GRADE 11 LEARNERS' ALTERNATIVE CONCEPTIONS ON THE STATES OF MATTER AND PHASE CHANGES

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ABSTRACT

Key words: states of matter, phase changes, alternative conceptions, teaching and learning

States of matter and phase changes are important topics in the teaching and learning of physical science. It is a common fact that learners find it difficult to understand the states of matter and phase changes. One of the main reasons is that learners do not abandon their own naïve perceptions when the scientific concepts are taught. They do not connect their experiences outside the laboratory / classroom with their experience in science lessons. Learners consequently hold their own views even after instruction. According to the constructivist view on teaching and learning educators need to take learners' perceptions into account in the teaching of these topics.

The first aim with this study was to determine learners` alternative conceptions about the states of matter and phase changes from a literature study. The second was to determine by means of an empirical study the alternative conceptions Grade 11 learners still hold after instruction of the topics. The empirical survey was conducted amongst a group of 110 Grade 11 learners studying physical science. A questionnaire was used to obtain information on this group of learners' knowledge on the states of matter and of phase changes after instruction of these topics. From the results of the questionnaire alternative conceptions could be identified.

The results of the empirical study indicate that learners still have alternative conceptions about the states of matter and phase changes after instruction. Alternative conceptions were identified and recommendations on how to teach the states of matter and phase changes more effectively were made.

OPSOMMING

Sleutelwoorde: toestande van materie, faseveranderings, alternatiewe opvattings, onderrig en leer.

Toestande van materie en faseveranderings is belangrike onderwerpe in die onderrig en leer van Natuur-en Skeikunde. Dit is 'n algemene feit dat leerders dit moeilik vind om die toestande van materie en faseveranderings te verstaan. Een van die belangrikste oorsake hiervan is dat leerders, wanneer hulle die wetenskaplike konsepte onderrig word, nie hul eie naïewe idees laat vaar nie. Leerders bring nie dit wat in die laboratorium / klaskamer geleer word in verband met hulle ervaring in die alledaagse lewe nie. Leerders het gevolglik, selfs na onderrig daarin, steeds hulle eie opvattings aangaande bepaalde konsepte. Volgens die konstruktivistiese siening van onderrig en leer moet opvoeders leerders se opvattings ook in aanmerking neem wanneer hierdie onderwerpe onderrig word.

Die eerste doelstelling van die studie was om deur 'n literatuurstudie vas te stel watter alternatiewe opvattings leerders oor die toestande van materie en faseverandering het. Die tweede was om vas te stel watter alternatiewe opvattings Graad 11-eerders nog het na onderrig oor die onderwerpe ontvang is. Die empiriese ondersoek is uitgevoer met 'n groep van 110 Graad 11 Nauur- en Skeikunde leerders. 'n Vraelys is gebruik om inligting oor dié groep leerders se kennis van toestande van materie en faseveranderings na onderrig vas te stel. Uit die resultate van die vraelys kon alternatiewe opvattings geïdentifiseer word.

Die resultate van die empiriese ondersoek toon dat Graad 11-leerders, na onderrig van die´ onderwerpe, steeds alternatiewe opvattings oor die toestande van materie en faseveranderings het. Alternatiewe opvattings is geïdentifiseer en aanbevelings oor hoe om die toestande van materie en faseveranderings meer doeltreffend te onderrig word gemaak.

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CHAPTER 1

INTRODUCTION

1.1 PROBLEM ANALYSIS

States of matter and phase changes are fundamental concepts in science (Gabel & Samuel, 1987:695). It is a common observation that learners find it difficult to understand the states of matter and phase changes. Scott *et al.* (1991:5) found that learners' alternative conceptions interfere with understanding science and are resistant to change. Learners' alternative conceptions are constructed through interaction between a child's cognitive system and his/her physical, social and cultural environment. Stavy (1988:553) states that our knowledge about alternative conceptions and how they change with age, culture and instruction may be helpful in designing better teaching methods for understanding.

In everyday language, matter, as many other scientific concepts, has multiple meanings (see paragraph 2.2). Words that express scientific concepts may have different meanings in everyday language, which may be one of the sources of children's alternative conceptions. This is because children have to fit or map their perception of the world they observe and experience into existing knowledge frameworks. It is expected that young children's perceptions of the matter concept would match the everyday meaning of the word. Learners' perceptions are expected to shift with age and instruction towards the scientific meaning (Stavy, 1991:240).

It is also a fact that learners do not connect what they observe in their everyday live experience with their science lessons and give interpretation about the outside experience. According to Ryan (1990:172), an analysis of learners' conceptions of the states of matter will help in the rational structuring of what is presently seen as foundation work in the learning of chemistry. Consequently, the aim of this study is to investigate the conceptions held by learners of states of matter and the related concepts such as phase changes. Nel (1996:7-8) states that a common obstacle in science learning is the difficulty in transferring scientific knowledge acquired in an academic context to a more familiar and everyday situation.

Learners not only have alternative conceptions about the states of matter, but also about transformations of matter from one phase to another. When matter undergoes a physical change (e.g. phase change in this context, see paragraph 1.6.2), the substance involved does not change its molecular structure, thereby conserving its identity. The chemical structure of water, for example, remains unchanged when it is transformed from the liquid to the solid state: (H_2O (*l*) $\rightarrow$ H_2O(*s*)). Alternatively, in chemical changes (e.g. chemical reactions), the molecular structure of the reacting substances is changed by the interactions between the molecules/atoms of the reacting substances and new substances are generated. Thus, during a chemical reaction, the molecular structures of the reacting substances are changed, and new substances are formed. What happens is the reorganization and distribution of the matter within the entities (Nel, 1996:07). It is thus possible to argue that the reacting substances are changed by a chemical reaction and new ones are formed but not the atoms within the substance. For example in the reaction $2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$ the number of type of atoms in the reagents are equal to the number and type of atoms in the products (law of conservation of matter).

Educators themselves may add to learners' alternative conceptions. They may transmit their own conceptions to learners, which then become learners' conceptions. If educators teach alternative conceptions to their pupils instead of scientifically accepted concepts, the aims of science teaching are not achieved. The aims of teaching science are, among others to prepare learners to become scientifically literate and to use and function effectively within the technological world. According to Wesi (1997:1-2), investigation into educators' knowledge and understanding is regarded as an inevitable exercise if teaching and learning problems are to be addressed. Wesi further states that the contribution of educators' own knowledge in teaching and learning cannot be underestimated. If educators do not themselves possess sufficient subject content knowledge and are not sure of what they teach, they are likely to lack confidence and motivation in class. This results in the poor performance of their learners (Wesi, 1997:1-2).

In keeping up with recent theories of cognitive representation, for example mental models (White, 1989:46) the alternative representation competes for their activation within the same subject. To predict the activation pattern for each idea the conceptual variables that influence the probability of use of such an idea should be known. It needs to be remarked that research on alternative conceptions reveals that context can only to a small extent be considered as a relevant variable (White, 1989:46).
A question that may arise is: Why is the study focused on matter? The two main reasons are firstly: matter, time and space are the three most fundamental concepts of physics (Lemmer, 1999:1-2). Secondly: in the New National Curriculum Statement (Department of Education, 2003:11) "Matter and Materials" is one of the learning areas in Grades 10 to 12. The states of matter and phase changes are part of this learning area. The outcomes of this study are expected to impact positively on the effectiveness of the teaching of natural sciences in the Republic of South Africa.

This study focuses on learners' alternative conceptions, specifically those related to the states of matter and phase changes. In the first part of the study learners' alternative conceptions identified in a literature study are reported. The second part involves a study of Grade 11 physical science learners' alternative conceptions after instruction on the states of matter and phase changes. Based on the results recommendations on how to improve the teaching of these topics are made in the last chapter.

In the context of the preceding discussion the research hypothesis for this study is formulated in paragraph 1.2. Based on the hypothesis the aims and objectives of the study are formulated in paragraphs 1.3 and 1.4. The motivation in paragraph 1.5 further contextualizes the study.

1.2 HYPOTHESIS

In the light of the introductory problem analysis (paragraph 1.1), the hypothesis to be tested in this study can be formulated as:

Grade *11 learners studying physical science still hold alternative conceptions about the states of matter and of phase changes after instruction.*

The research reported on in this dissertation is directed at the verification of this hypothesis.

1.3 AIMS

As stated in the hypothesis (paragraph 1.2), the target group is Grade 11 learners studying physical science. The specific aims of the study are to:

1.3.1 determine learners` alternative conceptions from a literature study about the states of matter and phase changes.

1.3.2 determine Grade 11 learners' alternative conceptions about the states of matter and phase changes after instruction.

Based on these aims, the objectives of the study can be formulated (paragraph 1.4).

1.4 OBJECTIVES OF THE STUDY

As stated in the hypothesis (paragraph 1.2), the focus of this study was on states of matter and phase changes. Specific objectives set in the context of the hypothesis and aims are:

1.4.1 To identify and list core concepts about matter, states of matter and phase changes

The list of core concepts is to include the basic concepts related to the sub-microscopic building blocks of matter and the structure of matter: atoms, molecules, ions and crystals. It also includes the macroscopic concepts: elements, compounds, mixtures and substances as well as the concepts related to phase changes: melting, boiling, freezing, evaporation, condensation and sublimation. The kinetic model of matter also forms part of the list. Descriptions or definitions of the entities, structures, models and processes listed will further be given. The identification of the core concepts resulted resulted from a literature study. As the level of the learners involved in this study is Grade 11, sub-atomic particles such as quarks and nuclear processes (for example nuclear reactions) are excluded.

1.4.2 To probe into Grade 11 learners' knowledge and understanding of the states of matter and phase changes after instruction.

The second objective of the study was to obtain knowledge of Grade 11 learners' perceptions of the states of matter and transformations between the states. Alternative conceptions about the states of matter and phase changes were identified in this part of the study, mainly from the results of the questionnaire. Interviews with learners and their educators, class discussions, tests and examinations served to outline some of the alternative conceptions identified in the questionnaires. Alternative conceptions related to states of matter and phase changes reported in literature were taken into account in compiling the questionnaire. The third objective of the study is stated in the next paragraph.

1.4.3 To propose teaching strategies to deal with the alternative conceptions learners hold about the states of matter and phase changes

This third objective serves to recommend effective teaching strategies to be applied in the teaching of concepts related to matter, states of matter and phase changes. The expectation is that the recommended teaching strategies would improve the effectiveness of the teaching of the topics under consideration. Wesi (1997:4) however warns that no teaching strategy could claim to have all the answers to the problems encountered in the understanding of science and particularly the concepts related to matter. This statement by Wesi implies that new possibilities on how to teach the topics under consideration should be explored.

The key terms, such as states of matter, phase changes, alternative conceptions and interventional strategies are described in paragraph 1.6. Alternative conceptions regarding the concepts related to matter and phase changes are discussed in detail in Chapter 3 of this dissertation. Interventional strategies and constructivism are reviewed in Chapter 4.

1.5. MOTIVATION

In this paragraph the motivation for the study reported in this dissertation is further elaborated on. It also serves to contextualize the research hypothesis, aims and objectives stated in paragraphs 1.2 - 1.4.

Learners' difficulties in understanding school science is a general problem caused by different factors (Driver, 1989:146). Among these factors is the learners' everyday reasoning, which conflicts with scientific reasoning. In general, learners that have been taught about states of matter and phase changes do not abandon their everyday reasoning (Anderson, 1990:25). Educators need to take learners' perceptions into account when teaching this topic. Anderson (1990:26), states: "Learners do not have any conscious models that they attempt to develop in interplay with observations. On the contrary, they appear to change the properties of their particles collectives from one situation to the next". Anderson gives examples: "If phosphorous melts, learners believe that the phosphorous atoms also melt and when water solidifies, its molecules cease to move. ``

The study reported by Anderson (1990:26) attempts to provide some insight into the learning difficulties that learners experience when trying to change from everyday reasoning to scientific thinking. Educators also need to devise an effective strategy of teaching matter at school in the learning area of Matter and Materials in the new curriculum.

A general observation by Anderson (1990) was that with regard to the conservation of matter during phase transformations, learners hold views of transformations related to the states of matter that are not accepted by scientists. A specific example of such a view reported by Anderson (1990:13) is that when you boil water, you get water vapour. Learners use this idea to explain chemical reactions and say for example: if you burn alcohol, you get alcohol vapour. According to Anderson (1990:13), learners believe that substances are conserved, whatever happens to it.

It was mentioned in paragraph 1.1 that learners' alternative conceptions of the states of matter and of phase changes are in some cases caused by educators' alternative conceptions and their methods of teaching. In traditional teaching methods learners are required to learn facts (sometimes rote) from the textbooks. Presentations made by educators and from textbooks are incomplete and sometimes confusing when learners try to integrate them with their own conceptions. It sometimes happens that educators give information by rote because they do not understand the facts and relationships between facts themselves. They have their own alternative conceptions and transmit them to learners. This leads to distorted views that oppose understanding. This study reports in chapter 4 on a few teaching strategies used in the teaching of science and specifically the teaching of states of matter and phase changes.
In paragraph 1.6 the terms used in this study is defined/described.

1.6 DESCRIPTION OF TERMS

1.6.1 Matter, states of matter and phase changes

The key concepts (terms) involved in a study of matter, states of matter and phase changes at Grade 11 level are: models, the kinetic model of matter, states of matter, phase changes, alternative conceptions, constructivism and interventional (teaching) strategies. These concepts are broadly described in paragraphs 1.6.2-1.6.6. A detailed description of the terms related to matter and phase changes is given in Chapter 2.

1.6.2 Models

In order to understand a specific model such as the kinetic model of matter, one needs to understand what a model in science is. According to Atkins (1994:3), a model is a simplified version of the system that focuses on the essentials of the problem, i.e., a model seeks to identify the core entity and ignores the possible ramifications that are considered to be of secondary importance. In this study, the basic model is that of the particle nature of matter.

Van Oers (1988:128) describes a scientific model as to constitute an artificial reality that can be investigated on mental, visual and material level. According to Johnson-Laid (1983:59), our knowledge of the world depends on our ability to construct models thereof. Every person has a mental model that represents that person's view of the world. In this study mental models will represent views of particles in different states of matter and during phase changes. The kinetic model of matter will be considered.

To summarise Smit and Finegold (1995:624), it can be stated that a model is a representation of reality, or something that represents the real thing. A model's main function is to help us to understand invisible particles, entities and processes. This study provides descriptions of models of solids, liquids and gases and of the phase transformations between the states of matter.

1.6.3 The kinetic model of matter

Learners have to know and understand the particle theory in order to understand matter, phases of matter and phase changes. In the particle model of matter, moving particles resembles atoms and/or molecules. This model and the theory involved are discussed in Chapter 2 of this study. The particle theory of matter helps learners to understand certain phenomenon, for example phase changes. Learners have to relate the moving particles to the macroscopic substances and processes that these substances undergo. This will also be discussed in the next chapter, Chapter 2. According to the kinetic model, all matter is made up of small perpetually moving invisible particles. Matter can be seen with the naked eye, but the particles constituting matter cannot be seen. The electron microscope is an instrument that can be used to see arrays of larger atoms (e.g. tungsten atoms). Gallagher and Ingram (1986:6) state that before this instrument was invented, nobody knew for sure that there were tiny particles inside matter. The electron microscope gave visible proof of the existence of these particles. Since this instrument (electron microscope) is unavailable in school laboratories (Gallagher & Ingram, 1986:6-7), models will be used in an attempt to facilitate understanding of the kinetic theory of matter.

In Chapter 2 (the literature study) the kinetic model of matter (specifically for the different states of matter) is extensively discussed.

1.6.4 Alternative conceptions

According to Wesi (1997:922-925) it is a common practice in the scientific community to come to a general agreement on what a particular concept should mean. These agreements are based on investigations and reliable theoretical reasoning. Such agreements may take the form of imposed definitions or generally accepted reasoning. All reasoning not in line with accepted scientific reasoning or arguments is regarded as scientifically unacceptable.

Several empirical studies Duit (2006:2) have shown that learners begin their study of science with strongly held but naïve ideas (conceptions) about phenomena, ideas that are in conflict with other observed phenomena. In general these conceptions differ from what is accepted by the scientific community. These naïve ideas are called alternative frameworks, alternative conceptions, pre-scientific or simply learners' ideas or conceptions (Roy Lee Foley 1999:46). The study reported in this dissertation examines and deals in detail with learners' alternative conceptions about the states of matter and phase changes. Questions are: why do these alternative conceptions exist? And what is the correct or best way to deal with these conceptions in teaching? (Roy Lee Foley 1999:46). Alternative conceptions about matter are extensively discussed in Chapter 3 of this dissertation.

1.6.5 Constructivism

Traditionally, matter, the states of matter and phase changes, (like all other topics in science), were taught in a transmission process (Kgwadi, 2001:23). In this process knowledge is transferred from the educator to the learner. In the transmission process knowledge is usually transferred without allowing learners to find answers for themselves. According to a report by Wesi (1998:30), this model of learning does not yield the results that could otherwise be expected. Hence, the constructivist view of teaching and learning, specifically applied to the states of matter and phase changes, is recommended (Wesi, 1998:29).

Constructivism is a theory of learning based on the assumption that learners construct their own knowledge structures and is responsible for their own learning (Watts, 1994:53). According to Wesi (1998:30), the educators' responsibility is only to guide the child systematically towards knowledge. The learners integrate the freshly reviewed incoming knowledge with their existing knowledge structures. In this study and particularly in recommendations on a teaching strategy, we focus on the constructivist approach and how it can be used to address the problems encountered within the learning of the states of matter and phase changes. In this way the aims and objectives of this research could be accomplished.

The constructivist view emphasises the importance of learners' alternative conceptions in the learning and teaching of science (Driver, 1989:150). According to this view, learner's alternative conceptions must be taken into account and addressed. If they were ignored, they stay firmly established within learners' mental structures and persist after formal instruction. Wesi (1998:31) states that a constructivist teaching strategy in general involves the following: establishing learners' existing knowledge (alternative conceptions), discrediting these ideas, and then the construction of scientific knowledge. After learners' conceptions have been discredited, they are ready to assimilate scientifically acceptable knowledge, knowledge that does not lead to contradictions and is not contrary to experimental observations. It fits in scientific knowledge frameworks. The essence of constructivist teaching is that learners must be allowed to construct their own knowledge. Steps involved in leading learners through the process of knowledge construction include allowing learners to discuss and interpret phenomena or experimental observations. If a scientific concept is considered acceptable (Wesi, 1998:32-33) learners discard their own naïve concepts in favour of the scientific one. In this way we say learning has taken place. An elaboration of this discussion is found in paragraphs 4.3.1 to 4.3.5.

1.6.6 Interventional strategies

Roy Lee Folley (1999:46) describes as extensive professional activities that help to reduce the frustration that educators feel due to the lack of adequate guidelines, theoretical models and practical resources that empower them to successfully implement educative reform in the reality of the school setting. Interventional strategies are powerful learning tools that can help learners to conceptualise abstract ideas, for example, the microscopic concepts of matter such as atoms and molecules.

