquid particles are freer to move. At melting point, both the solid and liquid particles have the same average kinetic energy, while their potential energies differ.

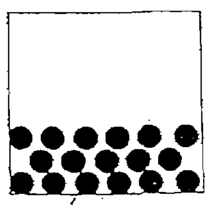
Possible alternative conception: Solid particles do not move. Liquid particles move because the liquid can flow.

1.6 When ice melts, the ice particles also melt.

Scientific view: In all states (solid, liquid and gas) the particles of a substance remains the same.

Possible alternative conception: The macroscopic melting of the ice is due to the microscopic melting of the particles.

1.7 The diagram below represents a certain state of matter, namely:



Scientific view: In a solid, particles are arranged in a regular pattern, which is not the case in liquids and gases. Spaces exist between the particles of a solid.

Possible alternative conception: Spaces do not exist between the particles of a solid. Since it does not fill the container, it must be a liquid.

Question 2: Law of conservation of matter during physical changes

2.1 When water boils, the H_2O molecules are destroyed.

Scientific view: Matter is conserved, therefore no molecule can disappear. The water vapour molecules move further apart and become part of the air around us.

Possible alternative conception: Gases are not matter because they are invisible.

2.2 *When sugar is added to water and stirred, it disappears.*

The intention of the question was to verify an understanding of the term "disappearing" in relation to the law of conservation of matter. Sugar does not disappear in water. Matter is conserved, meaning that no particles can be created or destroyed. The sugar particles diminish and move in between the water particles. Note that you can taste the sugar in the water – thus it must still be there! If the water were allowed to evaporate, the sugar crystals can be seen again.

Possible alternative conception: Because we cannot see the sugar particles, they do not exist any more.

2.3 *Salt granules melt when dissolved.*

The item investigates learners' understanding of a physical change. The salt granules reduce in size, but remain NaCl. The minuscule salt particles move in between the water molecules. Salt (NaCl) granules are in a solid state, while salt-water is a liquid.

Possible alternative conception: Because we cannot see the salt particles, they do not exist any more. They melted away and disappeared.

2.4 *When wood burns, some matter is destroyed.*

The intention of this item was to test for conservation of matter in a chemical change. The learners should realise that matter is always conserved. When wood burns, new chemical substances are formed, some of which move away into the air.

Possible alternative conception: Because the amount of ash is much less than that of the wood, some of the matter is destroyed.

2.5 *When a liquid evaporates, the liquid particles disappear completely (in other words, the particles cease to exist).*

The intention was to check if learners can appreciate the difference between evaporation and disappearing. Matter is always conserved and no particles can disappear or cease to exist. The gas particles move away into the air.

Possible alternative conception: Gases are not matter, because we cannot see them.

4.7 DATA ANALYSIS

Calculation of learning gains

To determine the effectiveness of the intervention, learning gains were calculated by using percentages for individual items as well as total percentages. The learning gains show which alternative conceptions were changed effectively towards the science concept, and which of them remained problematic.

Meltzer (2002:3) used the following equation to calculate the normalised learning gain <g>:

$$\text{Gain} <g> = \frac{(\text{post–assessment} - \text{pre-assessment})}{(100\% - \text{pre–assessment})}$$

The interpretation is that one should divide the actual gain (numerator) by the potential gain (denominator). The pre-assessment is the percentage correct answers in the pre-test and post-assessment is the percentage correct in the posttest.

McMillan and Schumacher (1989) indicate that there is only one exception to calculating gain scores that does not fit the above calculations. If the learner scores 100% on the pre-assessment, you must record 99% for the pre-assessment score. If the same learner scores 100% on the post-assessment, you must also enter a 99% for the post-assessment score.

4.8 SUMMARY OF CHAPTER

This chapter focused on the research design and methodology of the case study. The questionnaire is the main instrument used in the research. The structure of the questionnaire, the intention of the items as well as scientific answers and possible alternative conceptions, were given. The role of the pre-and posttests as well as the calculation of the learning gains was discussed. The next chapter (Chapter 5) will discuss the results of the questions and their analysis.

CHAPTER 5

ANALYSIS OF RESULTS

5.1 INTRODUCTION

In this chapter the focus is on the analysis of the results of the empirical study. The empirical study consisted of a pre-test, intervention and posttest (refer to paragraph 4.4). A discussion is given on how learners responded to the questionnaire. A detailed analysis is reported on with reference to the pre-test and posttest. The pre-test determined Grade 10 learners' alternative conceptions regarding phase changes and conservation of matter. These results are given and discussed in paragraph 5.2. The posttest was used to determine the effectiveness of the intervention in changing their alternative conceptions towards the scientifically correct views. The effectiveness of the intervention was determined in two ways, namely by analysing learners' answers (paragraph 5.3) and calculation of the learning gain (paragraph 5.4).

5.2 ANALYSIS OF PRE-TEST RESULTS

Vithal and Jansen (1997:27) indicated that the purpose of an analysis is to make sense of the accumulated information. The researcher should ensure that the data is organised and presented. The researcher should read the data, check for incomplete, inaccurate, inconsistent or irrelevant data.

In this research, organising data means that the researcher counted responses in terms of true, false and unsure answers. Learners' motivations were analysed to determine whether learners really understood the content of matter and materials or revealed alternative conceptions. Representing data means that the researcher summarised large amounts of data in tables. The results were quantified by calculation of learning gains.

In the following paragraphs learners' responses to questions of the questionnaires are given and discussed. The questionnaire is attached as Appendix A. The motivations that the learners gave for their responses are analyzed in paragraph 5.3.

5.2.1 Question 1

1.1 All material objects (solids, liquid and gases) consist of particles.

The scientifically correct answer is that the statement is true.

Table 5.1: Results of question 1.1

Question 1.1	No. of learners	Percentage (%)
TRUE	39	85%
FALSE	06	13%
UNSURE	01	02%
TOTAL	46	100%

From the results displayed in Table 5.1 and the motivations of learners for these answers, the following are deduced:

- The majority of the learners (85%) gave the scientifically correct answer, namely that it is true that all material objects consist of particles. Although this percentage is high, it is disturbing that 15% of the learners do not accept this most basic idea of the kinetic molecular theory.

- Of the 39 learners who answered TRUE, only 22 (56%) managed to write acceptable motivations, e.g. learners number 23 and 32 indicated that "Matter is made up of particles" and "because this material objects consists of mass", respectively. The percentage shows that more than half of the 39 learners have a good understanding of particles in matter.

1.2 Ice molecules differ from water molecules.

The scientifically correct answer is FALSE.