Interventional strategies (Fermin 1997:98) are viewed as instructional strategies that allow the integration of a variety of approaches such as hands-on activities, visualisation, writing, demonstrations, role-play and guided enquiry. The process of intervention is important in bridging the gap between the concrete and abstract understanding of scientific concepts and principles amongst learners. Fermin (1997:98) mentions that certain interventional strategies were found to improve the understanding of the nature of matter and the concepts related to matter.

(Abour *et al.* (1997:428) describe an interventional strategy as a tool for interpretation, learning, and expressing thoughts and ideas, and of demonstrating the understanding of abstract topics. They further state that it also helps learners to think, discover, develop and organise ideas and in general to learn effectively.

Abour *et al.* (1997:438) further state that interventional strategies intend to help learners to conceptualise abstract concepts and assist them to understand the results of science. Incorporating successful interventional strategies in the learning processes not only enhances learners' learning and understanding, but also creates fun for both learners and educators. Interventional strategies try to create the kind of environment that encourages learners to engage in constructing meaning and making sense of what they learn and do in class.

In this study the interventional strategies employed in the teaching of matter, the states of matter and phase changes complied with the descriptions given by Fermin (1997) and Arbour *et al.* (1997). These strategies are in harmony with the Outcomes-based approach at present in use in South Africa (Department of Education, 2003:7).

1.7 METHOD OF RESEARCH / INVESTIGATION

Material for the literature study (Chapter 2) was obtained from the library by means of the following electronic searches: ERIC, NEXUS, EBSCO-HOST and RSAT-SA. Key words were used. Journals and recent publications dealing with the issues relevant to this study were examined. A part of the literature study was conducted to gain understanding of problems that learners encounter with the understanding of the states of matter and phase changes.

The literature review was used to direct the construction of the questionnaire used to probe into learners' alternative concepts related to matter, states of matter and phase changes. The literature study reviewed and identified the concepts related to matter, alternative conceptions about the particle motion of matter, states of matter and phase changes. Lastly, it reviewed the interventional strategies generally applied to deal with learners' alternative conceptions.

The empirical investigation was guided by the literature study. Data on learners' alternative conceptions about the states of matter and phase changes were obtained by means of a questionnaire. The questionnaire was supplemented by interviews and class discussions. A group of 110 Grade 11 learners from four schools in the Rustenburg area were involved in the investigation. The statistical support services of the North-West University assisted in processing the data acquired from the questionnaires.

1.8 SUMMARY

In this chapter the research problem, research hypothesis, aims and objectives of the study are stated and the method of research is described. A description of the terms used and the method of research is also given in this chapter. The next chapter, Chapter 2, reports on the literature study dealing with the scientific concepts related to the particle nature of matter, states of matter and phase changes.

CHAPTER 2

LITERATURE REVIEW: CONCEPTS RELATED TO MATTER

2.1 INTRODUCTION

In this chapter the concepts of matter and the processes related to phase changes used at secondary school level and relevant to this investigation are identified and discussed. Concepts that will be discussed are matter and its constituents' particles, the states of matter and phase changes. The discussion deals with the concepts: element, compound, substance and mixture on the macroscopic level. On the microscopic level it deals with atoms, particles and ions. The relationships between these concepts will be discussed. A discussion of what matter is, is done first.

2.2 MATTER

In everyday language, matter, as many other concepts, has multiple meanings. For example, matter in the Longman Dictionary (1987:646) is described as the physical material of which everything that we can see or touch is made. The meaning of the word *matter* in the Hebrew language as stated by Anderson (1990:13-30), is clay, material for thought, or in more literary context, severity. According to Stavy (1988:6), matter is anything that has mass and occupies space; it is the stuff of the universe; it is made of everything that is tangible. Stavy (1988:6) further says that matter is the material from which all things in the universe are made, and that it is constructed of very small particles called atoms. The basic entities constituting all forms of matter are atoms or ionised atoms. Atoms belong to different elements, listed in the periodic table. Heyns *et al.* (1994:150) define matter as anything that occupies space and possesses mass. We will use this definition, since this research is focussed on Grade 11 learners, who are supposed to understand the meaning of matter as stated by Heyns *et al* (1994:150). According to Anderson (1990:13), matter is a basic concept in chemistry. A large number of studies have been devoted to matter in the educational context.

In the following discussions the concepts dealt with are related to entities and processes dealing with matter on the microscopic and macroscopic levels. Role players on the microscopic level are atoms, particles and ions. On the macroscopic level large collections of microscopic entities are considered, such as blocks of ice, solid carbon dioxide called dry ice, jugs of water or containers filled with liquid gas. The study intends to identify the difficulties that Grade 11 learners experience in the understanding of the different states of matter and phase changes. Campbell (2000:39) states that learners need to learn more about the variety of materials and concepts that make sense to them. They need to develop understanding of how the properties of a material relate to each other and to its microstructure and learn of new approaches to the study of materials.

This paragraph of the study aims to describe the constituent parts of matter, their properties and how they are related. The qualitative study of the relationship between the concepts describing the composition of matter (atom, molecule, ion, element, compound, substance and mixture) is reported. The discussion starts with the atom.

2.3 CONSTITUENTS OF MATTER

2.3.1 Atoms

An atom is the smallest part of an element that possesses the characteristics and chemical properties of that element. Microsoft Encarta Encyclopaedia (2000) states that in ancient Greek philosophy the word *atom* was used to describe the smallest bit of matter that could be conceived. This fundamental particle was thought of as indestructible and in fact the Greek word for atom means '*not divisible*'. Atoms are so small that they cannot be seen even with the aid of a powerful electron microscope. Electron microscope photos however provide evidence of the existence of atoms (Microsoft Encarta Encyclopaedia, 2000). Atoms vary in size, weight and shape, but all atoms of the same element are identical. Two of the important characteristics of atoms are mass and radius (Tsaparlis, 1997:924). Atoms, by means of chemical bonds form particles (Pozo, 2001:369). Knowledge about the nature of an atom has grown slowly throughout the centuries. In the early years of science people were content merely to speculate about it. With the advent of experimental science in the 18^{th} and 19^{th} centuries, progress in atomic theory quickened. Chemists soon recognised that all liquids, gases and solids can be analysed into atoms, their ultimate components (Microsoft Encarta Encyclopaedia, 2000). Many scientists have studied the structures of atoms and in this way the atomic theory was developed. The next paragraph focuses on the historic development of the atomic theory.

2.3.2 Historic development of the atomic theory

Long before Christ the Greek philosophers proclaimed that matter consist of tiny particles. Democritus (±420 B.C.) named such particles atoms, which is derived from the Greek word *atomos*, which means indivisible. For nearly 2000 years no contribution was made toward the development of a theory on the particle nature of matter. The first development came in 1803, when Dalton put forward the first real atomic theory. According to Dalton, the atom is a solid sphere, and he actually used solid spheres to illustrate his model (Brink *et al.*, 1988:137)

Dalton's model could not explain the force of attraction between particles of matter. He did not think that charges had any connection with the fact that matter is composed of different particles. The next development was when Faraday indicated the relationship between electricity and atomic structure (Brink *et al.,* 1988:149). According to Brink *et al.* (1988:149) Dalton conducted an experiment that signified the existence of the electron as a sub-atomic particle. Thomson (1856–1940), the discoverer of the electron in 1898, regarded the atom as a solid sphere, but one that consists of equal numbers of positive and negative charges distributed equally throughout the atom. Electrons carried negative charges. The atom as a whole is electrically neutral. Thomson's representation of an atom known as the "currant bun model'' is as depicted in Figure 2.1 (Brink *et al.*, 1988:149)

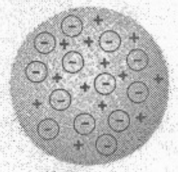

(b) 1903

Figure 2.1: Thomson's model of the atom

The negative charges in Thomson's model of the atom were associated with electrons (currents). The positive charges are not associated with particles, but are considered to be spread throughout the atom, like dough in a pudding or a bun. After Thomson's discovery of the electron, Rutherford (1871-1937) conducted more experiments. Far from being a solid bit of matter, Rutherford found the atom to consist mostly of space. According to Brink *et al.* (1988:149), Rutherford further demonstrated the existence of the atomic nucleus by detecting scattered α-particles. On the basis of further investigations, Rutherford established that the nucleus consists of positive particles, which he called protons. He further found that there are equal numbers of protons and electrons. Rutherford did not attempt to locate the exact position of the electrons but two years later, Niels Bohr (1913) became the first to do so (Brink *et al.*, 1988:149).

Bohr (1913) assumed that electrons are arranged in definite shells/quantum levels, at a considerable distance from the nucleus. The arrangement of these electrons is called the electron configuration of an atom. The number of electrons equals the atomic number of the atom. The electron shells are built up in a regular fashion from a first shell in the elements hydrogen and helium to a total of seven shells in the largest elements. Each shell has an upper limit to the number of electrons that it can accommodate. The last electrons, those in the outer electron shell, determine the chemical behaviour of the atom (Microsoft Encarta Encyclopaedia, 2000). The inner shell must be filled before an outer shell can start filling. The mass of an atom is concentrated in the nucleus. The mass of an electron is so small that it is neglected.

Arrangement of electrons in shells in an atom according to Bohr's atomic model is illustrated in Figure 2.2. The number of electrons per shell equals $2n^2$. (n is the number of the shell. The first shell thus contains two and the second eight electrons.)

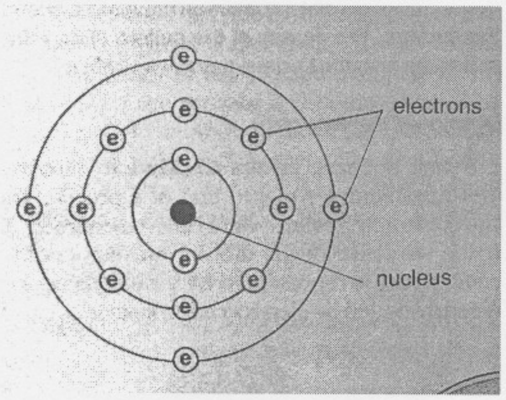


Figure 2.2: Bohr's model of an atom

This model of the atom developed by Bohr could account for the bonding of atoms to form molecules.

2.3.3 Molecules

A molecule is formed when two or more atoms bond to form a group or system of atoms. A molecule is a smallest unit that still exhibits the properties of that substance. Examples of molecules are, N_2, H_2, H_2O. Molecules are made up of atoms, so atoms combine (react) to form a molecule (Tsaparlis, 1997:924). The following examples are representations of H_2 and H_2O molecules respectively (Figure 2.3).

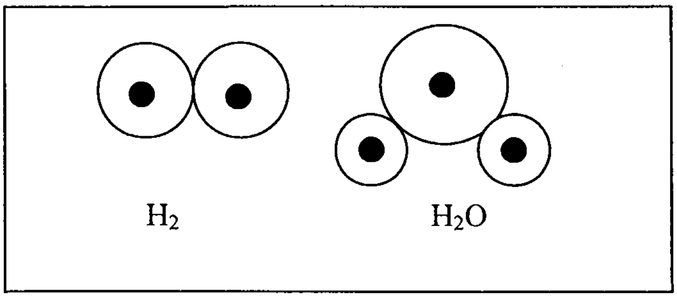


Figure 2.3: Representation of molecules of H_2 and H_2O

The process where two or more atoms or molecules react to form a new molecule is called a chemical reaction. An example of a balanced chemical reaction is shown below.

The formation of two water molecules when one molecule of oxygen and two molecules of hydrogen react is used as an example.

			Forms	
$\mathbf{O_2}$	+	$\mathbf{2H_2}$	$\longrightarrow$	$\mathbf{2H_2O}$
1 molecule of oxygen consisting of 2 oxygen atoms		2 molecules of hydrogen, each consisting of 2 hydrogen atoms		2 molecules of water, each consisting of 2 hydrogen atoms and one oxygen atom It no longer exhibit the properties of elements (H and O) but has new properties of the compound water

2.3.4 Ions

Ions are electrically charged atoms or molecules. By losing or gaining electrons, atoms form ions. Positive ions are formed when an atom has lost one or more electrons and negative ions are formed when neutral atoms has gained electrons. Positive ions are called cations and negative ions are called anions. Cations and anions combine in a fixed ratio to form ionic compounds, example, (Na^+Cl^-). The electrostatic attraction between anions and cations is known as the ionic bond (Pozo, 2001:369).

2.3.5 Elements

An element is a substance that consists of only one kind of atom. It is one of the basic concepts in chemistry. An element is defined as anything that cannot be broken down into simpler substances by chemical methods (Thickett, 1992:17). Elements are made up of atoms. The atoms in a specific element are similar and are represented by a unique symbol, e.g., Li, K, and P. Elements are composed of unique atoms that have fixed atomic weights and atomic radii. All atoms of a specific element have the same number of protons and electrons. The number of neutrons in atoms of an element may differ. Atoms of an element with different numbers of neutrons are called *isotopes* of the element. Elements are classified in a variety of ways: metals, semi-metals, non-metals, or solids, liquids and gases. Elements can be converted from one state to another either by heating or cooling. Elements can be defined by the atomic number (Z). Elements vary considerably in their physical properties: they have unique properties such as melting points, boiling points, density, electrical and heat conductivity (Thickett, 1992:8, 17-19). The periodic table is the best-known classification of elements. The sequence in the periodic table is according to atomic numbers. Elements in the same group in this table have the same valence and properties. The valence of an element indicates the number of electrons participating in a chemical reaction an atom of a particular element.

2.3.6 Compounds

A compound is a substance that can be broken down into simpler substances (e.g. elements or other compounds) by chemical methods. Its composition is constant. Compounds are made up of atoms of different elements (Pozo, 2001:369). According to Thickett (1992:65), atoms of different elements in a compound are combined in a fixed ratio (a fixed number of atoms of each element), and the sum of the mass of the atoms gives the molecular mass of a compound. Compounds are symbolised by a molecular formula that represents the actual number of atoms of each element present in the particle, for example, NaCl and Na_2CO_3 $C_{12}H_{22}O_{11}$, etc. According to Thickett (1992:66), there are two types of compounds, ionic compounds and molecular compounds. Ionic compounds consist of ions (an atom or group of atoms with an electrical charge), example, KBr, NaOH, NaCl, $MgSO_4$ etc. Molecular compounds consist of two or more non-metals bonded together, examples, N_2H_4 and SO_3.

2.3.7 Substances

Pozo (2001:369) states that substances are pure and refers to elements and compounds. He further states that a substance can be an atomic system of like atoms for example a piece of iron that consists only of iron atoms or a compound that consists of molecules formed from different elements like water that is a compound of hydrogen and oxygen atoms.

2.3.8 Mixtures

A mixture consists of two or more elements / compounds that do not combine with each other chemically. A mixture do not have a fixed composition. It is a non-chemical union of substances. A specific example is air. Air is a mixture of oxygen, nitrogen, carbon dioxide and other gases. A mixture is a substance consisting of various different atomic or molecular systems with no chemical union between them (Pozo, 2001:369). Other examples of mixtures are mud and solutions such as sugar in water.

Mixtures have variable compositions and can be separated into their components by using physical separation techniques. By considering the properties of the parts of a mixture, mixtures can be separated by the following processes: filtration, evaporation, distillation and magnetism. The analysis of the separate fractions reflects the proportion of each component. No new substance forms and no chemical reaction take place when a mixture forms (Thickett, 1992:8-9). There may be a change in temperature.

Mixtures can be solids, liquids or gases. Sometimes they are combinations of solids, liquids and gases, as shown in Table 2.1.

Table 2.1: Examples of mixtures

Example	Types of mixtures	Main parts of mixtures
Air	Gas in gas	Nitrogen and oxygen
Wine	Liquid in liquid	Alcohol and water
Brass	Solid in solid	Copper and zinc
Soft drink	Gas in liquid	Carbon dioxide in water
Black coffee	Solid in liquid	Coffee powder in water

This flow diagram in Figure 2.2 represents a mixture and its components.

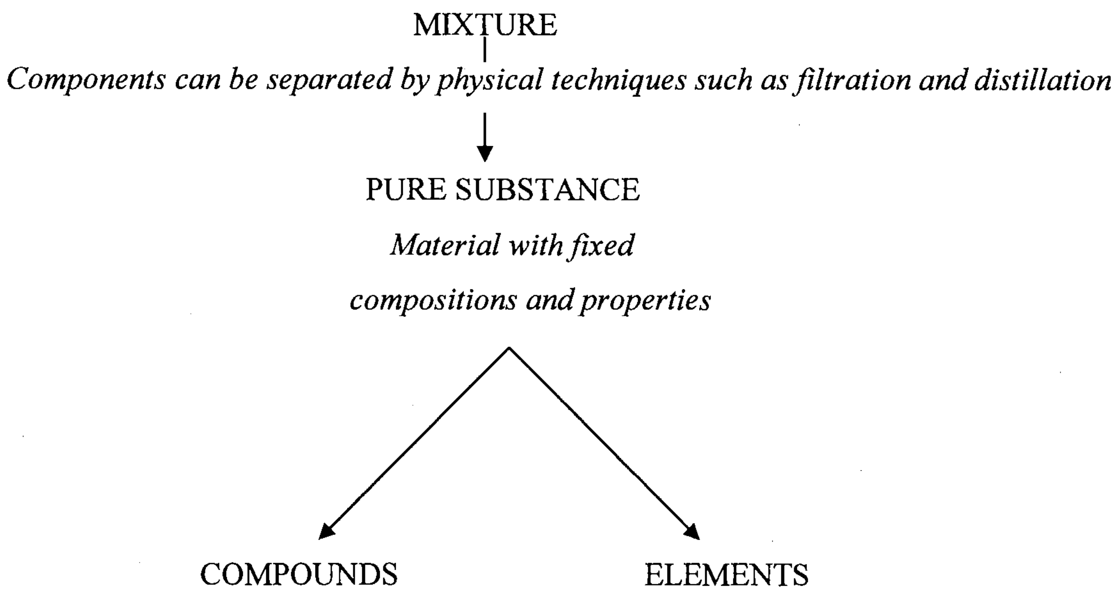


Figure 2.4: Representation of the relation between a mixture and its components (Thickett, 1992:10)

2.3.9 Summary of the constituents of matter

Matter consists of elements, compounds and mixtures. Elements are substances that cannot be broken down into other substances. Elements are made up of like atoms that are the smallest units of a substance that carries the characteristics of the substance. Compounds are substances that can be broken down into other substances (elements and compounds). Atoms found in a compound are unlike, since they are from different elements. Compounds are made up of atoms of different elements that are united by chemical bonding. Mixtures are made up of two or more elements or compounds without any chemical bonds between the different substances. According to Pozo (2001:366-367), mixtures are heterogeneous if one can distinguish between their components by sight, and homogeneous if more than one component cannot be distinguished by inspection.

According to Tsaparlis (1997:922), the union of atoms results in the synthesis of all substances, while their breaking results in the disintegration of the substance. This discussion of the relationship between the constituents of matter is important and fundamental in characterising and comparing the different states of matter. It is an important basic for the explanation of the physical and chemical changes of matter, since it forms the theoretical framework of these changes. The flow diagram (Figure 2.5) summarises the relationship between components of matter from the macroscopic to the microscopic level (Pozo, 2001:361).

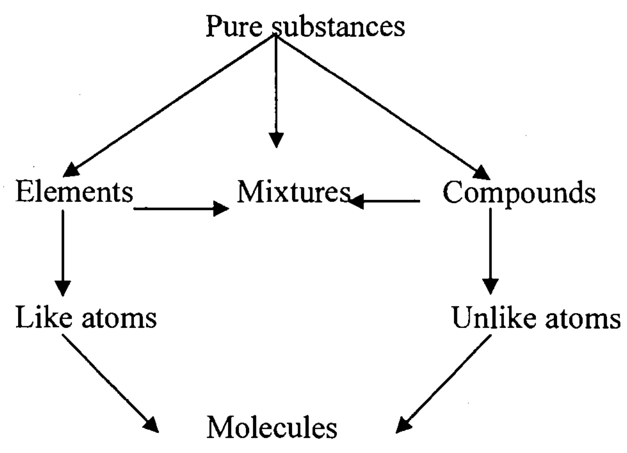


Figure 2.5: Representation of relationship between constituents of matter (Pozo, 2001:361)

In the light of what was dealt with in this discussion, a description of the macroscopic states of matter and phase changes is given in the next paragraph.

2.4 STATES OF MATTER

On the macroscopic scale matter can be classified into five main groups, namely solids, liquids, gases, plasmas and the Bose-Einstein condensate. These are usually called the states of matter. Matter in all phases consists of small particles with spaces between the particles. The particles are in continuous movement, and repulsive and attractive forces exist between the particles. What are the primary distinctions between these states of matter? Swartz. (1989:20) describes the three most common states of matter as follows:

- A solid has a definite shape and volume and is practically incompressible.
- A liquid maintains its volume but assumes the shape of its container, i.e., a liquid flows easily and its form depends on that of the container.
- A gas has the fixed volume and shape of whatever contains it, in other words; it has neither a definite shape nor volume; it completely fills its container. A gas is much lighter than the same volume of its solid or liquid. The density of a gas is less than that of the same mass of the substance in the solid or liquid states.

According to Cutnel and Johnson (1995:1020) plasmas are usually formed at high temperatures like that in the sun or in stars. A plasma has unique properties. For the purpose of this study that focuses on Grade 11 science, plasmas are not important. No further attention will be given to this state of matter in this dissertation.

At very low temperatures (about 3nK) the kinetic movement of atoms is very slow (about 1cm/s). At this temperature the De Broglie wavelength ($\lambda = h/p$, h = Plank's constant, p = momentum of atom), is larger than the atomic diameter and matter can go into a fifth distinctive state, called the Bose-Einstein Condensate (BEC). All atoms in a BEC are in the same quantum state. This state of matter was predicted by Einstein in 1924 and was first produced in 1996 by Prof. C Wiemann at Colorado University at Boulder in the United States of America (SAIP conference, 2003, Stellenbosch).

A substance may occur in the solid, liquid, gas, plasma or Bose-Einstein condensate phases, depending on the temperature and pressure. Taking water as an example, it is most familiar to us in the liquid form. Water can be a solid (ice), liquid (water) and a gas (water vapour or steam). What is true of water is true of other substances. Strictly speaking then, it is not accurate to call a substance a solid, liquid, or a gas because most substances can be found in one or another of the states of matter under certain conditions. However, most substances are solids, or liquids, or gases at room temperature and atmospheric pressure and we refer to them as such. Thus we call iron, for example, a solid, even though it will melt and become a liquid at a temperature of 1,535 ^{0}C. Carbon dioxide is called a gas, even though it can be transformed into a solid called dry ice at a pressure of 150 kPa at 0 °C (Roos, 1989:12). The discussions in paragraphs 2.4 - 2.5 are based on components of the particle model of matter that are of relevance to the school curriculum.

2.4.1 Particle model of matter

The particle model of matter pictures all substances as composed of very tiny particles called atoms and molecules. These particles are pictured to be small spheres, completely elastic during collisions and ever in motion. Between these particles are empty spaces. When energy is added to any system of particles the average velocity of the particles increases. In solids the particles only vibrate around a fixed position, in liquids they move around through the body of th liquid, but stay relative near to each other, due to small attractive forces. In gasses the average velocity is higher than in liquids and the particles only exert forces on each other when two collide (Moodie *et al.*, 2000:156).

2.4.2. Solids

Solids include materials that compose such things as a desk, a book, ice and most of the objects around us. These things occupy space and their masses can be measured. The volume and shape of a solid cannot be easily changed (Standard & Williamson, 1992:3).

Most of the physical properties of solids, such as hardness, tensile strength, brittleness and elasticity, depend on the type and arrangement of the tiny particles of which solids are composed of. The particle model of matter describes a solid as consisting of a large number of very small particles packed closely together in an orderly pattern. Particles in a solid are close together and each one vibrates around a fixed position. The forces acting between atoms in solids are such that atoms resist having their average distance from each other changed. They resist any change in the shape of the solid of which they form part. The result is that large forces are required to change the shape or volume of a solid (Roos, 1989:26).

Solids are divided into two classes, on the basis of their internal structure. Most solids are composed of small crystals and are called crystalline substances. In crystals the atoms are arranged in an orderly manner in units that are repeated regularly throughout the crystal. The simplest crystal form has a cubical pattern. The atoms are situated at the corner of the cubes, which are repeated throughout the crystal, as shown in Figure 2.4.

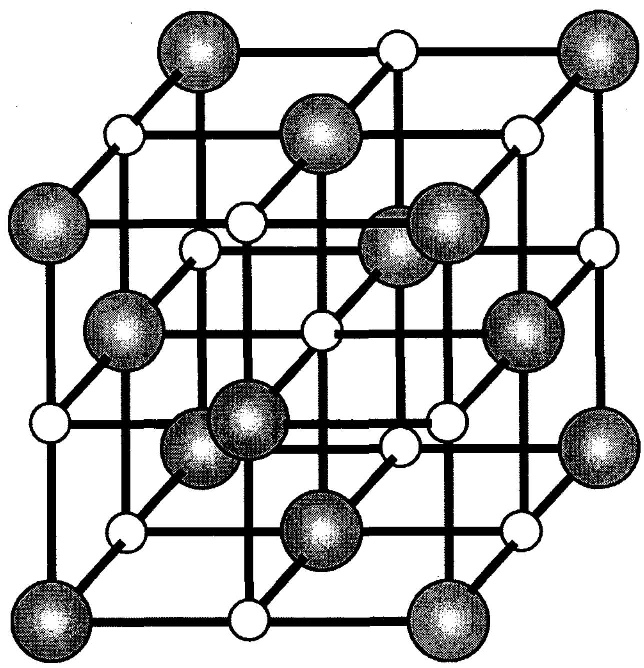


Figure 2.6: Arrangements of atoms in a cubical crystal

Substances that are not crystalline are amorphous (no fixed shape)for example plastic. Amorphous substances (solids) do not have a definite melting temperature. When these substances are heated, the heat is conducted through the solid. The higher temperature causes the atoms to spread further apart and to vibrate with larger amplitudes. When a solid substance is heated, it softens until it flows sluggishly, for example, waxes and glass. Crystalline substances, however, melt at a definite temperature: example, NaCl (Roos, 1989:26).

2.4.3. Liquids

Liquids include substances such as water, milk, oil, alcohol etc. that is known to flow at room temperature. The volume of a quantity of liquid does not change, but its shape does, e.g., if milk is spilt from a cup it takes another shape (Standard and Williamson, 1992:3).

According to the particle model liquids are composed of particles. The particle model describes a liquid as a large number of very small particles further apart than that of a solid. The particles in a liquid glide over each other and collide. The movement is disorderly. Neighbouring particles attract each other within a liquid. These forces operate at a very short range, so that only particles in the immediate vicinity of a given particle exert an appreciable force on that particle. A particle that is not near the surface of the liquid but in the body of the liquid is completely surrounded by other particles. Its neighbours equally attract it in all directions, and the resultant pull in any direction is zero. However, a particle at a liquid's surface does not have any particles above it and consequently experiences a resultant attractive force downwards. As a result of this inward directed force liquids act as though it is covered with a tightly stretched elastic membrane (Roos, 1989:22-23). This force can be measured and is called the surface tension. The surface tensions of different liquids are different.

2.4.4. Gases

The air around us is a mixture of gases composed mainly of nitrogen and oxygen. All gases occupy space and have mass. Other gases present in the atmosphere are hydrogen and carbon dioxide. Gases do not have a fixed shape or volume. A gas fills its container, no matter what the shape or size of the container is. Take an example of gas in a gas cylinder stove. If the gas is let out it can fill a balloon or various shapes of containers. If you leave a gas tap open, the gas will escape and spread out into the air. Gases can also be squeezed into a small volume (compressed). This cannot be done with liquids and most solids (Standard & Williamson, 1992:3).

To illustrate what happens in a gas, consider the experiment described below. Compress a gas in a cylinder with a piston that can be pushed or pulled up or down. In A (Figure 2.7) the piston is stationary in the cylinder. Note the density of the gas particles. In B the gas is compressed by moving the piston down. In C the piston is lifted. Note the difference in the density of the particles.

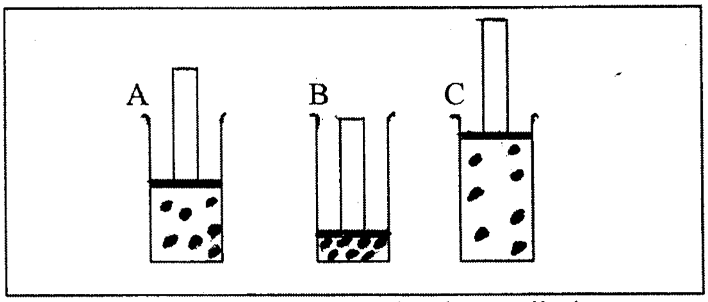


Figure 2.7: A gas at various stages of compression in a cylinder

The kinetic model describes a gas as consisting of a large number of very small particles in continuous disorderly movement. There are large spaces between the particles and no forces of attraction between them. The particles are in continuous, random and rapid motion. The particles continuously collide and exert forces on each other during collisions. This model accounts for the phenomenon of diffusion of gases into one another, the high compressibility of a gas and why a gas exerts pressure on the walls of its container. Table 2.2 summarises the properties of the three states of matter encountered at school level.

Table 2.2: Summary on properties of the states of matter

States of Matter	Properties				
	Can be weighed	Occupy space	Fixed shape	Fixed volume	Can be compressed
Solids	√	√	√	√	X
Liquids	√	√	X	√	X
Gases	√	√	X	X	√

The particle model of matter and the kinetic molecular theory explain phase changes in terms of the rearrangement of particles, the absorption, and the release of energy.

2.5. Kinetic theory of matter

The kinetic molecular theory of matter applied to the particle model of matter helps to understand the physical properties of solids, liquids and gases. According to this theory, as stated by Kotz and Treichel (1996:18), all matter consists of extremely tiny invisible moving particles (atoms and molecules) that are in constant motion. There are spaces between the particles. Forces of attraction exist between the particles when they are relatively far apart, while forces of repulsion act between them when they are relatively close together. The small particles move faster than heavier ones at a given temperature. As the temperature rises, the particles move faster. If heat is transferred to a substance, the average kinetic energy of the particles increases, causing a rise in temperature. The temperature of the substance is therefore a measure of the average kinetic energy of its particles (Heyns *et al*, 1994:153).

In solids the particles are close to one another and only vibrate around a fixed position. According to Kotz and Treichel (1996:18-19), particles in a solid are closely packed in a regular array. Kotz and Treichel (1996: 18-19) further state that the particles vibrate back, forth, up and down around their average positions. A particle in a solid seldom squeezes past its immediate neighbours to come into contact with a new set of particles. Because the particles are packed so tightly and in such a regular arrangement, a solid is rigid and its volume is fixed. The external shape of a solid often reflects the internal arrangement of its particles (Kotz & Treichel, 1996:18-19).

Kotz and Treichel (1996:18-19) state that the kinetic molecular theory of matter can also be used to interpret the properties of liquids and gases. Liquids and gases are fluids because the particles are in random motion, rather than arranged in a regular pattern as in solids. In the liquid state, the particles are further apart than in a solid and therefore a liquid's volume is a little more than when the substance is in the solid state. The particles move rapidly and randomly and glide over another one in a liquid. No particle goes far without bumping into another. The particles in a liquid collide with one another constantly. In gases, the particles are relative far apart in comparison with the spacing of particles in solids and liquids. Gas particles have enough kinetic energy to overcome the forces of attraction between them almost completely. The particles fly around to fill any container they are in, and so a gas has no fixed shape or volume. Evidence of moving particles in gases and liquids comes from diffusion and Brownian motion. Brownian motion is noticed when smoke particles in a smoke cell are viewed under a microscope (Hill *et al.*, 1980:573)

Roos (1989:13) states that the kinetic theory offers an explanation for many phenomena that were once thought to be mysterious. According to this theory, the particles of a gas are continuously colliding against one another and also against the walls of the container. Think of billiard balls on a billiard table, kept constantly in motion. Each ball will move in a straight line until it hits another ball or the sides of the table. After such a collision, it will bounce off and move in a new direction, often at a different speed. The gas particles follow much the same sort of chaotic pattern, except that they move in a three-dimensional space and not in a two-dimensional one such as a table surface. By using a microscope, we can observe individual smoke particles in a gas dancing continuously around in a chaotic way. This perpetual dance is called Brownian motion (Roos, 1989:11-12). Three factors affect the motion of the particles of matter. These factors are temperature, pressure and volume.

2.5.1 Effect of temperature on movements of particles in a substance

One further aspect of the kinetic molecular theory according to Kotz and Treichel (1996:20) is that the higher the temperature, the faster the particle moves. The energy of motion that the particles possess (kinetic energy) acts to overcome the forces of attraction between the particles. A solid can therefore melt to form a liquid when the temperature of the solid is raised to the point where the particles vibrate fast enough and far enough to push each other out of the way and move out of their regular spaced position. As the temperature goes higher, the particles move faster until they can finally escape the clutches of their comrades and became independent. The substance then turns into a gas. Increases in temperature correspond to faster motions of atoms and molecules (Kotz & Treichel, 1996:20).

The rate at which the particles move depends on the degree of hotness (temperature) of a given substance. As a matter of fact, heat is simply the kinetic energy or energy of motion of the particles of a substance. If there is a little heat in a given quantity of a gas, the motion of the particles is slow. If more heat is supplied, the particles will move more rapidly. When a gas is heated the particles will strike the walls of the container more often and with a greater force. The rate of movement of the particles in a gas gradually diminishes as the temperature drops. When the temperature reaches approximately –273 degrees Celsius, the motion of the particles stops and there is no longer any heat present in the substance. This point is known as the absolute zero of temperature (Roos, 1989:12). It is at these temperatures near absolute zero that a BEC forms.

2.5.2 Effect of pressure on the movement of particles in a substance

If pressing a piston down increases the pressure on the gas in a container as shown in Figure 2.7 of this chapter, the person pushing the piston performs work on the gas. Energy is transferred to the gas. This energy manifests in an increase in the kinetic energy of the gas particles. The kinetic energy of a particle of mass m, moving at speed v, is $\frac{1}{2}mv^2$. This means that the particles move faster after pressure has been exerted on the gas. The result is an increase in the gas temperature. The effect of pressure on solids and liquids are similar, though less noticeable than in the case of a gas.

2.5.3 Effect of volume on the movements of particles in a substance

Throughout all changes of temperature and pressure the number of moles of a gas within a sealed container will remain the same. Despite all changes there will be the same number of particles in the container. If the size of the container is reduced by half, the particles would still find space within the reduced space. Even if the temperature is kept constant, a particle will collide more often with other particles and the walls of the container. If on the other hand the size of the container is doubled, the particles will spread throughout the added space and collide less often with the walls and other particles. At the same temperature, particles thus exert less pressure because of the increase in volume (Roos, 1989:13).

2.5.4 Summary of kinetic model

Particles of a gas exercise continuous pressure on the walls of the container. The pressure depends on the temperature and volume of the gas. The volume of the gas can be increased or decreased without affecting the number of the particles in the container. The kinetic theory gives a picture of how particles behave when changing from one state of matter to another.

2.6 PROCESSES AT WORK WHEN MATTER CHANGES STATE (THICKETT, 1992:8-9)

For the understanding of phase changes we first need to understand the following processes.

2.6.1 Melting

Melting is the change of state of a substance from a solid to a liquid. The melting point is the temperature at which the solid changes to a liquid at the same temperature. The melting point of a substance not only depends on the type of substance, but also on the external pressure exerted on the substance and the impurities in the solid. At the melting point the solid absorbs heat, without change in temperature (Thickett, 1992:8-9).

2.6.2 Freezing

Freezing is the change of state from a liquid to a solid. Melting is the opposite of freezing. Therefore, the melting point of a substance is the same as its freezing point and depends on the same factors. The quantity of impurity in a substance influences the melting/freezing point. If, for example sodium chloride (considered to be the impurity) is added to water, its freezing point is lowered. When freezing, the substance releases heat, while the temperature stays constant (Thickett, 1992:8-9).

2.6.3 Boiling

Boiling is the process in which a liquid is converted to vapour at its boiling point. The boiling point of a liquid is the temperature at which the vapour pressure of a liquid is equal to the external atmospheric pressure. When a liquid changes at its boiling point to the gas phase, there is always a large increase in volume. Water, for example, increases in volume about 1 700 times when changing into vapour at atmospheric pressure. At the boiling point a liquid absorbs energy, while its temperature remains constant (Thickett, 1992:8-9).

2.6.4 Evaporation

Evaporation is the change of state from a liquid to a vapour at temperatures below the boiling point of the liquid. It is a gradual change of state from a liquid to a gas that occurs at the liquid surface. Evaporation really means, "vapour-making" or "gas-making". When a liquid evaporates, it usually cools down (Thickett, 1992:8-9).

2.6.5 Condensation

Condensation is the process in which a vapour is converted to its liquid. Condensation is the opposite of evaporation. Heat is given of at condensation (Thickett, 1992:8-9).

2.6.6 Sublimation

Sublimation is the change in state from a solid to a gas, without going through the liquid state. At the sublimation point a solid absorbs heat (Thickett, 1992:8-9).

2.7 Phase change

For the purpose of teaching at secondary school level, matter is classified into three phases: solids, liquids and gases. Heyns *et al.* (1994:155) state that matter can undergo a phase change, which occurs as a result of absorption or liberation of heat. Each change in state occurs at a particular temperature, which is commonly known as the melting point, boiling point, or freezing point. Heating causes a solid to change to a liquid and then to a gas. Cooling causes the reverse changes. These changes are called physical changes. According to the Microsoft Encarta Encyclopaedia (2000), a physical change is a change in matter that involves no chemical reaction. When substances undergo physical changes, the composition of its particles remains unchanged, and the substance does not lose its chemical identity. Melting, freezing, evaporation and sublimation are types of physical changes. This includes any alteration in shape and size of a substance.