Table 5.2: Results of question 1.2

Question 1.2	No. of learners	Percentage (%)
TRUE	27	58,7%
FALSE	15	32,6%
UNSURE	04	8,7%
TOTAL	46	100%

From the results displayed in Table 5.2 and the motivations of learners for these answers, the following was deduced:

- Less than one third of the learners chose the correct option.

- More than half of the learners (58,7%) believed that ice molecules and water molecules were different. This alternative conception is often held by learners, who reason that macroscopic observed features are also displayed on microscopic level (Smith *et al.,* 2006:3). They considered molecules in a solid to be hard, while liquid molecules should be soft.

- From the 27 learners who answered TRUE, only three learners gave acceptable motivations. For example, learner number 5 said that "because ice molecules are very close to one another and water molecules are having some space". However, he only focused on the difference in spacing between molecules, and did not refer to the forces between them or their motions. No learner referred differences in kinetic or potential energies of the molecules in ice and water.

1.3 Space exists between particles (atoms or molecule) in a solid.

The scientifically correct answer is TRUE.

Table 5.3: Results of question 1.3

Question 1.3.	No. of learners	Percentage (%)
TRUE	08	17,4%
FALSE	23	50,0%
UNSURE	15	32,6%
TOTAL	46	100%

From the results displayed in Table 5.3 and the motivations of the learners for these answers, the following was deduced:

- Only a minority of learners (17,4 %) agreed that space exists between particles in a solid. The other learners who did accept that all matter consist of particles (item 1.1), consider these particles to be closely packed.

1.4 The particles of hot water move faster than particles of cold water.

The scientifically correct answer is TRUE.

Table 5.4: Results of question 1.4

Question 1.4.	No. of learners	Percentage (%)
TRUE	31	67,4%
FALSE	09	19,6%
UNSURE	06	13,0%
TOTAL	46	100%

From the results displayed in Table 5.4 and the motivations of the learners for these answers, the following were deduced:

- Approximately two-thirds of the learners answered correctly. However, none of them referred to the relationship between temperature and kinetic energy of the molecules.

1.5 Particles in a liquid move faster than particles in a solid.

The scientifically correct answer is TRUE.

Table 5.5: Results of question 1.5

Question 1.5	No. of learners	Percentage (%)
TRUE	32	69,6%
FALSE	05	10,9%
UNSURE	09	19,5%
TOTAL	46	100%

From the results displayed in Table 5.5 and the motivations of the learners for these answers, the following can be deduced:

- As in the previous item, approximately two-thirds of the learners answered correctly. 19,5% of learners were unsure about this statement, as compared to that of the previous item.

- Instead of scientifically correct motivations, learners' reasons for faster motion of liquid molecules include
  - The larger availability of space between the molecules
  - The ability of a liquid to flow.
  - Liquids do not have a fixed shape.

- Some of the learners revealed the misconception that says "particles of solids have no motions". This was also found by Hapkiewicz (1999:26).

1.6 When ice melts, the ice particles also melt.

The scientifically correct answer is FALSE.

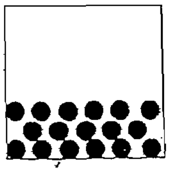
Table 5.6: Results of question 1.6

Question 1.6	No. of learners	Percentage (%)
TRUE	29	63,4%
FALSE	11	23,91%
UNSURE	06	13,4%
TOTAL	46	100%

From the results displayed in Table 5.6 and the motivations of the learners for these answers, the following was deduced:

- Only about 24 % of the learners chose the correct answer. The majority of learners revealed the alternative conception reported by Smith *et al.* (2006:3), namely that macroscopic observable properties of matter are projected onto the microscopic particles of the substance.
- Learner number 16 said that *"because ice melts and ice particles are also the same thing because ice is water and ice particles also water"*. The part *"ice is water and ice particles also water" is correct.* But the learner incorrectly deduced from this that when ice melts, the particles do the same.

1.7 The diagram below represents a certain state of matter, namely: (Gas state, solid state and liquid state).



The scientifically correct answer is solid state.

Table 5.7: Results of question 1.7

Question 1.7.	No. of learners	Percentage (%)
SOLID	15	32,6%
LIQUID	15	32,6%
GAS	16	34,8%
TOTAL	46	100%

From the results displayed in Table 5.7 and the motivations of the learners for these answers, the following was deduced:

- The percentage for all three the options was about 33 %.

- Neither one of the sixteen (16) learners who chose "gas" as their answer nor the 15 who chose the liquid state gave acceptable motivations.

- From the fifteen (15) learners who chose the solid state, only two learners managed to write down acceptable motivations, that is: learner 15, who wrote: "*because in liquids the particles are separated more. But in a gas state they are more separated and spread all over" and l*earner 36, who wrote: "*because the particles are close together".*

- As reported also by Hapkiewicz (1999:26) many of the learners incorrectly perceived relative particle spacing amongst solids, liquids and gases and did not generally related to the densities of the states.

5.2.2 Question 2

2.1 When water boils, the H_2O molecules are destroyed.

The scientifically correct answer is FALSE.

Table 5.8: Results of question 2.1

Question 2.1.	No. of learners	Percentage (%)
TRUE	08	17,4%
FALSE	26	56,5%
UNSURE	12	26,1%
TOTAL	46	100%

From the results displayed in Table 5.8 and the motivations of the learners for these answers, the following was deduced:

- Just more than half of the learners answered correctly. The best motivation was received from learner 6 who said that "*because water is water. Water is made from two hydrogens and oxygen so it can't change it will always be water*".

- The learners who did not choose the correct answer did not accept the law of conservation of matter.

2.2 *When sugar is added to water and stirred, it disappears.*

The scientifically correct answer is false.

Table 5.9: Results of question 2.2

Question 2.2.	No. of learners	Percentage (%)
TRUE	32	69,6%
FALSE	10	21,7%
UNSURE	04	8,7%
TOTAL	46	100%

From the results displayed in Table 5.9 and the motivations of the learners for these answers, the following was deduced:

- As noted, 32 learners dominated with wrong answers, indicating that matter is not considered to be conserved.

- Learner number 7 correctly reasoned that the taste of sugar would still be there. This is an explanation based on an everyday observation.

2.3 Salt granules melt when dissolved.

The scientifically correct answer is FALSE.

Table 5.10: Results of question 2.3

Question 2.3.	No. of learners	Percentage (%)
TRUE	17	37,0%
FALSE	11	23,9%
UNSURE	18	39,1%
TOTAL	46	100%

From the results displayed in Table 5.10 and the motivations of the learners for these answers, the following was deduced:

- Less than 25 % of the learners chose the correct option.

- From the learners responses it is clear that they confuse the concepts of melting and dissolving. For example, learner number 16 said: *"because salt is a thing that can melt when put in water"*. This is in accord with the findings of Hapkiewicz (1999:26) who said that learners find it difficult to differentiate between melting and dissolving and recorded the misconception that when something dissolves, it "disappears".

2.4 When wood burns, some matter is destroyed.

The scientifically correct answer is FALSE.

Table 5.11: Results of question 2.4

Question 2.4.	No. of learners	Percentage (%)
TRUE	34	73,9%
FALSE	05	10,9%
UNSURE	07	15,2%
TOTAL	46	100%

From the results displayed in Table 5.11 and the motivations of the learners for these answers, the following was deduced:

- The percentage of learners who chose the correct option is very small (only 10,9 %). As reported in literature, chemical changes are more difficult to understand than physical changes (Liu & Lesniak, 2005). The fundamental principle of conservation of matter that applies to both physical and chemical changes, is not part of the learners' pre-knowledge.

- The alternative conception concerning the projection of macroscopic properties on microscopic level was revealed in motivations such as that of learner 31: *"because the fire burn every particle in the wood and leave only ashes"*.

2.5 When a liquid evaporates, the liquid particles disappear completely (in other words, the particles cease to exist)

The scientifically correct answer is FALSE.

Table 5.12: Results of question 2.5

Question 2.5.	No. of learners	Percentage (%)
TRUE	18	39,13%
FALSE	15	32,61%
UNSURE	13	28,23%
TOTAL	46	100%

From the results displayed in Table 5.12 and the motivations of the learners for these answers, the following was deduced.

- In this item, the meaning of the term "disappear" was explicitly given to ensure learners' correct understanding of the term. Still, only about a third of the learners answered it correctly.

- From the eighteen (18) learners who chose the TRUE statement, none gave the correct motivation. Of the fifteen (15) learners who chose the FALSE block, only seven (7) learners gave a correct motivation. For example, learner number 3 said that *"because liquid evaporation and liquid particles are the same"*. From 13 UNSURE learners, only one learner managed to write down an acceptable motivation.

5.3 ANALYSIS OF THE PRE-TEST MOTIVATIONS

5.3.1 Summary of learners' pre-test motivations

Table 5.13 analyses the learners' motivations with respect to understanding of the concept in the questions, repetition of a question in the motivation and unclear motivations. Alternative conceptions that were revealed are given in paragraph 5.3.3.

Table 5.13.Analysis of pre-test motivations

Question	Understand Concept	Repeated question	Not clear
1.1	8 (17,4%)	11 (23,9%)	21 (45,6%)
1.2	16 (34,8%)	02 (4,3%)	23 (50%)
1.3	6 (13,04%)	10 (21,7%)	23 (50%)
1.4	2 (4,3%)	16 (34,8%)	23 (50%)
1.5	7 (15,2%)	8 (17,4%)	28 (60, 9%)
1.6	9 (19,7%)	4 (8,7%)	30 (65, 2%)
1.7	10 (21,7%)	1 (2,2%)	35(76,1%)
Question			
2.1	16 (34,8%)	1 (2,2%)	23 (50%)
2.2	17 (36,9%)	11 (23,9%)	15 (32,6)
2.3	0 (0%)	12 (26, 1%)	34(73,9%)
2.4	8 (17, 4%)	10 (21,7%)	28(60,9%)
2.5	3 (6,5%)	12 (26,1%)	32(69,6%)

5.3.2 Discussion about analysis of the pre-test motivations

From the results tabulated above, the largest percentage of learners wrote unclear motivations, i.e. their sentences did not make any sense. This was either brought about by learners' inability to express themselves or their non-coherent understanding of the kinetic molecular theory. For example, in question 1.1 (refer to Appendix A) most of learners answered TRUE, but later in the motivations of other questions they indicated that only solids consisted of particles. Contradictions between statements and its motivations were continuously recorded.

Learners often referred back to their everyday life experiences or knowledge to motivate their choice of answers. For example, learner 30 indicated that ice molecules are always stronger than water molecules (because it is difficult to crush), while learner 11 stated that "particles of hot water move fast because the bacteria died".

The most disturbing factor with reference to the high percentage in the unclear motivations was the language. Learners had previously indicated that English was their second language. Therefore, they interpreted concepts into their first language, which is Setswana, and tried to link their understanding with science concepts. Learner also often confused terminology, e.g. they confuse melting, dissolving and evaporation and regard them as the same process.

5.3.3 Pre-test alternative conceptions

The following are alternative conceptions recorded by learners during motivation. Alternative conceptions are given question by question.

Question 1.1 (Refer to Appendix A)

- Liquid and gases do not consist of particles (Learner 18).
- Only solids and liquids consist of particles (Learners 27 and 38).
- Any object is made up from different mixtures (Learner 28).
- Material objects have particles inside (Learner 30).

Question 1.2 (Refer to appendix A)

- In ice molecules there is no space between particles (Learner 33).
- Water molecules are always moving (Learner 33).
- Ice molecules are always stronger than water molecules (Learner 34, 36 and 40).

Question 1.3 (Refer to Appendix A)

- There is no space between particles of a solid (Learners, 19, 15, 23, 28 and 29).

Question 1.4 (Refer to Appendix A)

- Particles of cold water are not evaporating (Learner 5).
- Particles of hot water move fast because the bacteria died (Learner 11).

Question 1.5 (Refer to Appendix A)

- Solid particles are not moving (Learners 5, 7 and 11).

Question 1.6 (Refer to Appendix A)

- Particles dissolve when ice melts (Learner 16).
- Particles are always solids (Learner 28).
- Particles are destroyed when ice melts (Learner 43).

Question 1.7 (Refer to Appendix A)

- No alternative conceptions were recorded in their motivations.

Question 2.1 (Refer to Appendix A)

- When water boils, the water molecules are destroyed because the bacteria are destroyed (Learner 1).
- When water boils, oxygen is escaping (Learners 29 and 46).

Question 2.2 (Refer to Appendix A)

- Solids in liquids melt instead of dissolve (Learners 39 and 8).

Question 2.3 (Refer to Appendix A)

- No alternative conceptions recorded in their motivations.

Question 2.4 (Refer to Appendix A)

- No alternative conceptions recorded in their motivations.