As stated in paragraph 2.4, water can occur in the solid, liquid or gas phases. It is commonly referred to as the solid (ice), liquid and vapour phases. Phase changes can only occur if we heat or cool water. Ice (solid) changes to water (liquid) when it is heated. This change is called melting. A thermometer shows 0 ^{0}C until all the ice has melted, so 0 ^{0}C is called the melting point of ice. When water is heated, its temperature rises, and it changes to water vapour (gas). This change is called evaporation. As water gets hot, the rate of evaporation increases until it boils. At the boiling point, vapour is formed. This happens at 100 ^{0}C at normal pressure (100 kPa) and this temperature is called the boiling point of water. This process is called a phase change (Gallagher & Ingram, 1984:8-9). A vapour forms when a liquid is heated and the rate at which the vapour forms increases until it boils.

Cooling reverses this whole process. If vapour is cooled, it changes to the liquid form. This change is called condensation. If the same liquid is cooled further, it changes to the solid state. This process is called freezing. Condensation is the opposite process of evaporation and freezing the opposite process of melting. The freezing point of water is the same as the melting point of ice (Gallagher & Ingram, 1986:8-9). Teachers are advised not to let learners think substances can exist only in the states they observe at room temperature and atmospheric pressure. For example, learners think that lead (Pb) can only exist in the solid state because they always see it as such. Lead can melt and can even boil and evaporate to form lead vapour. The melting and boiling points of a few substances are given Table 2.3.

Table 2.3: Melting and boiling points of substances

SUBSTANCE	MELTING POINT (^{0}C)	BOILING POINT(^{0}C)
Oxygen	-219	-183
Ethanol	-15	78
Sodium	98	890
Sulphur	119	445
Iron	1540	2900
Diamond	3550	4832

No two substances have the same melting or boiling points. The melting point and boiling point of a substance changes even if a tiny amount of another substance is mixed with it. The melting and boiling points can be used to identify a substance and can be used to tell whether a substance is pure or not. Gallagher and Ingram (1986:9) mention the example of sea water that freezes at about –2 ^{0}C and boils at about 101 ^{0}C. Sea water contains impurities, mainly salts. A few substances can change directly from the solid to the gas phase; this process is called sublimation. Figure 2.8 represents the processes of phase changes.

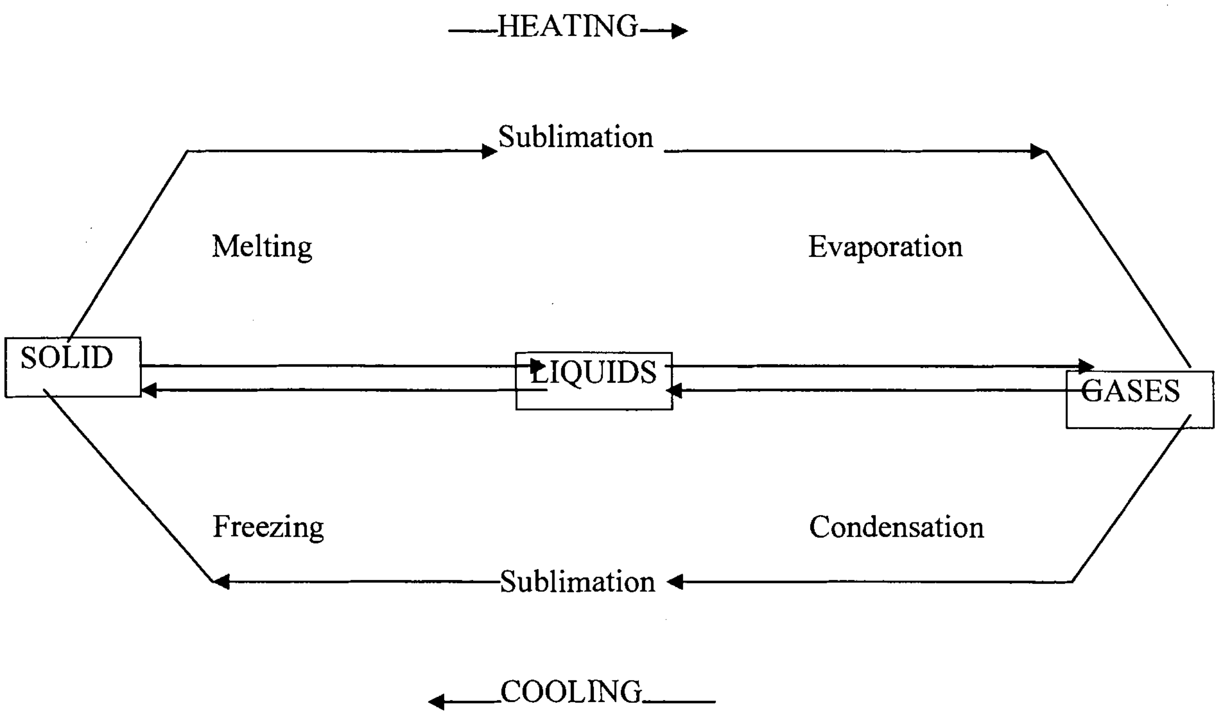


Figure 2.8: Diagrammatic representation of phase changes (Thickett, 1992:16)

The next discussion is about the explanation of phase changes based on the kinetic theory of matter.

2.7.1 Solids to liquids (melting)

If we raise the temperature of a crystalline solid, the vibration of its particles, atoms or ions becomes energetic enough to overcome forces between the fixed atoms. When the atoms move away from their fixed positions, the structure of the crystal is destroyed in for example a crystalline solid. The atoms or ions are freed from their rigidly set places in the crystal lattice, and then start to move around freely. At melting point, the temperature of the substance remains unchanged. When the temperature rises above melting point a solid changes into a liquid state. Melting points of solids vary widely, e.g., that of ice is 0 ^{0}C, lead 327, 4 ^{0}C and silver 1,535 ^{0}C. The melting point of any solid is the freezing point of its liquid (Roos, 1989:19). Figure 2.9 illustrates a phase change from a solid to a liquid.

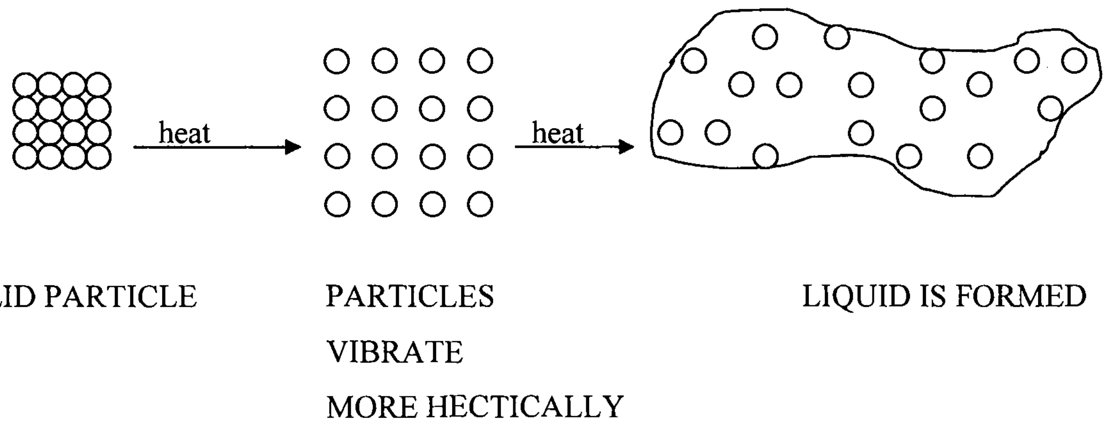


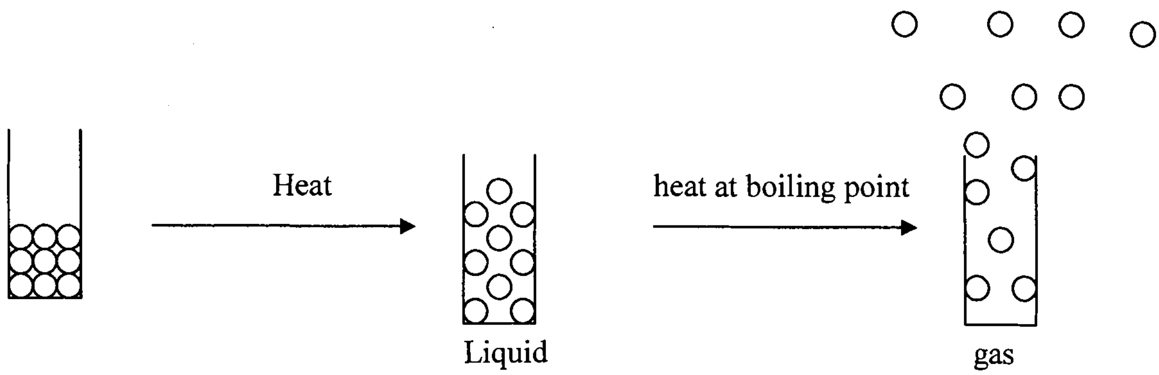
Figure 2.9: Illustration of the phase change from a solid to a liquid

2.7.2 Liquids to gases (evaporation)

It is a common fact that when damp clothes are hung on a line in the open air, the clothes gradually become dry. It is known too that if a bowl of water is left in a room, the level of the water in the bowl gradually lowers and in time the water disappears entirely. In both cases evaporation has taken place. When a liquid evaporates, its particles escape from the liquid surface and make their way into the open air. In other words, the moisture of the wet clothes and the liquid in the bowl of water has turned into the invisible and odourless gas called water vapour (Roos, 1989:15-16).

The kinetic theory explains how evaporation takes place. We know that all particles have a certain amount of heat, or kinetic energy, or energy of motion, except at the absolute zero. Particles of a liquid do not all have the same amount of kinetic energy at a given moment and therefore are not all travelling at the same speed. Some of the faster moving particles will break away from the attraction of the slower particles at the surface and will escape into the open space above the surface. This is the process of evaporation. As the temperature of a liquid is raised, the rate of evaporation is increased. The reason is that the average kinetic energy of the particles becomes higher and the rate at which particles breaks away from each other increases. Different liquids have different rates of evaporation because the forces of attraction between the particles are not the same in all liquids, e.g., ether and water have different forces of attraction between their particles (Roos, 1989:15-16). Evaporation is a process where a substance changes from the liquid to the gas phase from the surface of the liquid. When a gas changes to a liquid (that is, the opposite of evaporation) the process is called condensation. Figure 2.10 illustrate this phase change.

Figure 2.10: Illustration of phase change from liquid to gas state



2.7.3. Solids to gases (sublimation)

Substances can change from solids to gases without the formation of a liquid. This process is called sublimation. The opposite process when a gas changes directly to a solid is also named sublimation. In general, crystals whose units are molecules sublime most readily (Roos, 1989:19). An example of a substance undergoing sublimation is dry ice (solid carbon dioxide). It has a high rate of sublimation at room temperature and atmospheric pressure. Iodine is another substance that sublimates when heated. When heated, its particles get enough energy to break away from the solid and a gas forms. Even ice in a refrigerator sublimes! Ice cubes become hollow and sometimes disappear when left for a long time in a refrigerator. Figure 2.11 illustrates sublimation.

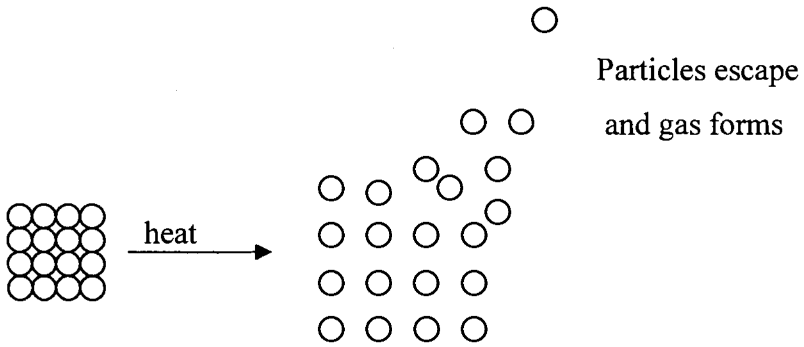


Figure 2.11: Illustration of sublimation

2.1 CONCLUSION

In this chapter an overview of the constituents of matter, the states of matter and phase changes were given. An explanation of phase changes was given in terms of the kinetic theory. It is expected that for learners to understand the states of matter and phase changes, they need to understand the particle nature of matter and how the particles behave according to the kinetic theory of matter. Learners who do not understand the kinetic theory will find it difficult to understand states of matter and phase changes.

The next chapter reports on a literature study of learners' alternative conceptions about the particle nature of matter, states of matter and phase changes.

CHAPTER 3

LITERATURE REVIEW: ALTERNATIVE CONCEPTIONS ABOUT THE STATES OF MATTER AND PHASE CHANGES

3.1 INTRODUCTION

An aim of this research was to study the knowledge that learners possess regarding the states of matter and phase changes (See Chapter 1, paragraph 1.4). Research findings show that learners spontaneously develop general ideas about matter prior to instruction. A number of studies have demonstrated that learners, prior to teaching, have specific intuitive conceptions or ideas that are different from the accepted scientific concepts. Although teaching these conceptions do change learners' perceptions towards the accepted scientific ones, it is often only to a very small extent (Stavy, 1988:553).

Matter is one of the important topics in physical science where many alternative conceptions are identified (Du Toit *et al,* 1991:49). A number of researchers refer to alternative conceptions based on states of matter and phase changes and outline the problems these conceptions have caused in the learning of science (Stavy, 1988:554). Remedial strategies to address these problems were attended to. This chapter deals with learners' alternative conceptions with specific reference to the states of matter and phase changes.

Research on alternative conceptions about matter, phase changes and the sub-microscopic building blocks of matter has several important implications for science teaching: It provides educators with comprehensive descriptions of learners' beliefs about these topics. It also helps to identify specific beliefs that learners have about matter and helps to understand how these beliefs are organised. For example, research helps us to identify whether learners have internally consistent beliefs about the domain of matter and the explanatory scope and power of their belief systems. By providing descriptions of the content, quality and organisational properties of learners' conceptual frameworks, research can help us to identify potential barriers and opportunities for helping learners to acquire the scientific framework for the domain. Disessa, as stated by Nakhleh and Samarapungavan (1999:778), describes novice knowledge and naïve ideas as a weakly organised system of beliefs that is internally inconsistent, unstable over time and problem-context, and infinitely malleable in the phase of anomalous evidence.

According to Anderson (1990:12-13), a fair number of studies have been devoted to the area of matter. This empirical study tries to find more general characteristics of learners' everyday thinking related to the states of matter and phase changes. It attempts to probe the essence of learners' everyday thinking so that efforts to improve their understanding of the states of matter and phase changes can be made.

The discussion begins with a description of learners' thinking about matter, how they perceive states of matter, and how they explain changes of states. The discussion will include a description of what happens when learners take their first step into the world of atoms and molecules. In the last part of the discussion specific educational implications of the research findings are discussed. This attempts to indicate ways to improve learners' understanding and includes proposals of interventional strategies to remove learners' conceptions. As the purpose of this study is to probe into learners' understanding of states of matter and phase changes, it will also inquire into learners' visualisation of models of the states of matter and phase changes, and the purpose and importance of understanding this from the microscopic point of view. Wesi (1997:46) states that alternative conceptions are well known for their resistance to instruction.

The alternative conceptions of learners discussed in this chapter are identified from a literature survey. Paragraph 3.2.1 deals with alternative conceptions, with specific reference to the particle nature of matter and the kinetic theory. Paragraph 3.2.2 deals with alternative conceptions about the states of matter, while 3.2.3 deals with alternative conceptions with reference to phase changes.

3.2 ALTERNATIVE CONCEPTIONS

3.2.1 Alternative conceptions about the particle nature of matter

One of the instructional goals of most junior high school science curricula is the understanding of the particle model of matter. For modern science, the fundamental notion is that all matter is constituted by particles. This notion is of primary importance for understanding changes of matter (Nussbaum, 1989:13). Learners' understanding of the particle nature of matter will be reviewed in this paragraph. Another purpose of this paragraph is to investigate the extent to which learners are able to apply the particle model in explaining simple phenomena associated with the different states of matter.

According to Nussbaum (1989:13), the aspects of the particle theory that were least assimilated by the learners were those that are in conflict with their prior conceptions about the nature of matter. These are: empty spaces, particle kinetics and interaction between particles during transformation. This literature review has attempted to ascertain how learners' conceptions change as they are progressively exposed to additional relevant information about the states of matter and phase changes in the higher grades at school.

The literature review has tried to offer a brief overview of knowledge about the kinetic theory of matter. The literature review serves to contextualise the hypothesis: *Grade 11 learners studying physical science have alternative conceptions about the states of matter and phase changes*. It will highlight alternative conceptions about this topic as identified in research conducted elsewhere in the world.

The study of Nakhleh and Samarapungavan (1999:779) of secondary learners' understanding of matter conducted at an urban elementary school in Indiana in 1994, expresses the opinion that the type of understanding present in their focus group was purely on the macroscopic level. This level dealt with bulk, observable properties and did not extend to further understanding of the composition or processes on microscopic scale. The study reported in this dissertation will also focus on similar problems as those addressed by Nakhleh and Samarapungavan (1999:779), where learners were unable to link the macro-properties and micro-properties of matter. The analysis is based on the concepts describing the composition of matter.

According to Nakhleh and Samarapungavan (1999:779-778), learners appear to have descriptive rather than explanatory beliefs related to many observable properties of matter, e.g., when asked why copper wire bends and wood does not, learners typically say that this happens because wire is bendable and wood is not. This sub-paragraph on the nature of matter focuses on assisting learners to make the transition from thinking about matter purely in terms of observable macroscopic properties to thinking about matter as being composed of microscopic particles with properties and ways of behaving that differ from the macroscopic, observable properties and phenomena (Nakhleh & Samarapungavan 1999:779-778).

Atoms and molecules are familiar terms to the learners, centred on the idea of a small thing or part that makes up matter. Almost no reference is made to the arrangement and structure of the particles composing matter (Pozo, 2001:354). Pozo (2001:353) further states that the possible cause of these alternative conceptions is the influence of perception, especially in passing from macro- to micro-properties. For example: what happens to the particles inside matter when changing from one state to the other? Or: what happens to these particles' structure and arrangement in the different states? The possible causes of these alternative conceptions are the abstract characteristics of the microscopic concept and their close interrelationships (Pozo, 2001:354).

The conceptions of atoms and molecules of school and university learners have been studied and analysed thoroughly. According to Kgwadi (2001:90), an introduction of the atomic concepts should be a model that describes matter as consisting of a large number of separate individual and invisible particles. No mention should be made of the nature and composition of these particles at the introductory phase of teaching. Phund, as stated by Anderson (1990:23), systematically investigated the extent to which learners spontaneously imagine matter as consisting of building blocks that are there all the time, in contrast to particles that appear temporarily, especially during transitions. Phund (Anderson, 1990:23) further noted that learners when interviewed showed that they did not understand the concepts of atoms and molecules. Only a few of them conceptualised matter as consisting of primary invisible building blocks. Learners have, in various connections, drawn, described and discussed systems of many particles. This was seen as evidence of a conflict between everyday and scientific reasoning. Learners have been taught at school that there are atoms and molecules in objects but, nevertheless, they do not abandon their everyday reasoning about phenomena and processes. The material status of atoms and molecules is unclear to learners. Learners do not have any conscious models that they attempt to develop in interplay with observations (Anderson, 1990:23).

Educators do not maintain a clear distinction between substances and atoms/molecules. Assume for example, that a chemistry educator says that water consists of hydrogen and oxygen atoms. Learners who use their own personal concepts can easily take the statement to mean that water is a mixture of two different substances, hydrogen and oxygen. Macroscopically seen, it is wrong, water is water and nothing else. It has neither the properties of hydrogen nor oxygen, but is a unique substance. A problem is that learners only see symbols but are unable to visualise the sub-microscopic structures represented by the symbols. An analysis based on recent research demonstrates that there is room for improvements in teaching practices related to illustrations, language and the model-observation relationship (Anderson, 1990:28).

According to Stavy (1988:559), learners' knowledge and understanding of the particle theory of matter is fragmented. Stavy (1988:559) says that learners apply the particle theory in some situations but not in all. For example, they apply the particle theory to explain the term gas but not to explain the terms solids and liquids. It seems that it is easier to accept formal theoretical explanations in cases when they are not counter to pre-existing intuitive ideas. Stavy (1988:559) is of opinion that since learners accept the particle theory mainly with respect to gases and not with respect to solids and liquids, it is advisable to confront them with this contradiction. This will help them to treat the processes of change of states from gases to liquids, and vice versa, in terms of the identity of the substance, conservation of mass, identity of particles and conservation of the number of particles (Stavy, 1988:559-560).

Teaching should follow the natural sequence and pace of learners learning. According to Stavy (1988:560) it was found that when learning about the gas state, learners first acquire knowledge about the substantial nature of a gas, and then develop the general idea of gases as a form of matter. Only in the last stage they acquire knowledge of the particle theory of matter. It seems logical to follow this sequence, as is often the case, but usually not enough to allow ideas to be incorporated and understood. Since learners react differently to essentially identical tasks across different contexts, one should try to present learners with as many contexts as possible and emphasise the form and essence of the tasks or problems (Stavy, 1988:560).

Novick and Nussbaum, as stated by Stavy (1988:554), investigated the extent to which learners were able to apply aspects of the particle model in explaining simple physical phenomena. Their findings indicated that a significant proportion of the focus group failed to understand important aspects of the particle model. These aspects were empty spaces between particles, motion, and interaction between particles (Stavy, 1988:554). In view of these findings, the purpose of the study reported in this dissertation was to ascertain how knowledge about the states of matter and phase changes is developed by Grade 11 physical science learners.

The paragraph on states of matter and phase changes focused on learners' knowledge acquisition processes. It outlines learners' spontaneous constructed or naïve ideas about the nature of matter. This will form the basis of our empirical research on knowledge acquisition by learners about the states of matter and phase changes.

3.2.2 Alternative conceptions about the states of matter

Learners need to understand the states of matter and must be able to classify them. According to Ryan (1990:181-182), learners are unable to classify substances that are used every day into solids, liquids or gases. Examples are dough, lipstick, sugar and salts. According to Ryan learners' alternative conceptions about the states are revealed in their inability to classify substances correctly as solids, liquids or gasses. The descriptions of substances' and their behaviour in different states are scientifically unacceptable.

Ryan (1990:175-177) states that with regard to powders, learners did not necessarily recognise that powders, including many chemicals from the laboratory, belong to the class of solids. Not all learners spontaneously incorporate powders within the solids class. Stavy, as stated by Fensham (1994:125), says powders are problematic to learners at all ages. Powders are materials that take on the shape of their container, such as liquids. Learners therefore have a tendency to include them under liquids. Stavy (Fensham, 1994:125) states that it seems that the finer its grains, the less likely powders are to be classified as solids (Fensham, 1994:125). The microscopic view that describes the behaviour and structure of materials in terms of their properties can deal readily with the ill-defined materials in terms of bulk properties. The particle theory of matter gives a clear definition of the states of matter relating to order, mobility and temperature dependence. Water is a good example of a substance since it can easily be identified in the solid, liquid and gaseous states, since it clearly shows the temperature dependence of the different phases at temperatures easily obtainable in everyday life. Ryan (1990:177) states that in one of her discussions with learners, one learner was able to use the aspect of a temperature-dependent model to explain the effect of temperature on a lipstick. "Yes, lipstick is an example of a solid, for instance, if it is a very hot day, it would change its state and be much more liquid." Remarked the learner. This learner was able to relate the states of matter and temperature to her everyday experience. Ryan used such examples to broaden learners' view of what a solid is. Learners' own views were used as starting points in discussions about matter. Ryan started at this point and converted it to the scientific view (Ryan, 1990:171-182).

The research reported by Anderson deals with learners' conceptions of a gas. According to Anderson (1990:32), studies about the gaseous state clearly demonstrate that the majority of learners find it difficult to understand that a gas is a material in nature and weighs something; that there are different gases with different properties, and that air is a mixture of gases. The majority of studies concerned with the gaseous state involve air. Anderson (1990:21) states that learners at secondary school level seldom regard air as an example of a gas and consider it to be two different things/ideas. They do not know that air is a mixture of different gases (e.g. air contains oxygen, which is an example of a gas). They also do not understand that since a gas can be changed to a liquid (condensation) and to a solid (freezing), air can also undergo such processes. Learners also have the alternative conceptions that air does not have weight and that a gas is lighter than the same material in its liquid or solid states. This proves that they do not consider air as matter (Anderson, 1990:21). As part of this investigation, an experiment on the weight of a gas was conducted in class.

Stavy (1995:223) states that when learners are asked what a liquid is, they explain it as something that pours or something that resembles water. Stavy (1995:223) is of the opinion that representing a liquid as something that pours may cause over-generalisation. This representation would include substances that can be poured that are not liquids, such as powders. Representing a liquid as something watery may also cause under-generalisation. In referring to all liquids as if they were water heavy oils are excluded. Stavy (1995:223) elaborates on the problem of generalisation and also states that the description by learners of solids as something hard causes conceptual difficulties. By describing a solid as something hard leads to the exclusion of sub-groups, such as non-rigid solids (elastic and plastic solids) and powders.

Another area from which examples of alternative onceptions might be drawn is the one about gases given by Stavy (1988:559). Stavy is of opinion that after learning about the states of matter and the particle theory of matter, learners first acquire knowledge about the nature of gases. They then refer to a gas as a form or state of matter and only thereafter do they apply the particle theory of matter in order to explain what a gas is. This study offers interesting and specific ideas about how this might be done in order for learners to understand.

Anderson (1990:27) states that through in his investigations and discussions it was revealed that learners have a wide range of concepts about the states of matter that require better definitions. This problem will also be attended to in this study.

3.2.3 Alternative conceptions about phase changes

This paragraph examines the literature on learners' conceptions of phase changes, from liquids to solid to gases, as well as their understanding of the reverse processes. The purpose of this paragraph is to unveil the mental images regarding matter and its properties held by learners in general.

Learners' patterns of reasoning help them to simplify the complexity of the world and frequently yield the correct solution. It usually does not demand too much effort. Unfortunately, common sense reasoning is also responsible for a great number of alternative conceptions about the behaviour of the natural world. For example: learners think that condensed water on the outside of the glass containing ice is the liquid that has filtered through the walls, others think of a glass as having a leak. These learners are looking for the most probable cause, so they draw a parallel, they make an analogy. They do not think of a phase change as taking place (Posner and Gertzog, 1982:195-209.)

Nakhleh and Samarapungavan (1999:783) state that for phenomena such as phase transitions (e.g. melting of ice cube), the causal models are rather shallow. They mention as example that learners say that a phase transition occurs when a substance gains or loses properties, such as heat or cold. However, learners cannot explain why such losses or gains in properties bring about changes in states (Nakhleh & Samarapungavan, 1999:777-805).

Stavy (1990:247) investigated the mental images formed by learners regarding the properties of matter, and the picture was characterised as follows:

a) Matter has no permanent aspect. When matter disappears from sight, it ceases to exist (e.g. sugar dissolving in water).

b) Matter can disappear, whereas its properties such as sweetness or smell can continue to exist completely independent of it.

c) Weight is not an intrinsic property of matter; the existence of weightless matter can be accepted.

d) A simple physical transformation is not grasped as reversible (Stavy, 1990:247).

For Stavy's investigations, she presented two practical experiments to learners: the change of states from liquid to an invisible gas (using acetone) and from a solid to a visible gas (using iodine). The learners were asked about the conservation of matter, its properties and weight changes during these transformations. Stavy (1990:256) found hat learners believe that when matter is invisible, it does not exist and that weight and other properties disappear in certain phase changes. Learners conceive matter as something concrete and solid. The purple gas of iodine that forms when it is sublimed from its crystals was not seen as matter, although the solid crystals before heating were perceived as matter. Learners' reaction to the evaporation of acetone was similar to that regarding gases. The *water* of the acetone disappeared, while the smell remained stuck to the side of the test tube. For learners the properties of a material can be disassociated from the material, especially when the material undergoes a change. Smell can leave the material, and leave it without smell, or the material can disappear and leave its properties of colour, smell and sweetness. Learners believe that matter exists only when there is evidence of existence. According to this idea, matter does not have to be solid or liquid to be conceived as matter, there must be a perceptual evidence of its existence. On the other hand, the visual properties of colour provide more evidence of existence of matter than smell does (Stavy, 1990:256-258).

This was similar to findings of Piaget as stated by Stavy (1990:258) regarding the existence of air. Piaget found that children believe that air exists only when it moves, an observation that provides proof of its existence. When it does not move, air does not exist. Its existence therefore is not permanent. This is a misconception perceived from everyday reasoning. This finding is similar to that of Sere as stated by Stavy (1990: 257), who found that learners believe that a gas exists when it moves, when they can feel the pressure or when it is coloured and can be seen. Learners also believe that weight can change with the state of matter during a phase change (Stavy, 1990:257).

Fermin (1997:70-72) elicited the following alternative conception by learners about phase changes in the Spanish education reform project: Evaporation is considered as a loss of water; there is no clear idea of conservation of mass. Water that has evaporated is completely lost. Water, when boiling, throws off gas (which is inside water), and is released by heating. According to Fermin (1997:70-72), the observation of either water, water vapour or ice as different realities proves that learners lack the scientific idea of matter transformation and state changes. The idea of the existence of a gas inside water and that it is released by heating, involves a misconception strongly rooted in learners. It seems that learners are confused about what air is and what water vapour is. There is no clear idea about either conservation of mass or change of state (i.e., water that has evaporated is completely lost, while water vapour and ice are identified as different things.). There is no idea of the transition water to water vapour.

According to Anderson (1990:23), learners conceive the smallest unit of matter to be the final stages of processes. It is perhaps not surprising that they project macroscopic properties onto atoms and molecules. For example, if phosphorous melts, its particles also melt; when water is hot, its molecules are also hot. They also think that the molecules in a soft substance must also be soft. A soft substance cannot be made of hard molecules. Anderson (1990:23) further says that the projection of macroscopic properties onto the micro world by learners is evident especially during transformations.

3.3 CONCLUSION

The literature on alternative conceptions in physics among school learners is extensive. According to Rollnick (1990:101), alternative conceptions on the idea of states of matter and phase changes have been investigated in many Western countries. In general, a similar pattern of these alternative conceptions have emerged from the different studies. However, two omissions can be noted in the reported research. Firstly, little investigations on African learners' alternative conceptions have been done. Secondly, virtually no research has been reported on the alternative conceptions held by educators, let alone in the African context. The importance of educators in the forming of learners' alternative concepts must not be underestimated. Educators are at the spearhead of formal education and exert a great influence on the thoughts and ideas of young learners. In fact, several alternative conceptions identified in older learners can be traced to ideas transmitted by educators.

However, the impact of educators on learners' alternative conceptions does not form part of our research, so we will not investigate that. This study therefore investigated alternative conceptions on the states of matter and phase changes held by senior secondary African learners, specifically the Grade 11's on these concepts, phenomena and processes.

Gonzalez (1997:72) states that since the success of solving a problem depends on the dynamic competition between the different bits of knowledge in which the stronger knowledge prevails, it is clear that the learner should be assisted in strengthening the correct bits of knowledge in his/her cognitive system and should be helped to find the boundaries within which this knowledge can be applied. Gonzales promotes the strategy of giving learners the opportunity to use their knowledge in solving different problems and allowing them to propose hypothesis and examine them in light of the physical reality. This view of Gonzalez will be taken into account in the recommendations on a teaching strategy (Chapter 7) to address the teaching of the sectors dealing with matter, its phases and phase changes (See also Chapter 1, Objective 1.5.3).

The state of affairs in science education obliges educators to consider changes in attitudes, teaching and evaluation methodology. It is necessary to recognise conceptually both curriculum and instruction to promote meaningful learning by sharing meanings to displace alternative conception from learners' cognitive structures. It is thought that knowledge about these intuitive conceptions and how they develop with age and instruction may be helpful in designing better teaching methods. In this study, the tool used to deal with these alternative conceptions was based on constructivism (Hewson & Hewson 1989).

3.4 SUMMARY

This chapter has reviewed the alternative conceptions that learners have about the kinetic molecular theory, states of matter and phase changes as reported in the literature. A summary of these alternative conceptions of learners is tabulated below.

TABLE 3.1. Summary of the reviewed alternative conceptions

ALTERNATIVE CONCEPTIONS	REFERENCES
1. Particles appear temporarily, especially during a transition.	Anderson, 1990:23
2. Water is a mixture of hydrogen and oxygen atoms.	Anderson, 1990:28
3. Learners use the particle theory to explain gases but not solids and liquids.	Stavy, 1988:559-560
4. Powders are not seen as solids.	Ryan, 1990:175-177
5. Learners have difficulty in understanding that a gas is material and weighs something.	Anderson, 1990:32
6. Air is not seen as an example of a gas and air and gas are considered to be two different things or ideas.	Anderson, 1990:21
7. When matter disappears from sight, it ceases to exist.	Stavy, 1990:247
8. When matter is invisible, it does not exist and has no weight and other properties (matter exists only when there is concrete evidence of existence).	Stavy, 1990:256-258
9. Learners conceive matter as something concrete and solid.	Stavy, 1990:256-258
10. Weight can change with the state of matter during phase changes.	Stavy, 1990:257
11. Liquid is something that pours, so powders are classified as liquids.	Stavy, 1995: 225
12. Evaporation is considered as a loss of water. Water that has evaporated is completely lost.	Fermin, 1997:70-72
13. Water when boiling, throws off gas (which is inside water) and the gas is released by heating.	Fermin, 1997:70-72
14. The smallest unit of matter is considered to be the final stage of processes, and projection of macroscopic properties onto the microscopic world is common, for example: -	Anderson, 1990:23
a. If phosphorous melts, then its particles also melt.	Anderson, 1990:23
b. If water is hot, its particles are also hot.	Anderson, 1990:23
c. Molecules in a soft substance are also soft; a soft substance cannot be made of hard components.	Anderson, 1990:23

The next chapter will report on a literature review on the interventional strategies that deal with alternative conceptions. The different strategies reviewed will give an idea as to how to deal with alternative conceptions on matter and phase changes found in the group of learners involved in this study (See Chapter 1, Objective 1.5.3). The involved constructivist model, practical work, visualisation, and the use/application of models are some of the strategies that can be applied / used.

CHAPTER 4

INTERVENTIONAL STRATEGIES FOR CONCEPTUAL CHANGE

4.1 INTRODUCTION

In this chapter the different teaching strategies that are used in the natural sciences are reviewed. Specific reference is made to teaching strategies such as constructivism, the role of cognitive conflict, and the importance of visualisation. This review is done because the third objective (see paragraph ...) of this study is to propose interventional strategies for the teaching and learning of science and specifically for the teaching of the states of matter and phase changes.

Basili and Sanford (1991:294-295) states that researchers have shown that the traditional method - or what some researchers refer to as the transmission model of teaching - involves learners as passive recipients of facts. This is not an effective teaching strategy to make conceptual change possible. Conceptual change from the alternative conceptions hold by learners to the scientific concept.

Basili and Sanford (1991:293) mention that science educators are now brought face to face with a direct and difficult challenge. This is namely how to design classroom instruction that effectively address individual learners' alternative conceptions and change these conceptions to scientifically accurate understanding. This two researchers continues by saying that some researchers have convincingly demonstrated that learners can indeed be helped to construct accurate conceptions. Many of the interventional strategies have been based on theoretical conditions for conceptual change. Recent experiments implementing the transmission model in regular classroom settings with typical educators, however, at best yielded limited success. A high proportion of learners retain their alternative conceptions. Based on that, recommended strategies (interventional strategies) for conceptual change will be discussed in this chapter (Basili and Sanford, 1991).

In this chapter the question of how instruction can make explicit use of learners' prior knowledge is addressed. Learning is viewed as an activity to result in bringing a change in learners' conceptions. The specific relevance of the conceptual change model to the design and especially to the implementation of the interventional strategies is outlined. The following discussion deals with the conceptual change model and interventional strategies. Some of the strategies discussed was used by the educators involved in this study in the teaching of the states of matter and phase changes. Paragraph 4.1 deals with conceptual change, while 4.2 deals with a few of the most popular interventional strategies used at present..

4.2 CONCEPTUAL CHANGE

One of the factors affecting learners' learning in science is their existing knowledge prior to instruction. The learners' prior knowledge provides an indication of alternative conceptions possessed by the learners. This study is concerned primarily with learners' alternative conceptions and with instructional strategies to affect the learning of scientific concepts, i.e., to effect conceptual change from alternative to scientific conceptions. The conceptual model used here suggests conditions under which the alternative conceptions can be replaced or differentiated into scientific conceptions and new conceptions can be integrated with existing conceptions (Hewson & Hewson, 1983:731).

Hewson and Hewson (1983:731) developed instructional strategies and material for a particular learner population. They used identified prior knowledge (conceptions and alternative conceptions), and incorporated the principle of conceptual change. A group of learners was taught the same concepts by using the interventional strategies and material, while a control group was taught these concepts by using a traditional strategy and material. The result showed a significant improvement in the acquisition of scientific conceptions as a result of interventional strategies that explicitly dealt with the identified alternative conceptions. The study report was based on the assumption that a significant source of the learning difficulties experienced by science learners lies in the knowledge they had acquired prior to instruction. The objective of their study was to investigate the effect of instruction, which makes explicit use of learners' prior knowledge on their acquisition of certain basic scientific concepts (Hewson & Hewson, 1983:731).

Hewson and Hewson (1983:731) state that there is an expanding collection of literature concerning the role of existing knowledge on learning. Ausubel, as quoted by Hewson and Hewson (1983:731), states that the most important single factor influencing learning is what the learner already knows. He further says that one should ascertain this and teach them accordingly. In the study of Hewson and Hewson, (1983:731) the question of how instruction could make explicit use of learners' prior knowledge was addressed by seeing learning as a change in learners' conceptions. In this view learning is not simply the addition of new bits of information, but involves the integration of new knowledge with existing knowledge. The process of reconciliation may involve the rejection of some conceptions (Hewson & Hewson, 1983:731)

According to Hewson and Thorley (1989:543), a literature research was conducted to gauge to what extent the conceptual change model had been used in the design of instruction and the extent to which it had proved effective, both in helping learners to adopt scientific conceptions and to reject alternative conceptions. Hewson and Thorley (1989:543) further state that the studies have all claimed significant success in promoting the development of scientific instructional interventions. It proved to be effective in bringing about conceptual change towards the scientific view, thus providing support for the value of the conceptual change model in instruction (Hewson & Thorley, 1989:543).