5.4 INTERVENTION

With reference to paragraph 4.4.3 in Chapter 4, intervention was done by using experiments. An example is given in Appendix B. The intervention was activity-based and learners worked in groups to encourage sharing of information from the observations. It was through this activity that the learning principles were applied as stated in 4.4.3.

The intervention was based on the following: If the mass measurements before and after a change gave the same reading, it implied that the number of particles (whether atoms or molecules) remained the same. From a difference in volume, measurements can be deduced that spaces exist between the particles of one substance that can be occupied to some extent by other particles.

The researcher intended the learners to learn about the following:

- Irrespective of the change that matter undergoes, its mass remains constant. Matter is always conserved.
- It is important for learners to learn that matter cannot be created nor destroyed. With reference to the study, in a physical change the identity of the substance is preserved even though it may have changed its state.
- The advantages of learning procedures and particular reasons for using such a strategy, that is, constructivism, e.g. group work and guided discovery, is important. Through constructivism learners were expected to share their experiences and their understanding on the material learnt.

The difficulties that were encountered during the practicals were:

- *Learners experienced problems to understand the demonstrations on mass conservation with respect to the micro particulate view of matter:*
  Learners were confused because they felt that only the mass of objects that can be seen can be measured. Consequently they did not relate the total mass of a salt solution to the total mass of the salt and water particles.

- *The learners did not link what they observe on macroscopic level with what happens on microscopic level:*
  Learners found it difficult to accept that in a physical change the identity of the substance is preserved even though it may have changed its state, e.g. that water molecules and ice molecules are H_2O molecules.

- *Alternative conceptions were resistant to change:*
  Alternative conceptions are formed from learners' past experiences, incorrect past teaching, while at times it is difficult to identify causes.

- *Usage of proper scientific words by learners*
  Learners failed to explain processes in scientific terms. They did not display scientific knowledge of terms such as evaporation and dissolving.

- *Language of learners (second language) - difficult to understand some concepts /ideas in a second language*
  The learners also had severe problems to express their ideas. Many of their explanations were unclear. Instead of explaining their results, they often described what happened.

As an example, the learning difficulties that the learners experienced with getting and understanding their results and writing the conclusions in the experiments on conservation of mass in mixtures is summarized in Appendix B.

5.5 ANALYSIS OF POSTTEST RESULTS

The same group of learners was re-tested and the following results were obtained:

5.5.1 Question 1

1.1 All material objects (solids, liquid and gases) consist of particles.

Table 5.14: Results of question 1.1

Question 1.1.	No. of learners	Percentage (%)
TRUE	42	91,3%
FALSE	04	8,7%
UNSURE	00	0%
TOTAL	46	100%

1.2 Ice molecules differ from water molecules.

Table 5.15: Results of question 1.2

Question 1.2.	No. of learners	Percentage (%)
TRUE	19	41,3%
FALSE	26	56,5%
UNSURE	01	2,2%
TOTAL	46	100%

1.3 *Space exists between particles (atoms or molecule) in a solid.*

Table 5.16: Results of question 1.3

Question 1.3.	No. of learners	Percentage (%)
TRUE	16	34,8%
FALSE	25	54,3%
UNSURE	05	10,9%
TOTAL	46	100%

1.4 The particles of hot water move faster than particles of cold water.

Table 5.17: Results of question 1.4

Question 1.4.	No. of learners	Percentage (%)
TRUE	35	71,8%
FALSE	05	12,8%
UNSURE	06	15,4%
TOTAL	46	100%

1.5 Particles in a liquid move faster than particles in a solid.

Table 5.18: Results of question 1.6

Question 1.5.	No. of learners	Percentage (%)
TRUE	33	71,7%
FALSE	10	21,7%
UNSURE	03	6,5%
TOTAL	46	100%

1.6 When ice melts, the ice particles also melt.

Table 5.19: Results of question 1.6

Question 1.6.	No. of learners	Percentage (%)
TRUE	22	47,8%
FALSE	23	50,0%
UNSURE	1	2,2%
TOTAL	46	100%

1.7 The diagram represents a certain state of matter.

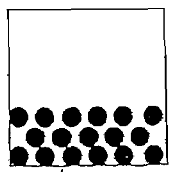


Table 5.20: Results of question 1.7

Question 1.7.	No. of learners	Percentage (%)
SOLID	27	58,7%
LIQUID	13	28,3%
GAS	06	13%
TOTAL	46	100%

5.5.2 Question 2

2.1 *When water boils, the H_2O molecules are destroyed.*

Table 5.21: Results of question 2.1

Question 2.1.	No. of learners	Percentage (%)
TRUE	06	13,0%
FALSE	36	78,3%
UNSURE	04	8,7%
TOTAL	46	100%

2.2 When sugar is added to water and stirred, it disappears.

Table 5.22: Results of question 2.3

Question 2.2.	No. of learners	Percentage (%)
TRUE	13	28,3%
FALSE	32	69,6%
UNSURE	01	2,1%
TOTAL	46	100%

2.3. *Salt granules melt when dissolved.*

Table 5.23: Results of question 2.3

Question 2.3.	No. of learners	Percentage (%)
TRUE	33	71,7%
FALSE	05	10,9%
UNSURE	8	17,4%
TOTAL	46	100%

2.4 When wood burns, some matter is destroyed.

Table 5.24: Results of question 2.4

Question 2.4.	No. of learners	Percentage (%)
TRUE	8	17,4%
FALSE	36	78,3%
UNSURE	2	4,3%
TOTAL	46	100%

2.5 When liquid evaporates, the liquid particles disappear completely (in other words, the particles cease to exist).

Table 5.25: Results of question 2.5

Question 2.5.	No. of learners	Percentage (%)
TRUE	14	30,4%
FALSE	27	58,7%
UNSURE	05	10,9%
TOTAL	46	100%

5.6 ANALYSIS OF THE POST-TEST MOTIVATIONS

5.6.1 Summary of learners' motivations

Table 5.26 below analyse the learners' motivations with respect to understanding of the concept in the questions, repetition of a question in the motivation and unclear motivations.

Table 5.26 Analysis of posttest motivations

Question	Understand Concept	Repeated question	Not clear
1.1	15 (32,6%)	8 (17,4%)	22 (47,8%)
1.2	26 (56,5%)	2 (4,3%)	18 (39,1%)
1.3	17 (36,5%)	3 (6,5%)	26 (56,5%)
1.4	19 (43, 5%)	12 (26,1%)	12 (26,1%)
1.5	25 (53,3%)	6 (13%)	15 (32,6%)
1.6	9 (19,6%)	10 (21,7%)	26 (56,5%)
1.7	26 (56,6%)	0 (0%)	20 (43,5%)
Question			
2.1	24 (52,2%)	0 (0%)	19 (41,3%)
2.2	35 (76,1%)	0 (0%)	11 (23,9%)
2.3	29 (63%)	2 (4,3%)	15 (32,6%)
2.4	13 (28,3%)	2 (4,3%)	22 (47,8%)
2.5	17 (36,9%)	6 (13%)	23 (50%)

5.6.2 Discussion about analysis of the posttest motivations

The results tabulated in 5.6.1 show the positive impact played by the intervention shown in the increased percentage in the understanding of learners. The alternative conceptions that occurred are discussed in the next paragraph.