Hewson and Thorley (1989:545) raise issues that are central to the successful implementation of the conceptual change model in the classroom. To develop the culture of using interventional strategies in learners (and educators) would have obvious value with regard to the quality of classroom discussions and the implementation of teaching for conceptual change. However, the potential contribution of the conceptual change model is in the interpretation and management of classroom interaction. The creation of dissatisfaction with alternative conceptions, and the status of scientific conceptions in terms of their intelligibility, plausibility and fruitfulness are about the learners' own perspectives. So bringing interventional strategies more into practice can improve learners' own perceptions. Educators need to monitor the status of their learners' conceptions. Alternative conceptions and interventional strategies are often utilised in conceptual change. The use of such interventional strategies is necessary to create dissatisfaction with non-scientific conceptions. It is critical to know how such events influence learners' experience, anomalies and naïve ideas. According to Hewson and Thorley (1989:545), educators must be able to do two things: diagnose the conceptions that the learners are using to interpret the phenomena, and monitor the status of old and new conceptions in the minds of the learners. Interventional strategies seem to be established sufficiently to note the value of asking questions that elicit evidence about the status of conceptions in the minds of learners. The possibility of using interventional strategies was investigated in this study (Hewson & Thorley, 1989:545-546).

Scott *et al.* (1991:1) state that the importance accorded to learners' existing conceptions about natural phenomena is a common theme running through research programmes. Learning is seen in terms of conceptual development /change rather than just learning of new information. Various models of learning, based on this viewpoint, have been proposed. This work has strong implications for classroom practice. Approaches of teaching that acknowledge learners' alternative conceptions about matter have been researched, developed and now have to be tested. These teaching approaches involve a range of different interventional strategies. They draw upon various aspects of underlying theory and have tended to be tested and reported for a limited age range (Scott *et al.*, 1991:1).

According to Scott *et al.* (1991:1-2), the research programme on alternative conceptions had a limited impact on classroom practice. By then (1999), their study was examining ways in which its findings could be used to inform science-teaching practitioners more generally. This review has been prepared in order to identify the range of strategies being proposed and to analyse the different assumptions on which they are based. For effective teaching and learning for conceptual change, educators need to foster a learning environment, which will, for example, provide opportunities for discussion and consideration of alternative viewpoints and arguments. Thereafter, a selection of teaching strategies can follow. Scott *et al.* (1991:1-2) say that they see strategies in terms of overall plans, which guide the sequencing of teaching within a particular topic. Finally, the choice of a specific learning task must be considered. The task must fit into the framework provided by the selected interventional strategy and must address the demands of the particular science domain under consideration (Scott *et al.*, 1991:1-2).

Hewson and Thorley (1989:545) state that the conceptual change model might be perceived as incomplete or an invalid model of learning unless interventions are used. Interventional strategies proved to be a tool for conceptual change. Another model of learning scientific conceptions is called conceptual substitution. The next paragraph provides a review of this model.

4.3 CONCEPTUAL SUBSTITUTION

For effective teaching, educators need content knowledge, knowledge of learners' conceptions and effective teaching strategies. Grayson (2004:1126) states that much information is available on learners' conceptual and reasoning difficulties in physics, but much less information is available on how to remedy such difficulties. As it will be discussed in this paragraph, conceptual change is seen to be one of the solutions that is useful when learner difficulties arise from a failure to distinguish distinct, but related physics concepts (Grayson, 2004:1126).

Concept substitution is one teaching strategy for exploiting learners' correct ideas in a particular content. It involves identifying a learner's intuition that has been linked to an inappropriate physics concept and helping learners associate their intuitive idea with the appropriate scientific concepts. Grayson (2004:1131) states several advantages of this strategy: "First, learners may find it encouraging hearing that they have some correct ideas. Second, because learners are not asked to give up their intuitive ideas, they may feel that physics makes more sense to them than often happens when traditional teaching approaches are used. Third, when the concept that has been substituted by their instructor (educator) is encountered later on in the course, learners already have some intuition about that concept. Fourth, the approach encourages learners to distinguish among related concepts that may otherwise remain undifferentiated in their minds. As a result, certain apparent alternative conceptions may be remediated."

According to this model as acknowledged by Grayson (2004:1133), the sound understanding of the targeted physics concepts strongly suggest that the new ideas make sense. The process of sense-making was almost certainly enhanced by allowing learners to retain their intuitions and build on them rather that insisting that these ideas be cast aside. There is also an affective dimension to the process – when learners are told that their ideas are right, it probably boosts their confidence. Given the widespread perception that physics is difficult, this point is not trivial (Grayson, 2004:1131).

However, conceptual change is not a quick or simple process. Learners may spend some time in an unstable conceptual state, oscillating between their original concept and the targeted scientific concept. Learners may also combine elements of both concepts into a sort of intermediate conception. Nonetheless, concept substitution seems to provide the conditions that are required for conceptual change to occur, namely that the new concept should be intelligible, fruitful and plausible and should not be a source of disaster (Grayson, 2004:1131).

The following paragraphs provide a review of different interventional strategies reported in literature, which are broadly based on a view of learning by conceptual change and substitution.

4.4 INTERVENTIONAL STRATEGIES

It is a broadly accepted assumption that human beings construct their knowledge by a continuous process of interaction between the individual's cognitive system and his/her physical world and cultural environment. If we understand how learners represent these concepts, how they construct their knowledge about them and how factors around them affect these processes, educators would be able to improve methods, timing and the sequence of teaching them (Stavy, 1995:221).

These reviews suggest interventional strategies to deal with learners' alternative conceptions to help learners' to extend or to limit knowledge to the appropriate boundaries of each specific concept. The current study specifically referred to states of matter and phase changes. Interventional strategies are part of the strategies that were used in teaching the states of matter and phase changes to the target group of learners involved in this project. The strategies integrate a variety of approaches, each of which is discussed in the following paragraphs: Constructivism (4.3.1), Cognitive conflict (4.3.2), Practical work (4.3.3), Co-operative learning (4.3.4) and Visualisation (4.3.5).

4.4.1 Constructivism

Constructivism tries to create the kind of environment that encourages learners to engage in constructing meaning and making sense of what they learn and do in class. It is often used to give meaning, facilitates a number of desired goals, and to enhance learners' long-term understanding of the scientific concepts and principles (Abour *et al.*, 1997:437).

Constructivism is a model of teaching that looks differently at the roles of the educator and the learners in the science classroom. The educators' role is that of a facilitator of the learning process and not as instructor. Learners are not just passive recipients of what is taught, but are actively involved in interpreting and constructing their knowledge. Constructivist learning is always an interpretative process involving an individual's construction of meaning relating to specific occurrences and phenomena. New constructions are built through their relation to prior knowledge. The challenge of this research, specifically in the teaching of matter and related issues, is to focus on learners' learning with understanding rather than the more common and straightforward emphasis on covering content. Learning science from a constructivist departure point implies direct experience with science as a process of knowledge generation in which prior knowledge is elaborated and changed on the basis of fresh meaning (Watts, 1994:51).

Basili and Sanford (1991:294) investigated constructivist work incorporating appropriate focusing tasks as a strategy for fostering conditions for conceptual change. According to these authors this was designed to bring learners alternative conceptions to light, where they could be examined in contrast to scientific concepts presented through direct instruction.

Abour *et al.* (1997:294) stated that they have tried to create the kind of environment that encourages learners to engage in constructing meaning and making sense of what they learn and do in class. This type of learning (constructivist-learning model) is often used to activate constructive meaning, facilitating a number of desired goals, and enhancing learners' long-term understanding of the learning concepts and principles. In the use of these methods, Abour *et al.* (1997:438) state that they observed that learners have increased enthusiasm for the abstract subject and show better recall of the basic information and an enhanced ability to apply the information to different situations (Abour *et al.*, 1997:438).

Scott *et al.* (1991:5) explain constructivism as a teaching strategy that builds on learners' existing ideas. There have been closely related developments in science education, and they state that they have accepted constructivism as a powerful perspective for understanding, interpreting and influencing learning in science. Constructivism is rather a different approach to produce conceptual change (Scott *et al.*, 1991:5-6). Stavy (1991:305) states that a new approach to change alternative conceptions of learners is to build on ideas that match learners' existing intuitive knowledge.

According to Scott *et al.* (1991:5), a theory is not only replaced by a more plausible theory or discarded on the basis of contradictory evidence alone. The construction of a new theory need not involve an immediate confrontation with the knowledge that an individual spontaneously considers relevant. Knowledge needs to be constructed. Scott *et al.* (1991:5) are of the opinion that the ideas that learners consider relevant to the problem situation need to be established. After establishing these ideas, learners are instructed, and their help is required in the construction of new concepts. Subsequent teaching and learning involves that the learners develop and extend these existing ideas toward the scientific viewpoint. Learners are not going to adopt new conceptions unless they can first represent it to themselves. In other words, they must find it intelligible, plain and clear (Scott *et al.*, 1991:9).

Niedderer, as quoted by Scott *et al.* (1991:6), reported that this is rather a different approach to the problem of producing conceptual change. Scott *et al.* (1991:6) acknowledge this approach as being based on a new philosophy of science and that it aims not to replace learners' theories related to everyday life thinking and scientific thinking. According to these researchers, constructivism consists of six stages as outlined below (Scott *et al.*, 1991:19).

1. Preparation

   Teaching processes that precede the intervention, and which may contain tools and concepts that may be drawn on.

2. Initiation

   An open-ended problem is posed

3. Performance

   This comprises parts on the following sequence: Formulating questions or a hypothesis, planning and performing experiments, making observations, theoretical discussions, and formulation of findings

4. Discussion of findings

   These take place in a class forum.

5. Comparison with science

   Class findings are compared with similar historical theories or modern ideas. Differences are stated and possible reasons for those differences are discussed.

6. Reflection

   Learners are encouraged to look back on the process of performance and to consider particular questions or difficulties that have arisen.

Scott *et al.* (1991:6) claim from their investigations on learning processes that it seems plausible that this teaching strategy has started a far-reaching learning process by letting learners come to their own results and by comparing these results systematically with the results of scientific research.

Watts (1994:40) refers to the wealth of research data about learners' scientific construction and interpretation of phenomena in everyday life. Watts (1994:40) says that although much research has been conducted on strategies and methods, he believes that we lack understanding of the scientific construction and interpretation of phenomena in everyday life. Science needs to be relevant to learners' everyday lives, since this real context provides the roots from which their studies should be drawn.

Learning science should be lively and interesting, though it is sometimes a struggle to keep the laws and principles of science within the boundaries of everyday activities. Educators must choose the best interventional strategies from a wide range of possibilities to enable them to reach their goals. The main point of adopting this approach is to require the learner to use a planned approach to tackle a new problem based on their prior knowledge and learning. It must produce a tangible outcome. The learners' success is judged by the effectiveness of the solutions they develop (Watts, 1994:40).

Fensham *et al.* (1994:5) ask what can be said about the virtues of learning and how it generally fits into constructivism and conceptual change. In their view, constructivist learning is always an interpretative process involving individual's constructions of meaning relating to specific occurrences and phenomena. New constructions are built through their relations to prior knowledge. The challenge for educators is to focus on learners' learning-with-understanding, rather than more common (and straightforward) emphasis on covering content. To learn science from the constructivist philosophy implies direct experience within science as a process of knowledge generation in which prior knowledge is elaborated on and changed on the basis of fresh meanings negotiated with peers and educators. It is important to promote learning of this kind relating to a variety of concepts in science. The challenge of this study (research reported here) is to teach the states of matter and phase changes, while at the same time fostering a constructivist approach through active problem-solving strategies (Fensham *et al.*, 1994:5).

Watts (1994:56) is of the opinion that constructivism in general can be seen to provide opportunities to explore and elaborate learners' alternative conceptions and developing understanding of science. Watts (1994:56) further says that this approach can be seen to promote active learning, and actionable learning, where learners must put their understandings into practice and use their knowledge. Constructivism works through the use of open-ended investigations. Constructivism also makes science relevant, enjoyable, fruitful, plausible and highly motivating (Watts, 1994:56). According to Watts (1994:56), constructivism centres upon six points that are tabulated in Table 4.1. The points are: cognitive construction, constructive process, oppositionality, critical realism, self-realism, self-determination and collegiality.

Table 4.1: Summary of concepts that centre upon constructivism (Watts, 1994:56)

CONCEPTS	EXPLANATIONS
1. Cognitive construction	The heart of constructivism is the view that cognition is the result of pro-active mental construction. Conceptualisation arises through the interaction between previously accumulated knowledge and current data.
2. Constructive process	The emphasis on processes is upon to-and-fro between deep and surface structures as they slowly adopt through interactions in everyday life.
3. Oppositionality	As we construct and qualify meaning, we do so in comparison with or constructed with the other meanings. Constructivism suggests pluralism and a relationship between ideas, rather than simply that development takes pride of place over concept formation.
4. Critical realism	Constructivism views knowledge as transitory and provisional. Knowledge of the world is constructed on the basis of the constraining influences of the nature of phenomena, personal context, language, pre-disposition, etc., judged by such criteria such as utility, plausibility and fruitfulness.
5. Self-determination	That is, constructivism sees human actions, including learning, to be purposeful, consciously aimed towards some end.
6. Collegiality	Constructivism implies a social context where ideas and conceptions are communicated, shared, tested, negotiated and reported. There is also a sense in which constructivism implies caring for ideas, it is not a take it or leave it thing.

The emphasis in constructivism is based on active learners that are constructing and reconstructing their own ideas, taking responsibility for their own learning in ways they know they can do, being self-determining within a caring group, negotiating with others towards a purposeful end. Watts (1994:53) states that constructivism stops at the point when learners begin reaching understanding rather than at the point of transfer and application to ideas. If learners come to lessons with ideas about their world that already make sense to them, teaching needs to interact with these ideas. Firstly by encouraging their declaration of whether other ideas make better sense. A feature of this approach to science teaching is that the outcome is convincing and outstanding. It is important to note that it is difficult to design a strategy to cater for all educators including those who are not experts on subject content. Such educators must make extra efforts to equip themselves with the knowledge they need. The educator's role in the teaching of matter is to generate changes in the learners' experiential field that lead them into a situation where they experience conflict or contradictions between their own representations and those needed to interpret the situation. (Watts, 1994:53).

Watts (1994:53) states that the aims of science education are fairly wide and all-embracing and that no single approach to teaching and learning can possibly do them all justice. In the paragraphs to follow, some of the interventional strategies based on constructivism are reviewed. The strategies include co-operative learning, cognitive conflict, practical work and visualisation.

4.4.2 Cognitive conflict

According to Scott *et al.* (1991:2), cognitive conflict is used as the basis for developing a number of approaches to teaching for conceptual change. These approaches involve promoting situations where learners' existing ideas about some phenomenon are made explicit and are then directly challenged in order to create a state of cognitive conflict. Sometimes teaching strategies are used as a combination designed to make learners aware of the conflict existing within their thinking (Scott *et al.*, 1991:2).

According to Niaz (1995:959), cognitive conflict must be based on problem-solving strategies that learners find relatively convincing. He further says that it is partially based on the fact that cognitive conflict within learners engenders in trying to cope with their world and motivates their cognitive development. They are their own motivators for reconstructing their systems of cognitive schemes. Teaching strategies used for introducing cognitive conflict must be based on data that may be contrary to the expectations of at least some learners. After having generated cognitive conflict (a situation contrary to learners' expectations), it is essential that learners be provided with an experience that could facilitate the resolution of the conflict (Niaz, 1995:959).

According to Niaz (1995:960), cognitive conflict can be produced by various situations. Surprise produced by results that contradict a subject's expectations, result in the generation of perturbation. Experience of puzzlement, a feeling of uneasiness, a more or less conscious conflict, or a simple intellectual curiosity produces a cognitive gap, as if the person involved were vaguely aware that something within his/her knowledge structure was missing. Within the constructivist framework the development of conflict or contradictions is essential to facilitate conceptual change. The main objective of Niaz's study was to construct a teaching strategy based on cognitive conflict within a dialectic-constructivist framework (Niaz, 1995:960).

According to this theory as stated by Niaz (1995:961), conflict generation would correspond with the concept of assimilation, whereas conflict resolution will correspond with accommodation (this is referred to as internal-external relation). The strategy developed in this study is based on an interactive approach within an intact classroom, which provides the educator with an opportunity to facilitate conceptual change as part of normal classroom activities (Niaz, 1995:961).

It is important to note that it will be difficult to design a strategy that might provide a conflicting situation for all learners in a classroom. The instructor's role in the teaching of matter is to generate changes in the learners' experiential field that lead them into a situation where they experience conflict or contradictions between their representations and those needed to interpret the situation. Niaz (1995:961) indicates that although experimental treatment was effective in improving learners' performance on the post tests immediately after application thereof, the effect of this treatment was not enough to produce long lasting changes in the cognitive structures of the learners (core beliefs, establishing equivalent relations between different reactants). This type of intervention could facilitate lasting conceptual change (Niaz, 1995:961).

Nussbaum (1989:143) states that learners' alternative conceptions should motivate researchers to invent more effective teaching strategies, strategies for initiating and encouraging desired conceptual change. Any proposed interventional strategy should result in major conceptual change that results from some conceptual conflict between a person's previous held personal concepts and contradicting evidence supplied in teaching. There is nothing unique and innovative in assuming the first part of the above statement. The contribution is in adding the second assumption. Unless learners are aware of the elements of their own existing conceptions they are unlikely to sense a conflict. The implication is that if we want to enable learners to benefit from the conceptual conflict we must help them to expose and articulate openly their alternative conceptions (Nussbaum, 1989:143).

From a philosophy of science perspective, any conceptual change would have to go through the following sequence: Learners must become cognisant of the conflicting data; based on this experience, learners must discard their existing theoretical frameworks. Then a better theory must be constructed that explains the data. This is by no means a task that can be easily accomplished. According to Lakatos, as quoted by Niaz (1995:968), scientists do not abandon a theory on the basis of contradictory evidence alone and there is no falsification before the emergence of a better theory (Niaz, 1995:968).

An important implication of this study is that learners should be provided with a sufficient range of experiences to provoke cognitive conflict, which should help them to discard their existing theory based on the construction of a better one (Niaz, 1995:968).

4.4.3 Practical work

Raghubir (1979:13) states that educators *tell* learners too much, and deprive learners of the opportunity to learn for themselves. He further states that educators are likely to tell learners just everything and no mental involvement of learners is provided for. In this case learners frequently leave classes having performed the exercises very well, but with low retention of information and even lower comprehension of the significance of that information. The laboratory provides the enquiry role to help in the learning of science (Raghubir, 1979:13). Though time is a limiting factor for learners to construct own knowledge, Coleman (1996:2) is of the idea that less is more. This has the implication that in devising a teaching strategy, the topic should be cut to include only the most important ideas.

According to Raghubir (1979:14), a practical approach is based on the idea that science instruction is composed of laboratory investigations from which science concepts evolve. In many instances, learners begin a study of a unit with laboratory investigations rather than a textbook assignment. Raghubir (1979:14) argues that it is far easier to teach what happens or even why it happens. However, the outcomes of this approach to teaching outweigh the learners' difficulties.

According to Raghubir (1979:14), a laboratory investigative approach occurs in three stages: pre-laboratory, laboratory and post-laboratory, as outlined below.

1. **Pre-laboratory:** Here the learners discuss techniques and equipment that they use in the investigation. The purpose of the investigation is given in such a way that the conclusion is not revealed.

2. **Laboratory:** Here the learners engage in the process of investigation to illustrate concepts, without any assistance from the educator, who also refrains from giving outcomes of the investigation. The educator rather poses the questions and has the learners answer it. Minimum assistance should be given in setting up the apparatus. A laboratory report must be written according to the scientific method before the post-laboratory activities.

3. **Post-laboratory:** Here the learners discuss the scientific significance of their observations. The discussion may lead to the development of theory, formulation of hypotheses, understanding variables, analysing and interpreting results, and synthesising new knowledge.

According to Ragbihir (1979:16), the laboratory-investigative approach has been shown to be a successful teaching method for high school instruction. With this method learners acquire a greater understanding of science, greater information retention, and a better ability to think scientifically. A very important aspect of this approach is what the learners gain in the affective domain seems to have a positive effect on their achievement.

A laboratory allows learners to experience the process by which scientific information is generated. The laboratory provides learners with opportunities to discover information and serves as a centre for the verification of information they already have. Ragbihir (1979:13) states that other recommended strategies for science instruction fail to teach or develop a variety of cognitive skills. These are among others the formulation of hypothesis, making assumptions, designing and executing investigations, understanding variables, observing carefully, recording data, analysing and interpreting results, synthesising new information and satisfaction, which are necessary characteristics for making scientific decisions. Raghubir (1979:13) further stated: "There is a need to provide learners with the opportunity to develop these cognitive factors and the associated attitudes. The laboratory-investigative approach to science instruction should develop those types of cognitive factors and the associated attitudes, because it provides learners with the opportunity to develop the strategies and attitudes associated with those of scientists."

According to Tamir (1991:14), practical work involves two key words, that is, discovery and enquiry. The rational for practical work in science involves a number of reasons. Science could involve highly complex and abstract subject matter, where many learners may fail to comprehend the relevant concepts without the concrete props and opportunities for manipulation afforded in practical work. Practical experience could be effective in inducing conceptual change. Learners' participation in actual investigations, employing and developing procedural knowledge and skills may be an essential component in the learning of science as an enquiry. Practical work may give learners an opportunity to appreciate the spirit of science and promote problem solving, analysing and the ability to generalise. A practical experience is qualitatively different from non-practical experience and essential for the development of skills and strategies with a wide range of generalised effects. It allows learners to act like real scientists, and develops an important attitude such as readiness to admit failure and critical assessment of results and of limitations better known as scientific attitudes.

It is asserted that hands-on practical experience could give learners a more realistic view of the trial and error processes. It challenges experimentalists in many of the scientific investigations and involves them first-hand in the careful observation and manual skills required for gathering accurate data. The hands-on procedure seems to provide the mental activities necessary to assimilate the abstract concepts involved in the interactions taking place in the study of science (Bourque & Carlson, 1987:232).

Science should provide learners with the real experience of the scientific processes. Yager (1991:29) states that practical work is essential for science teaching; however, it should be carried out from the learners' point of view as opposed to the view of educators and textbook authors. According to Yager (1991:29): "If learning science is to be useful and meaningful, the learners must identify and experience the idea, the activity and the laboratory as needed. To teach basic concepts and processes and then proceed with illustrating practicality is to rob learners from direct experience. They are recipients instead of active participants."

Laboratory practical activities could enable learners to work with real materials and phenomena and to experience their physical environment. Thus learners need direct experiences with materials and phenomena, which may be essential elements in cognitive development (Tamir, 1991:14).

Practical work could also offer unique opportunities conducive to the identification, diagnosis and remediation of learners' alternative conceptions. Hofsteinn and Cohen as quoted by Motlhabane (2003:54) further support this and assert that practical work attempts to teach learners central concepts and basic skills. The general method of presentation could be geared to prevent learners from developing alternative conceptions. Laboratories are designed to help explain the concepts, familiarise learners with the properties of many substances and compounds and help them to understand the consecutive steps used to form a specific scientific theory (Motlhabane, 2003:54).

4.4.4 Co-operative learning

Van Rensburg and Bitzer (1995:138) argue that no one teaching strategy / method is better than another. They say what is important is that learners should share their views during learning with their educators because the comments and questions of learners reveal what part of learning they do not understand and what parts need to be review. Co-operative learning, where the learners are active in class and not merely passive recipients of information, is propagated in literature as an efficient way to enhance learner participation (Van Rensburg & Bitzer, 1995:138).

Co-operative groups as described by Basili and Sanford (1991:294) are an instructional environment in which individual and group incentives are used to promote learner engagement in tasks structured to increase helping behaviours among group members. They further state that studies employing this strategy have consistently produced a positive effect on learner achievement. Analysis of learners' verbal interaction within small groups was found to be a variable positively related to achievement. Fisher and Limpson, as quoted by Basili and Sanford (1991:294), suggest that if concept learning requires learners to give up previously held concepts, an atmosphere must prevail in which learners feel free to express their ideas, relate their experience, explain, debate and clarify their thinking through peer verbal interaction (Basili and Sanford, 1991:294).

According to Watts (1994:43), the main aim of co-operative learning is to explore learners' ideas and provide tasks to encourage discussion and debate of how things work. Small group team work in which individuals have roles within the team, which rotates during the course of the work should be build. It moves between educator-directed and learner-directed activities and employs a variety of teaching learning strategies. It also promotes conceptual change and the reconstruction of prior conceptions. It generates differentiated tasks and activities to cater for mixed ability classes. Last but not least, it uses a range of communicative techniques to focus upon both specific knowledge and higher-level cognitive activities (Watts, 1994:43).

The absence of the authority figure in small group settings provides opportunity for individuals to express ideas. Basili and Sanford (1991:294) say that their study provides evidence that co-operative group work can provide a valuable environment for learners to overcome alternative conceptions in chemistry (Basili and Sanford, 1991:294).

Basili and Sanford (1991:301) state that in their investigation of co-operative learning; more successful groups had leaders who checked to see if everyone understood before going on to the new activity. These leaders drew learners into the discussion and urged that the group continue working on a question until all felt that they understood. These leaders also called upon the instructor for assistance when the group had reached an impasse/deadlock (Basili and Sanford, 1991:301).

The qualitative finding of Basili and Sanford (1991:301) contained implications for managing small group work to foster desired outcomes. Analysis of group dynamics as suggested by Basili and Sanford (1991:301) was that poor leaders prevented effective discussions by rushing through a question and imposing their narrow view of the purpose of the task. They emphasised that good leadership behaviour should be taught to learners and be part of the instructions, and should be reinforced by being made a formal part of the group grading procedure. Peer group discussions can help learners clarify the scientific view until it is understandable and resides comfortably among the rest of their ideas of what the world is like. Carefully structured small group tasks can encourage learners to take more responsibility for making sense of concepts (Basili and Sanford, 1991:302).

4.4.5 Visualisation

Visualisation is a mental activity. Scientists use it to comprehend abstract concepts by forming mental images (visualise). The mental images often involve thought experiments. Many famous thought experiments have led to important discoveries in science by helping us to understand the results of real physics experiments. For example, in the fifth century B.C., the Greek philosopher Democritus used thought experiments to understand that matter consists of tiny particles called atoms. Visualisation helps learners to understand matter, especially the particle nature of matter (Abour *et al.*, 1997:429).

Visualisation has always been important in physics. The important aspect of visualisation in physics teaching is the complement between visual and symbolic learning. Efficient visualisation is thus an important skill for learners to acquire (Kgwadi, 2001:74). In this study by Kgwadi learners were required to visualise atoms and molecules (sub-microscopic particles). This activity helped them to understand phenomena and processes related to phase changes and states of matter in the context of this study.

According to Bitbol, as quoted by Kgwadi (2001:74), Einstein used visual/thought experiments to explore his ideas and Einstein self described his mental style as highly visual. This visualization is needed to understand the particle theory of matter. In physics, information (e.g., particle theory) is often presented through diagrams and illustrations. Chalkboards and overhead projectors are used in lectures to draw illustrative sketches and diagrams. Such illustrations are usually more elaborate and serve as aids to memory and understanding. Kgwadi (2001:75) states that the important aspect of visualisation in physics teaching is the complement between visual and symbolic learning. Visualisation should not only be taught but its effect in teachibg should also be evaluated (Kgwadi, 2001:74-75). In terms of the behaviour of particles of matter in different states and during phase changes, learners should construct mental models. Emphasis in teaching should be on the understanding of the arrangement and behaviour of particles inside matter so as to serve as a good foundation for learning about the states of matter and phase changes. Prior to the teaching of the topics phases of matter and phase changes to the target group of this study all the participant educators were briefed on visualization.

According to Pozo (2001:355), learners think in terms of observable and direct experience. For example, a learner can experience the difference in properties of states of matter because they are observable with the human senses. The explanation of these observations in terms of the structure and motion of particles inside matter requires learners to imagine things and processes they cannot see. Learners can be assisted to develop these non-observable pictures if they can compare them with something observable and familiar to them. They must be able to form analogies. In the responses of learners reported by Pozo (2001:355) regarding the change of states of matter, he argued that the problem could be solved with the modification of the model involved in the analogy. However, many different models given without any explanations may confuse learners. It would seem that the only possibility of sorting out this non-observable picture problem is to provide an explicit explanation of the nature of the model. The teaching of science involves a great deal of abstract reasoning in order to explain principles and phenomena, especially in terms of atomic and molecular structure and dynamics. However the majority of learners are still not making the transition from the concrete operational mode of thinking to that of abstract reasoning (Pozo, 2001:355).

Nakhleh and Samarapungavan (1999:781) believe that part of the reluctance to introduce learners to the microscopic worldview is based on a long-standing belief that learners are essentially concrete thinkers. They further believe that the abstract world of atoms and molecules is too far removed from the child's concrete experience to be comprehensible. The world of atoms and molecules is no more visible or accessible (to learners) through direct experience. The understanding of the microscopic view requires an act of the imagination. Nakhleh and Samarapungavan (1999:781) ask whether children are capable of such acts. The results of their investigation showed that children are capable of fairly complex and abstract scientific reasoning, especially in appropriately supportive instruction contexts. These authors were of the opinion that conceptual change would easily happen about the states of matter and phase changes if we start the explanation of these phenomena from the microscopic point of view. An electron microscope is at present the most effective instrument to show these particles, but since the instrument is unavailable in schools, the visualisation activity can help to form mental models of atoms, molecules and the structures they form.

4.5. CONCLUSION

The discussion in this chapter has centred on interventional strategies that involved a variety of approaches such as hands-on activities, visualisation, constructivism and other teaching strategies. An important aspect is how to bridge the gap between abstract and concrete understanding of scientific concepts and principles in learners' thinking. Abour *et al.* (1997:428), used integration as instructional strategy in classes and found it to be useful in assisting learners towards better understanding of the nature of matter, atoms, molecules and related concepts. The common thread among all the learning activities/ideas and the real-life situation in the learning situation created by Abour and his team is the integration activities. Abour *et al.* (1997:428) further states that this integration is the tool for interpretation, learning, expressing thoughts and ideas, and of demonstrating the understanding of the abstract topics.

Asoko (1991:15) states that effective interventional strategies involve phases where learners have the opportunity to make their own views explicit (clear and exact). Differences between the learners' ideas and the scientific viewpoint are identified in the process. In all these instances, learners' ideas are explicitly brought out into the open and used as a basis for subsequent teaching. In reviewing the main types of strategies for teaching science, it was indicated that cognitive conflict is widely used to promote the learning of scientific concepts through conceptual change (Asoko *et al.*, 1991:2-15).

The state of affairs in science education obliges educators to consider working towards changes in attitudes towards learning, teaching and evaluation methodology. It is necessary to conceptually recognise both curriculum and instruction to share meanings and to displace alternative conceptions from learners' cognitive structures. The interventions discussed in this study are suggested to prove to be an efficient and effective tool to reveal cognitive structures of the learners. The majority of these interventions are expected to show the vital necessity for change that has to be taken into account.

According to Van Rensburg and Bitzer (1995:138), effective teaching enhances motivation and improves study achievements. Perspectives on the relationship between teaching and learning are continuously changing. Evaluation of teaching is becoming increasingly important, because a rapidly changing education society is demanding improved work performance. This review on interventional strategies is done because the purpose of this study is to investigate the impact of these strategies towards the difficulties that learners have on the teaching and learning gain in the topic of matter and related concepts in Grade 11. Some of the interventional strategies discussed in this dissertation for example, constructivism, practical work, visualization and co-operative learning (see paragraph 4.4.1-4.4.5) were applied in this research (refer to appendix B).

Hewson and Hewson (1983:740) state that instructional strategies have to be designed in such a way that the individual is convinced that the scientific conceptions are more useful than the existing alternative conceptions. They further say that the results indicate the significantly greater acquisition of scientific conceptions when applying interventional strategies. When the accepted scientific view is presented it must be reconciled if it is to be accepted by the learner. If no reconciliation is effected, either by appropriate teaching or by the learners' individual efforts, the results are that science is progressively viewed as complex, difficult, incomprehensible and irrational. Alternative conceptions may be seen as the key to successful instruction if they are explicitly considered. While the use of interventional strategies still needs more investigations, there seems little doubt that using them for conceptual change is a powerful agency to bear on the problems of science learning and to make the research effort worthwhile (Hewson & Hewson, 1983:742).

4.6. SUMMARY

This chapter has dealt with aspects of learning and teaching science, particularly with interventional strategies that proved to have or is expected to have conceptual change as outcome. Modern views and strategies of learning and teaching were discussed, which was referred to as interventional strategies. The literature review on interventional strategies was aimed at identifying the most effective and the best teaching and learning strategies to be used to teach the topic phases of matter and phase changes. Interventional strategies, uniqueness and the purpose of it as used at secondary school level and the benefit of it were reviewed. This study will provide indications of the success and failure of some of these interventional strategies in the Grade 11 physical science class.

The next chapter (Chapter 5) outlines the research methodology followed in the investigations. It focuses on the measuring instrument, the sampling techniques, population, data collection, data analysis and processing and interpretation of the data.

CHAPTER 5

RESEARCH METHODOLOGY

5.1 INTRODUCTION

In this chapter an outline of the method and procedure used in the empirical research component of this study is discussed. Specific reference is made to the questionnaire design, sampling, procedure, population, data collection and data analysis. The empirical research was aimed at verifying the research hypothesis (paragraph 1.2.) and in reaching the aims and objectives of the investigation stated in paragraphs 1.3 and 1.4. The field of study is demarcated, the target group of learners identified and the teaching strategies used in the presentation of the topic in classes involved are outlined.

5.2 DEMARCATION OF FIELD OF STUDY

Gay and Airasian (2000:122) assert that the population is the group that is of interest to the researcher; the group to which he/she would like the results of the study to be generalised. Generalisation is the extent to which the results of a study can be applied to other populations or situations not directly involved in the survey. In this research, a sample of 110 learners from three different high schools in the Rustenburg area in the North West Province was used. A sample is described by Gay and Airasian (2000:121) as a subset from a larger population. Gay and Airasian (2000:121) further indicate that a sample comprises the individuals, events or items selected from a larger group, referred to as a population. The purpose of this sampling was to gain information about the population.

The sampling technique used in this research is cluster sampling. According to Gay and Airasian (2000:129), this technique randomly selects groups, not individuals. Cluster sampling is useful when the population is very large or spread over a wide geographical area. This research targeted Grade 11 learners that were studying physical science as one of their choice/major subjects. It is assumed that the results of this survey can be generalised to include all Grade 11 physical science learners in the Rustenburg area and in the North West province of the Republic of South Africa. The validity of these generalisations is based on the assumption that all physical science learners in the province are taught according to the same syllabus by educators that are trained in a similar way and teach under more or less similar circumstances. All physical science educators are regularly workshopped by subject advisors and staff of the Mathematics, Science and Technology (MST) Unit of the North West Education Department. Most of the publick schools use the same textbook and study material supplied by the provincial education department. A common focus that directs teaching in physical science and levels (standardises) teaching at all schools is the national Grade 12 examinations for physical science. The learners in Grade 11 in the North West province are more or less of the same age of about 18 years.

Three schools were randomly selected to participate in this investigation. All were black Grade 11 learners of almost the same age and grew up in similar circumstances.

5.3 DEVELOPMENT OF RESEARCH STRATEGY AND ASSESSMENT INSTRUCTION

The overall aim of the study was to gain an in-depth understanding of Grade 11 learners' understanding and knowledge of the states of matter and phase changes with focus on the alternative conceptions retained after instruction on these topics. A questionnaire administered after instruction on these topics was used to obtain the required information from learners.

The strategy used in the instruction of states of matter and phase changes in Grade 11 is based on Chapter 3 of the literature review of this dissertation. This strategy matches with the outcomes-based approach followed at present in the teaching of physical science in all schools. In a section of Chapter 3 of the dissertation a literature review of alternative conceptions related to matter and phase changes is reported. Based on the outcomes of that chapter and the grade 11 physical science syllabus (Physical Science 2000), a questionnaire with the specific purpose to probe into learners' alternative conceptions about the states of matter and phase changes was developed (Appendix A).

A broad holistic approach was followed in the teaching of the topics phases of matter and phase changes to the group of learners involved. Each topic was introduced by starting with the basic content knowledge. Topics drawn from the OBE theme (Matter and Material) were integrated with states of matter and phase changes as outlined in the Grade 11 syllabus (Physical Science 2000), from which learners could benefit directly. The 2004 Grade 11 learners was the first group of learners who completed their GET education by means of OBE. Therefore the content of the theme "Matter and Material" of OBE (GET band) served as the basis for the lessons presented in this survey. The three participating educators were briefed on the methods of presentation (interventional strategies) to be employed and the experiments to be performed. Appendix B contains examples of experiments educators could implement. Educators were not limited or confined to certain strategies or experiments. In the spirit of OBE they could adapt and change their strategy or experiments to serve the class situation the best. The three educators are considered to represent the average physical science educator in the North West province.

Practical work and a number of enrichment experiments not included in the syllabus supplemented those in the syllabus to form an integral part of the teaching of these topics. Learners used work sheets to work through these experiments, and class demonstrations were done for enrichment.

During the presentation of this topic in class questions were asked randomly to get clues of alternative conceptions that learners have on these topics. A notebook was kept to jot down possible alternative conceptions that surfaced when learners answered questions during the lesson. The three participating educators were briefed on this also before teaching the topics.

In the classes learners were allowed to be active participants, discovering knowledge on their own as required by the constructivist approach that underpins outcomes-based education. Learners were regularly engaged in small groups in practical investigations and simple experiments. Where apparatus or material for example dry ice caused limitations experiments were demonstrated.