5.6.3 Posttest alternative conceptions

Although the percentage of correct answers improved, alternative conceptions still persisted. The following are alternative conceptions recorded by learners in the posttest motivations.

Question 1.1

- Liquid is the object that has many particles. Learner 16.

Question 1.4

- The particles move fast in hot water because there are no bacteria. Learner 11.
- The particles of hot water move faster because the oxygen in hot water is escaping. Learner 22.

Question 1.6

- The particles change with substance. Learner 9.

Question 2.1

- The molecules take on another form when water is boiled. Learner 9.
- The molecules of water change into a gas state. Learner 24.
- Oxygen molecules can be seen and hydrogen molecules cannot be seen. Learners 34 and 46.

Question 2.3

- Salt granules undergo a chemical change when dissolved. Learner 2.

Question 2.4

- When wood burns, some matter is destroyed and change to be small and be a coal. Learners 6 and 11.
- Wood will turn into ashes, it will not occupy space but the mass may be the same if you collect all ashes. Learners 15, 25, 29, 35, 39 and 42.
- When wood is burnt, it will be lighter in weight and change colour. Learner 24.
- Matter can be destroyed by fire or by hot things. Learners 40 and 43.
- Some matter are weak, therefore they can be destroyed easily. Learner 41.

The alternative conception that occurred most commonly was that microscopic particles display macroscopic features.

5.7 CALCULATIONS OF THE LEARNING GAINS

Table 5.27 summarises the results of the calculation of the learning gains (Refer to Chapter 4 paragraph 4.7).

Table 5.27 Results of learning gains

Question	Pre-test % correct	Posttest % correct	Normalised learning gains	% learning gain
1.1.	85%	91,3%	0,4	40%
1.2.	32,6%	56,5%	0,4	40%
1.3.	17,4%	34,8%	0,2	20%
1.4.	67,4%	76,1%	0,3	30%
1.5.	69,6%	71,7%	0,1	10%
1.6.	23,9%	50,0%	0,3	30%
1.7.	32,6%	56,4%	0,4	40%
2.1.	56,5%	78,3%	0,5	50%
2.2.	21,7%	69.6%	0,6	60%
2.3.	36,9%	71,7%	0,6	60%
2.4.	10,9%	78,3%	0,8	80%
2.5.	32,6%	58.7%	0,3	30%
Averages	40,6%	66.1	0.4	40,8%

According to Hake (1998), the learning gain is:

- high if $(<g>) \geq 0,7$
- medium if $0,3 \leq (<g>) < 0,7$ and
- low if $(<g>) < 0,3$.

Before the intervention, 15% of the learners (7 out of 46) who did not know that all material objects consist of particles (item1.1), were still on the macroscopic level of thinking, i.e. the first category of Nakhleh and Samarapungavan (1999:782).The responses of the majority of learners who participated in the study can be classified as macro-particulate. They accepted that all material objects consist of particles, but could not correctly explain physical changes in terms of the particulate model. None of the learners were on the micro-particulate level before the intervention.

The intervention increased the number of learners who accepted that all material objects consist of particles to 91,3% (item1.1). Only 8,7% (4 out of 46) remained in the macroscopic category. There was also an increase in the number of learners who explained physical changes in terms of particles. A few learners gave more or less accurate scientific explanations in some of the items, but none of them consistently applied the accurate model correctly.

For half of the items (i.e. 6 out of the 12 items), a medium learning gain was obtained. The items that yielded a low learning gain were items 1.2, 1.3, 1.4, 1.5, 1.6, 1.7 and 2.5. Learners perceived that spaces existed between particles of a solid (item 1.3) and this alternative conception occurred amongst learners of all ages (Andersson, 1990:14). It is, however, understandable that learners could have this alternative perception, because spaces cannot be seen in most solids, e.g. in a metal bar.

A larger percentage of learners (32,6%) said that the arrangement of particles shown in the diagram of item 1.7 belonged to a solid. Some of them knew that the particles of a solid were arranged in some lattice, while others motivated their answers by saying that "the particles are close together" or "there is no space between the particles". These learners consistently used their perception of a continous solid.

The second set of items investigated the learners' perceptions of conservation of matter (Table 5.22, Part 2). Although more than half of the learners (56,5%) correctly said that the water molecules were not destroyed when water boils (item 2.1), some of them referred to the water remaining in the pot, and not the water vapour.

A smaller percentage of learners (32,6%) answered item 2.5 correctly, where the evaporation of the liquid was specified. These two items dealt with phase changes, while items 2.2 and 2.3 referred to another physical change, namely dissolving. Only 21,7% and 36,9% respectively of the learners responded correctly. The alternative conception that the particles of the solvent disappeared or melted was revealed in their responses. The item on chemical change (item 2.4) yielded the lowest percentage of all the items, i.e. only 10,9% of the learners gave the correct answer.

Before the intervention, the average number of learners performed better in the items of Part 1 (i.e. on the particular model) than of Part 2 on conservation of matter. The difference between the averages for the parts is 15,2%. This can be due to the fact that the learners were taught the particular theory in the GET band, while conservation of matter did not form part of that curriculum.

5.8 SUMMARY

In this chapter the results of the empirical study was given and discussed, namely the percentages correct answers to the pre-and post-tests, the motivations that learners gave for their responses and the problems that learners experienced during the intervention.

From the results followed that, although an average learning gain of 40 % was obtained, learners still have problems in understanding phase changes in terms of the molecular kinetic theory and the law of conservation of matter. These problems include alternative conceptions that are difficult to change, language problems, confusion of scientific terms such as dissolving and melting.

After the intervention, learners had a better understanding of the Law of Conservation of matter, while alternative conceptions regarding the particulate model persisted. For example, items 2.2 and 2.4 recorded learning gains of 60% and 80% respectively. This indicated that the intervention that emphasised both the knowledge domains was therefore more successful in enhancing the learners' knowledge on conservation of matter than on the particulate model. This is in accord with the finding of Liu and Lesniak (2005) that learners grasp the conservation of matter more readily and at an earlier age than the particulate model.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

Learners find chemistry one of the most difficult courses at secondary and undergraduate levels, because they have to link several modes of representing matter and its interactions (Gabel, 2003). Since chemistry is the science of matter and its transformations, appropriate understanding of matter determines learners' understanding of principles and theories of physical and chemical changes (Liu & Lesniak, 2005). The South African National Curriculum Statement for Natural Sciences (Department of Education, 2003) recognises the importance of matter as a basic concept by calling one of the four modules *Matter and Materials.* This module of the GET band (Grades 7 - 9) lays the foundation for formal chemistry in the FET band (Grades 10 – 12).

Chapter 6 provides a summary of the literature and empirical study as well as the conclusions and recommendations of the study. The aim of the empirical study was to improve learners' understanding of phase changes by emphasis on the law of conservation of matter. The particulate nature of matter is the scientific framework for explaining physical and chemical changes. This study focused on phase changes, which is a physical change. Physical change is understood at an earlier age than chemical changes are (Liu & Lesniak, 2005).

6.2 LITERATURE STUDY

The literature review reported in chapter 2 gives an overview of the scientific view of matter as well as reported alternative conceptions. The results of this literature study informed the compilation of the questionnaire and the interpretation of the learners' responses to it.

Understanding of phase changes relates to the understanding of two fundamental domains, namely the particulate nature of matter and the law of conservation of matter. Science education researchers have shown that learners experience conceptual problems in both the domains of the particulate model and conservation of matter:

Learners' problems concerning the particulate nature of matter include:

- Macroscopic properties are projected onto the microscopic world, e.g. water molecules become solid when frozen (Smith *et al.,* 2006:3).
- Due to the fact that ice floats, learners deduced that ice did not have mass (Stephens, 1996:1).
- Gases are not matter because they are invisible (Anon, 1990:6).
- Air and oxygen are the same gas (Anon, 1990:6).
- Particles of solids have no motion (Anon, 1990:6).
- Only water can undergo a phase change (Anon, 1998:6).
- Bonds between oxygen and hydrogen atoms break during boiling (Smith *et al.,* 2006:3).
- Learners do not appreciate that the substance remains the same during phase changes, because the appearance change (Driver, 1989).
- Learners incorrectly perceived relative particle spacing amongst solids, liquids and gases and do not generally related to the densities of the states (Hapkiewicz, 1999:26).

Matter is not considered to be conserved by learners, who think that:

- Mass is not conserved during phase change (Stephens, 1996:1).
- A molten material weighs less than the same material in its solid state. Similarly, a gas weighs less than the same substance in its liquid or solid form (Stavy, 1990:501).
- sugar disappears when dissolved (Driver, 1989); or that

- acetone gas has no weight (or loses weight) when liquid acetone evaporates (Stavy, 1991).

These alternative conceptions are mostly based on learners' experiences and observations of everyday phenomena. To explain macroscopic observations of phenomena such as phase changes in terms of microscopic particles, an ontological shift in learners' thinking is needed (Nakhleh & Samarapunga, 1999). The transition to a systematic microscopic worldview is difficult for learners of all ages. Learners from different countries, religions, cultures, norms and values tend to share the same misconceptions due to lack of proper introduction of the basic concepts of matter and material (Gomez *et al.,* 1990:78).

In Chapter 3, the focus was on a learning theory that may be applied to enhance learners' understanding of phase changes. Emphasis was placed on constructivism as it is the learning-teaching theory recognised by the NCS. Attention was paid to what it entails and how it was developed..

The following nine principles of constructivist learning (Fardanesh, 2006:3), were discussed in this chapter, namely

1. *Learning is an active process in which the learner uses sensory input and from which he constructs meaning.*
2. *People learn to learn as they learn.*
3. *Physical actions and hands-on experience may be necessary for learning.*
4. *Learning involves language.*
5. *Learning is social activity.*
6. *Learning is contextual.*
7. *One needs knowledge to learn.*
8. *Learning is not instantaneous; it takes time to learn.*
9. *A key component to learning is motivation.*

6.3 RESULTS OF EMPIRICAL STUDY

Learners revealed alternative conceptions regarding phase changes. These conceptions were in accord with those reported in the literature study (Chapter 2). The intervention lessened the occurrence of alternative conceptions, but could not eliminate them. Two alternative conceptions that were found to be very resistant to change are that no space exists between the particles of a solid and that the microscopic particles of substances demonstrate macroscopic observable properties and changes. These alternative conceptions oppose learners' understanding of the particulate nature and the conservation of matter, and consequently the understanding of physical and chemical changes.

The success of the intervention of this study was measured by means of pre- and post-test results and calculation of learning gains. It was complimented by an analysis of the motivations that learners gave for their responses to the pre- and posttests, as well as their laboratory reports.

The average normalised learning gain yielded a result of 0,4 (or 40%). A larger conceptual change was obtained in learners' understanding and application of the conservation of matter than for the particulate model. This is in line with the findings of Liu and Lesniak (2005), namely that conservation of matter can be comprehended at a much earlier age than the particulate model.

The intervention that addressed conservation of matter in phase changes adhered specifically to the following of the constructivist principles listed in paragraph 6.2:

1. *Learning is an active process in which the learner uses sensory input and from which he constructs meaning.*
3. *Physical actions and hands-on experience may be necessary for learning.*
5. *Learning is social activity.*
9. *A key component to learning is motivation.*

From the laboratory reports and the motivations that learners gave for their responses to the questionnaire, it follows that the following principles of the list provided by (Fardanesh, 2006:3) are equally important:

2. *People learn to learn as they learn.*

The learners had to learn how to do experiments and how to relate the results to a scientific theory. In their laboratory reports the learners often described rather than explained phenomena and experienced difficulties to interpret their observations and results. They had to learn how to learn from their experimental observations and results.

4. *Learning involves language.*

Communicating results is an important part of doing science. The learners had to motivate their answers to the questionnaires and write laboratory reports. From their written responses followed that they had severe difficulty to express themselves, even in simple sentences. This aspect needs much more attention in the future.

6. *Learning is contextual.*

The learners did not have a framework according to which they explain observations. Therefore their answers to the items in the questionnaire were not coherent.

7. *One needs knowledge to learn.*

The learners did not have a good understanding of matter in such a way that they could use it productively to explain their observations and experimental results. Instead, some changed their results to fit their predictions which were due to alternative conceptions.

8. *Learning is not instantaneous; it takes time to learn.*

The learners needed more time to think and explain what they observed. Some of the alternative conceptions were found to be very resistant to change. In agreement with Kyle *et al.* (1989:3), one or two classroom activities are not going to change learners' own interpretations of their experiences.

Learners' misconceptions can be dealt with if we as educators gain a clear understanding of when learners are developmentally ready to make a shift from macroscopic explanations to microscopic explanations (Meyer, 2007:7). At the same time, educators need to investigate when learners are ready to make a developmental shift from understanding matter as a continuous substance to a particulate substance in all phases of matter. The intervention of this study accomplished some shift in the direction of the scientifically accepted micro-particulate view (Nakhleh and Samarapungavan, 1999:784), but none of the learners used it consistently or accurately.

6.4 LIMITATIONS OF THE STUDY

The sample of 46 learners used in this study was too small to give statistically valid results and to generalize the results. However, the findings are in line with those of other researchers and acceptable explanations could be given for the results.

6.5 RECOMMENDATIONS

Recommendations are based on the results of this study. The aim of the recommendations is to help Grade 10 NCS learners to alleviate alternative conceptions experienced when learning Physical Sciences. It is important that educators should identify learners' alternative conceptions when introducing new sections of Physical Sciences. Principles of learning are important, as they guide both learners and educators. Educators should have proper knowledge of possible alternative conceptions, how to address them in accordance with constructive principles of learning and teaching and reflecting on the success of the strategy.

In order to counteract alternative conceptions, science educators need to practise meaningful approaches to learning so that better learning outcomes may be yielded. Intervention strategies should be carefully designed according to the constructivist principles to bridge the misunderstandings between the learner, the educator and the learning content.

Curriculum designers should take science education research into account to determine which concepts and applications should be introduced, in what order and at what levels. Textbooks authors need to take learners' alternative conceptions into account and select the most appropriate teaching strategies to gradually shift learners' perceptions towards the scientifically correct concepts, models and theories. Their knowledge will then be useful and appropriate in interpreting actual events.

The understanding of explanatory mechanics is largely affected by age and instruction (Gomez *et al.,* 2004). A spiral development of the concepts and applications with increase in abstraction throughout the elementary and high school science curricula, are needed to ensure learners' understanding. All physical or chemical changes taught in the school curriculum should be accompanied by explanations in terms of these fundamental domains.

6.6 CONCLUSIONS

From the results of this study and the literature survey it follows that learners experience problems with the understanding of phase changes, mainly due to difficulties to understand two core knowledge domains, namely conservation of matter and the particulate model. The conceptual understanding of these core knowledge domains can be enhanced by implementation of all the constructivist principles. The aims of the research were achieved and the hypotheses were proven to be true.

The findings and recommendations of this research provide other researchers with a platform to explore more about learners' difficulties to learn about matter and materials and how to address these.

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APPENDIX A

QUESTIONNAIRE

Dear Grade 10 Learner

(National Curriculum Statement Learners)

NOTICE: Fill in the number provided to your desk.
(follow the instructions below).

Leaner no:

Identify yourself as MALE / FEMALE

MALE	FEMALE

Kindly answer the following questions as good as possible and follow the instructions in each case. No mark be will allocated and you will remain anonymous.

QUESTION 1

Read each statement carefully. Cross the **TRUE** box if you think the statement is correct or the FALSE box if you think the statement is wrong. If you are not sure whether the statement is **TRUE or FALSE**, cross the **UNSURE** box. Motivate your answers.

1.1. All material objects (solids, liquids and gases) consist of particles.

TRUE	FALSE	UNSURE

Motivation:

____

____

____

1.2. Ice molecules differ from water molecules.

TRUE	FALSE	UNSURE

Motivation:

____

1.3. Spaces exist between particles (atoms or molecules) in a solid.

TRUE	FALSE	UNSURE

Motivation:

1.4 The particles of hot water move faster than particles of cold water.

TRUE	FALSE	UNSURE

Motivation:

1.5 Particles in a liquid move faster than particles in a solid

TRUE	FALSE	UNSURE

Motivation:

____

____

____

1.6 When ice melts, the ice particles also melt.

TRUE	FALSE	UNSURE

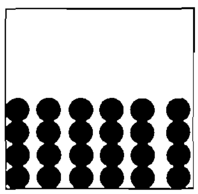
Motivation:

____

____

____

1.7. The diagram below represents a certain state of matter, namely: (Choose ONLY the correct answer from the given options and motivate it).



A. Gas state	B.Solid state	C. Liquid state

Motivation:

____

____

____

QUESTION 2

Read each statement carefully. Cross the **TRUE** box if you think the statement is correct or the FALSE box if you think the statement is wrong. If you are not sure whether the statement is **TRUE or FALSE**, cross the **UNSURE** box. Motivate your answers.

2.1 When water boils, the H_2O molecules are destroyed.

TRUE	FALSE	UNSURE

Motivation:

____

____

____

2.2. When sugar is added to water and stirred, it disappears.

TRUE	FALSE	UNSURE

Motivation:

____

____

____

2.3. Salt granules melts when dissolved.

TRUE	FALSE	UNSURE

Motivation:

____

____

____

2.4. When wood burns, some matter is destroyed.

TRUE	FALSE	UNSURE

Motivation:

___

___

___

2.5 When a liquid evaporates, the liquid particles disappear completely (in other words, the particles cease to exist)

TRUE	FALSE	UNSURE

Motivation:

___

___

___

APPENDIX B

EXAMPLE OF EXPERIMENTS USED IN INTERVENTION

EXPERIMENTS ON CONSERVATION OF MASS IN MIXTURES

AIM

To understand that

- spaces exist between molecules
- mass is conserved

in mixtures of 2 liquids, a solid in a liquid and two solids

LESSON 1: MIXTURE OF WATER AND ALCOHOL (METHELATED SPIRITS)

Method:- Accurately measure the volume and mass of 50 ml water and 50 ml alcohol (methelated spirits).

- Mix the two liquids.
- Measure the total volume.
- Measure the total mass.

Expected results:-Total mass = mass of water + mass of alcohol.

-Total volume < volume of water + volume of alcohol.

Conclusion: - No particles were lost (no loss in mass).

- There are spaces between the particles of the liquids ("loss" in total volume / space occupied).

LESSON 2: DISSOLVING OF SALT IN HOT WATER

Method :
- Measure the volume of water.
- Measure the mass of salt.
- Dissolve salt in hot water.

Expected results:
- Total mass = mass of water + mass of salt.
- Total volume < volume of water + volume of salt.

Conclusion :
- Some of the salt particles filled the spaces between the water particles.

LESSON 3: MIXTURE OF SALT AND STONES

Method:
- Place small stones in a beaker.
- Take the volume and mass readings.
- Place salt in another beaker.
- Take the volume and mass the readings.
- Pour the salt into the beaker with small stones.
- Take the volume and mass readings.

Expected results:
- Total mass = mass of stones + mass of salt.
- Total volume < volume of stones + volume of salt.

Conclusion:
- Some of the salt particles filled the spaces between the stones.

LEARNERS' WORK SHEETS

NAME : ______________________________

LESSON 1

GRADE : 10 **CURRICULUM : NCS** **TIME: 45 MINUTES**

FACILITATOR: SEGALE R. D.

The purpose of the following activity is to remedy learners' alternative conception with regard to

SPACES BETWEEN MOLECULES (**Law of Conservation of Mass**)

SAFETY NOTE

- Safety goggles and aprons must be worn.
- Be alert at all times.

Tools and materials needed for the activity:

- 50ml of water in a glass beaker.
- 50ml alcohol in a glass beaker (menthylated spirit).
- Electronic measuring scale

Carrying out the activity: (Method)

- Accurately measure the volume and mass of 50ml water and 50ml alcohol (menthylated spirit).
- Mix the two liquids carefully.

Fill in the table below:

Prediction

Water	Alcohol	Mixture (water and alcohol)
Vol : ____________	Vol : ____________	Vol : ____________

Observation

Water	Alcohol	Mixture (water and alcohol)
Vol : ________________	Vol : ________________	Vol : ________________

Explanation / Conclusion :

____

____

____

Fill in the table below:

Prediction

Water	Alcohol	Mixture (water and alcohol)
Mass : ________________	Mass : ________________	Mass : ________________

Observation

Water	Alcohol	Mixture (water and alcohol)
Mass : ________________	Mass : ________________	Mass : ________________

Explanation / Conclusion :

____

____

____

NAME : ____________________________

LESSON 2

GRADE : 10 **CURRICULUM : NCS** **TIME: 45 MINUTES**

FACILITATOR: SEGALE R. D.

The purpose of the following activity is to remedy learners' alternative conception with regard to

SPACES BETWEEN MOLECULES (**Law of Conservation of Mass)**

SAFETY NOTE

- Safety goggles and aprons must be worn.
- Be alert at all times.

Tools and materials needed for the activity:

- Salt
- Hot water
- Measuring cylinder
- Measuring scale

Carrying out the activity: (Method)

- Accurately measure the volume and mass of salt and hot
- Dissolve 10ml of salt in 50ml of hot water.
- Taste the mixture to ensure that salt was dissolved in water.

Prediction

	Salt	Hot water	Salt and hot water
Volume	10 ml	50ml	________ml
Mass	__________g	____________g	__________g

Observation

	Salt	Hot water	Salt and hot water
Volume	10 ml	50ml	________ml
Mass	__________g	____________g	__________g

Explanation / Conclusion :

____

____

____

NAME : ______________________________________

LESSON 3

GRADE : 10 **CURRICULUM : NCS** **TIME: 45 MINUTES**

FACILITATOR: SEGALE R. D.

The purpose of the following activity is to remedy learners' alternative conception with regard to

SPACES BETWEEN MOLECULES (**Law of Conservation of Mass)**

SAFETY NOTE

- Safety goggles and aprons must be worn.
- Be alert at all times.

Tools and materials needed for the activity:

- Small stones
- Beaker
- Water
- Measuring scale

Carrying out the activity: (Method)

- Measure water in a beaker (take the readings) ______________
- Place small stones in a beaker with water.(take the second readings) ________________
- Take the volume by subtracting the initial volume from the final volume. ___________________
- Place salt in another beaker, take the readings. _______________________
- Pour the salt in the water and stone mixture . Record readings. ___________________

Prediction

Small stones	Small stones and salt
Volume : ____________ Mass : ______________	Volume : ____________ Mass : _______________

Observation

Small stones	Small stones and salt
Volume : ____________ Mass : ______________	Volume : ____________ Mass : _______________

Explanation / Conclusion :

____

____

____

DIFFICULTIES THAT LEARNERS EXPERIENCED WHEN DOING AND REPORTING ON THESE EXPERIMENTS

LEARNERS' RESULTS:

LESSON 1:

All groups predicted that the total mass and the total volume both will equal the sum of the individual mass or volume readings.

Four groups correctly found that the volumes decreased.
Three groups found that the total volume equals to sum of the individual volumes, i.e. their predictions were correct. They either did not take accurate measurements, or changed their measured results to fit their predictions.
The last group incorrectly measured an increase in total volume.

In the mass measurements the learners did not subtract the mass of the beakers and consequently got incorrect results.

LEARNERS' CONCLUSIONS:

The majority of learners did not write a conclusion, but simply wrote down their findings, e.g. that the observed total volume is less than the predicted total volume. A few learners wrote down the method of the experiment, telling what they have done. Amongst those that tried to explain their results, misconceptions were revealed, e.g.

- Some liquid is lost (i.e. neglect conservation of mass).
- Alcohol is very light in volume (confusing mass and volume).
- When water and alcohol are mixed, they are contaminated (no scientific reasoning).

- When water and alcohol are mixed they become thicker (do not understand density).

LESSON 2:

All groups attempted to perform the experiment.
Only three groups were able to indicate that: Total mass = mass of water + mass of salt.
Only two groups indicated that: Total volume < volume of water + volume of salt.

LEARNERS' CONCLUSIONS AND PROBLEMS:

- Learners did not recognise the process of dissolving and conservation of matter in their explanations.
- Learners felt that salt as a solid will always weigh more than water.
- Only one group was able to relate the mixture as homogenous.
- Learners failed to explain or conclude about their observations. They repeated what they recorded as their observations as conclusions.
- Language is recorded as a problem due to poor construction of simple sentences.
- Learners have a fear of using simple apparatus, for example, taking measurements from the beaker, taking readings from the scale and meniscus reading.

LESSON 3:

All groups attempted to perform the experiment.
Only one group was able to perform the experiment outstandingly.
Experiment three was concerned with the understanding of the law of conservation of matter.
Learners performance in this experiment was really not acceptable due to incorrect observations and conclusions recorded.

LEARNERS' CONCLUSIONS AND PROBLEMS:

- Learners had a problem of taking the volume of small stones and salt.
- Majority of learners requested a further explanation on the experiment and further examples but failed to draw correct conclusions.
- Law of conservation of matter is a problem to learners to understand.