Problems learners have with mental models (visualisation) on states of matter and phase changes were attended to at stages when it was necessary. The briefing of educators prior to instruction included the aspect of visualisation.

5.4. QUESTIONNAIRE

A questionnaire (Appendix A) was used to obtain data about Grade 11 learners' alternative conceptions about states of matter and phase changes after instruction on the topics. The items in the questionnaire were structured in a simple manner. In most items learners had only to make a tick (√) in an appropriate box to indicate their response. The questionnaire consisted of different types of items. The majority of items were of the true-or-false or yes-or-no type, or classifications. The questionnaire was easy to respond to and for a researcher easy to analyse. Learners were allowed to comment about any statement in the questionnaire. In order to simplify the analysis, items in this questionnaire were divided into subtopics with spaces provided for each subtopic. The spaces provided were kept relative small as possible to avoid long complicated comments.

The questionnaire was divided into parts A and B. Part A dealt with phase changes and has six compound items on melting, freezing, condensation and sublimation, (see Appendix A). The items in part B included the alternative conceptions revealed by the literature study reported in Chapter 3. Part B also included classifications of material/substances. It was assumed that learners were familiar with substances named in the classification. Most of these substances are used daily by learners. In both parts (A and B), the kinetic molecular theory was addressed. Questions on the behaviour of particles in different states of matter and during phase changes were included in both parts.

Items in different subtopics of part A and part B were matched to check the validity of learners' answers. Examples of such questions to check validity are outlined below and can be referred to in the appendix.

EXAMPLES

1. Part A, number 1.1.c, 2.2.a and 3.f.
2. Part A, 2.1.b and 2.2.b.
3. Part 1.1e, 3.d of part A and 5.S., 5.T. of part B.

As was said these items were included in the questionnaire to test the validity of learners' answers.

How was the validity checked? Taking example 2: If a learner gets 2.1.b right and 2.2.b wrong, (refer to Appendix A: it checks the aspect of temperature during freezing), you would expect that the respondent was guessing. The respondent had to get both answers right or wrong if he/she was sure of the answer or held an alternative conception. In this way it could be concluded whether the learner has mastered the concepts or not, or whether the respondent was guessing. In processing the results it was found that the validity of the questionnaire was quite high. In more than 70% of the pairs of items (see examples above) learners responded in a consistent way. This proves that most learners were honest in their responses and served as check on the validity of the probing instrument and the reliability of the results. Valid conclusions could thus be drawn from the results.

The questionnaire was formulated and then evaluated and corrected (where necessary) by two physicists and two experienced science educators. The researcher's own experience and observations of learners during the teaching experience also played a major role in the formulation of items in the questionnaire. In this regard, the researcher surveyed learners' responses to questions on the subject and learners' reasoning during the presentation of the topic. The researcher and the two other educators participating in the survey also noted the alternative conceptions that learners displayed during the presentations of the topic in class.

Before the questionnaire was administered to the classes participating in the investigation, six Grade 12 learners from two different schools completed it in a trial run. According to Gay and Airasian (2000: 287), few things are more concerting and injurious to a survey than sending out questionnaires only to discover that the participant did not understand the directions given or that many of the questions were not clear. This thorough editing before administering prevented such a situation to arise in the survey reported here. Pre-testing the questionnaire provide information about deficiencies and suggestions for improvement (Gay & Airasian, 2000:287). As was stated earlier six Grade 12 learners read and completed the questionnaire used in this research and were requested to identify problems. They were encouraged to make comments and to state suggestions concerning the items in the questionnaire and the questionnaire as a whole.

To check for validity and reliability of a questionnaire prior to administering, two physical science educators from high schools who are also studying for MEd were requested to work through the instrument and to comment on it. Gay and Airasian (2000:289) state that having reviewers to examine the questionnaire is one way to determine its content validity. Feedback from the two educators was carefully studied and changes were made accordingly.

5.5 SUMMARY

This chapter (Chapter 5) reflects on the procedure followed in the teaching of the states of matter and phase changes and on how alternative conceptions learners have after instruction on these topics were probed into. The target group under investigation, 110 Grade 11 learners in three schools in the Rustenburg area is described. The teaching strategies used in presenting the topics are outlined and the development of the questionnaire used to determine learners' alternative conceptions after instruction is described. The results of the empirical survey are discussed in the next chapter, Chapter 6.

CHAPTER 6

RESULTS AND DISCUSSION OF THE RESULTS

6.1 INTRODUCTION

In this chapter the empirical research and its results are given. The empirical investigation was concluded by administering a questionnaire. The questionnaire probed Grade 11 learners' knowledge and understanding of the states of matter and phase changes after instruction on the topics received.
Prior to instruction on these topics the three educators involved in the survey was briefed on the methodology. Emphasis was on visualization and the importance of learners' own perceptions. Worksheets were provided to every educator. An example of a worksheet is attached as Appendix B.

Learners were taught about these topics by using modern teaching strategies discussed in Chapter 4 and related to outcomes-based education. The teaching-learning process was based mainly on constructivism that is educational theory basic to outcomes-based education. This approach is believed to ensure better understanding and conceptualisation of physical science.

A broad holistic approach as advocated by outcomes-based education was followed in the presentations in the classes. Each topic was introduced by referring to the basic content relevant to it. Topics drawn from the OBE theme "Matter and Material" were integrated with states of matter and phase changes as outlined in the Grade 11 syllabus (Heyns *et al.*, 1994). The 2005 Grade 11 learners was the first group from OBE (GET). Therefore the theme "Matter and Material" of OBE (GET band) served as a basis for the topics that was presented. Where possible, attempts were made to relate matter to other areas of physics and science in general (for example energy and change in the syllabus, GET band), and to highlight the relevance of states of matter and phase changes to real-life situations and natural phenomena.

Practical work and a number of enrichment experiments not included in the syllabus supplemented those in the syllabus to form an integral part of the teaching of these topics. Learners used work sheets (See Appendix B for an example) when performing the experiments. Class demonstrations were done for enrichment or when the availability of material or apparatus restricted group experiments.

As was said earlier in this chapter a questionnaire (Appendix A) was used to test learners' knowledge and understanding of states of matter and phase changes after instruction. The aim with the questionnaire was to determine the alternative conceptions that learners still hold after instruction. All 110 Grade 11 learners in the three participating schools completed the questionnaire. Sufficient time was permitted so that all learners were able to complete the questionnaire. During instruction (teaching), learners' alternative conceptions that surfaced were noted by the educators and taken into account when setting the questions in the questionnaire. These alternative conceptions were linked to learners' comments that were requested in the questionnaire. Alternative conceptions were identified when the results of the questionnaire were analysed. The results are discussed in paragraph 6.2 and are summarised in tables 6.1 to 6.12.

A comprehensive discussion of the results is given in paragraph 6.3. Paragraph 6.4 lists and discusses the alternative conceptions identified during the empirical study in comparison with those revealed in the literature review.

6.2 ANALYSIS OF RESULTS AND DISCUSSION OF RESULTS

The results of the learners' responses to the items in the questionnaire are summarised in tables 6.1 – 6.12. A discussion of the results noted in each table is presented in the paragraphs following each table. The sequence of the numbers and the percentages of learners that gave a particular response are indicated in the first column of each table under the captions: True, False, Unsure and Missing. In Table 6.7 the columns are labelled: Solid, Liquid, Gases, and 'I do not know', in sequence. The number and percentage of the correct responses are highlighted.

6.2.1. Learners' responses on phase changes

6.2.1.1 Condensation

Table 6.1 summarises learners' responses to statements on the condensation process of a gas to a liquid.

Table 6.1. Learners' response to statements on condensation process (N = 110).

	FREQUENCY RESPONSE		
ITEMS	**STATEMENT**	**NUMBER**	**%**
	What happens when a gas condensates to form a liquid?	**TRUE** **FALSE** **UNSURE** **MISSING**	**TRUE** **FALSE** **UNSURE** **MISSING**
1.1.A.	The volume of the gas decreases when it becomes liquid.	83 26 1 0	75 24 1 0
B.	The gas gives off energy (heat) when it forms a liquid.	75 33 2 0	68 30 2 0
C.	The gas takes up energy to form a liquid.	53 52 3 2	48 47 3 2
D.	The particles move slower when it changes to liquid.	80 29 1 0	73 26 1 0
1.2.A	The gas can change to a liquid at any	9 94	8 85

	temperature.	5 2	5 2
B	The gas can change to a solid if the gas temperature is below the boiling point of the liquid it forms.	60 37 12 1	55 34 11 2

DISCUSSION

From Table 6.1 it can be concluded that question 1 was fairly satisfactory answered from a scientist's point of view. However, a number of conceptual problems with regard to items 1.1.B and C (refer to Appendix A) were identified. Item C (gas takes up energy to form a liquid) is the opposite of item B (gas gives off energy when it forms a liquid). From the analysis of results, 68% of learners answered B correctly, while item C was only answered correctly by 48% of the learners. The percentage dropped by twenty. This indicates that 20% of the learners that answered B correctly did not actually understand the question (or guessed). If they really understood it, they would have answered both B and C correctly. A small percentage of 3% did not attempt to answer this question.

Item 1.2.B was mostly answered correctly (from a scientist' perspective): 55% of learners answered it correctly, 34% incorrectly, and 11% did not attempt to answer. One of the comments from learners who answered this item incorrectly stated that gases do not only change to solids at any temperature below the boiling point of the liquid, but specifically at its freezing point. Based on this comment, it could be possible that they could have performed better if the question specified the temperature below the boiling point of that particular liquid. Some 20% of learners (9% who ticked off "unsure" + 11% who answered incorrectly) stated in their comments that they did not understand the question. This might be a valid remark, as knowledge of the triple point of a substance is required to answer this item correctly. The triple point concept is not dealt with in the school syllabus. Other items in this question on gases were answered satisfactorily.

6.2.1.2. Freezing

Table 6.2 summarises learners' responses to statements dealing with the freezing of liquids.

Table 6.2. Learners' response to statements on freezing

	FREQUENCY		
	STATEMENT	**NUMBER**	**%**
	What happens when a liquid freezes?	**TRUE** **FALSE** **UNSURE** **MISSING**	**TRUE** **FALSE** **UNSURE** **MISSING**
2.1.A.	The volume of the solid is more or less the same as that of the liquid.	49 47 11 3	40 44 10 6
B.	The temperature of the liquid when it freezes is higher than that of the frozen substance.	57 50 2 1	47 48 2
C.	The particles move slower in the frozen substance than in the liquid	103 6 1 0	94 5 1
D.	The particles move faster in the frozen substance than in the liquid.	9 100 0 1	8 92 0
E.	The liquid particles become hard.	75 28 4 3	70 26 4
2.2.A	When freezing heat is given off by the liquid.	69 25 12 4	65 24 11
B	While freezing, the temperature of the liquid is the same as that of the frozen substance.	32 74 3 1	29 68 3

DISCUSSION

The results summarised in Table 6.2 reflects that this subtopic was fairly well answered. 57% of learners performed well in this item. However, a considerable number of learners did not perform well. Some 43% did not respond correctly. The analysis of the results of this question showed that in three of the seven items learners performed poorly. These items are 2.1B, 2.1.E and 2.2B (refer to Appendix A).

Items 2.1B and 2.2B tested for the same concept, the concept of temperature during freezing. Some 47% answered 2.1B incorrectly, while 68% answered 2.2B incorrectly, which gives an average of 57,5% incorrect responses. This percentage clearly indicates that learners have alternative conceptions about this concept. These learners do not know that the temperature of a substance remains constant during freezing although heat is given off. Similar comments of learners were identified. One stated: '*When freezing, heat is given off, and when heat is given off, the temperature also drops.*' Based on such comments, it seems that learners think that the temperature drop of a substance is always associated with energy being given off.

Item 2.1E was not well answered. Only 26% answered correctly while 70 % gave an incorrect answer. There were no learners' comments for this item. It is possible that learners think that particles of liquids are soft, and as the liquid changes to solid, the particles become hard. This would be in accord with the findings of Anderson (1990:23) that learners perceive particles of soft substances to be soft and those of hard substances to be hard (refer to paragraph 3.2.3).

6.2.1.3. Melting

Table 6.3 deals with the melting of solid substances.

Table 6.3. Learners' response to statements on melting (N = 110)

	STATEMENT	NUMBER	%
	What happens when a solid melts?	**TRUE** **FALSE** **UNSURE** **MISSING**	**TRUE** **FALSE** **UNSURE** **MISSING**
3. A.	The volume of the solid increases.	74 35 1 0	67 32 1
B.	The temperature of the solid increases.	90 20 0 0	82 18 0 0
C.	The particles of a solid move faster when it changes to a liquid.	102 6 1 0	94 6 1
D.	The particles of a solid become soft.	47 52 10 1	43 48 9
E.	The solid takes up heat to melt.	101 3 3 3	94 3 3
F.	The temperature of a solid remains the same at its melting point.	38 68 4 0	35 62 4

DISCUSSION

From Table 6.3 it can be concluded that question 3 was generally not well answered and the performance in four items was below 50%. These items are 3A, B, D and F (refer to Appendix A).

In item A, that states that the volume of the solid increases during melting, 32% answered correctly and 1% was not sure. Based on the comments of the 67% that answered incorrectly, their explanation was based on the space that substances occupy during melting. One of the general comments was: '*When a substance melts, it occupies a bigger space, which means a bigger volume.*' Confusion could be caused by the process of evaporation, where particles occupy a bigger volume when changing from a liquid to a gas. To this group of learners, the situation appears to be the same during melting.

In item D, that states that the particles of a solid become soft during melting, the percentage of correct responses was 48%, 10% was unsure, and 44% indicated that the statement was true. The reason for the latter response could be that learners look at matter from a macroscopic point of view, as suggested by Anderson (1990:23). From this viewpoint a solid is hard, and a liquid is soft (refer to paragraph 3.2.3). One other comment that supports the statement from those respondents that ticked off "unsure" was that there are soft solids and that learners believe that these solids are made of soft particles.

There were two other items (B and F) that probed the knowledge of the same concept, i.e. the concept of temperature during melting. Some 72% of the learners believed that the temperature of solids increased during melting. This question reveals an alternative conception. It was also identified as an alternative conception in another paragraph (see discussion 6.2.1.2 of paragraph 2). One learner's comment was that the temperature of a solid had to change so that melting could occur; otherwise, solids would remain the same. A possibility is that they think absorption of energy causes a temperature increase. A recommendation with regard to this issue is that a simple experiment should be performed: Put a thermometer in a jug filled with ice cubes and water. Watch the temperature till all the ice has melted. It will be noted that the temperature remains constant. It can thus be concluded that the ice (a solid) absorbs energy without an increase in temperature. No such an experiment was conducted during the instruction phase of this investigation.

6.2.1.4 Evaporation

Table 6.4 displays learners' responses on the evaporation of a liquid to form a gas.

Table 6.4 Learners' response to statements on evaporation (N=110)

	STATEMENT	NUMBER	%
	When a liquid evaporates to form a gas, the ...	**TRUE** **FALSE** **UNSURE** **MISSING**	**TRUE** **FALSE** **UNSURE** **MISSING**
4.A.	volume of the liquid increases (gas has more volume than liquid).	78 31 0 1	72 28 0
B.	liquid gives off energy (heat) when it forms a gas.	70 36 3 1	64 33 3
C.	particles move slower in the gas that forms than in the liquid.	31 76 2 1	28 68 2
D.	temperature of the liquid is always the same (in other words, a liquid evaporates only at a specific temperature).	77 26 5	71 24 5

		2	
E.	liquid must boil (in other words, a liquid evaporates only at the temperature where it boils).	82 24 3 1	75 22 3
F.	liquid particles disappear completely (in other words, the particles cease to exist).	28 75 6 1	26 69 5

DISCUSSION

This question was not well answered from a scientist's point of view. The overall performance in this item was 48% acceptable responses. Generally, it can be concluded that learners find it difficult to understand the concept of evaporation. Considering sub-items, there were three that displayed learners' problems with regard to evaporation, namely items B, D and E.

Item B states that when a liquid evaporates to form a gas, the liquid gives off energy (heat). Some 64% of the learners answered incorrectly. Learners' comments confirmed that they had an alternative conception about the statement. Three learners were interviewed and also confirmed this alternative conception. They thought the steam they saw during evaporation was the heat given off.

Item D (liquid evaporates only at a specific temperature) was also incorrectly answered by 75% of the respondents. Follow-up interviews revealed that learners regard boiling and evaporation as synonymous. One of the learners' comments was that liquids evaporate only at boiling point temperature. Item E also focused on the same concept as D, namely the concept of temperature during evaporation. It was clear that learners had an alternative idea about this concept, since both items (D and E) were incorrectly answered. A total of 71% of learners with regard to D, and 75% with regard to E, believe that evaporation occur at a specific temperature (boiling point). A simple real-life situation experiment could remove this alternative conception: Observe a saucer with hot water. The water evaporates even if the water is not boiling.

The result of item 4F indicates that the majority of learners (69 %) do not think that liquid particles cease to exit when a liquid evaporates, as was found by Fermin (1997).

6.2.1.5 Boiling

Table 6.5 summarises learners' responses to the boiling of liquids.

Table 6.5 Learners' response to statements on boiling (N = 110)

	STATEMENT	NUMBER	%
	When a liquid boils, the ...	**TRUE FALSE UNSURE MISSING**	**TRUE FALSE UNSURE MISSING**
5. A.	temperature remains the same (constant).	54 52 3 1	49 48 3
B.	liquid particles are destroyed.	18 87 5 0	16 79 5
C.	particles go into the gaseous phase but remain the same as in the liquid.	78 29 3 0	71 26 3
D.	speed of the particles changes. The particles move faster in the gas than in the liquid.	99 11 0 0	90 10 0

DISCUSSION

This sub-item was one of the well-answered questions, since the overall percentage of correct responses was 72% (refer to Table 6.13). Only in item 5A did the learners not perform well. This reveals an alternative conception that was also identified elsewhere (see discussion 6.2.1.4 of the last paragraph). Only 49% of the responses agreed with the statement that the temperature remained constant when a liquid boiled, while 48% believed that it changes while boiling. Based on the discussions in 6.2.1.4 and 6.2.1.5, the conclusion is that there is a general belief among learners that a liquid's temperature changes when it boils.

6.2.1.6 Sublimation

Table 6.6 summarises learners' responses to statements dealing with the sublimation process.

Table 6.6. Learners' response to statements on sublimation (N = 110)

	STATEMENTS	NUMBER	%
		TRUE FALSE UNSURE MISSING	**TRUE FALSE UNSURE MISSING**
6.A.	It is possible for a substance to change directly from a solid to a gas.	94 12 4 0	85 11 4
B.	Dry ice (steam ice) melts to form a liquid.	29 80 1 0	27 73 1
C.	Ice cubes in a freezer become hollow because water molecules leave the ice (without becoming a liquid first).	42 55 11 2	39 51 10

DISCUSSION

This item consists of three sub-items. Two of those items were answered satisfactory from a scientists' point of view, while one was incorrectly answered. Item C states that *'Ice cubes in a freezer become hollow because water molecules leave the ice without becoming a liquid first.'* Some 39% of the respondents agreed with the statement, 51% did not agree, while 10% was not sure whether the statement was true or not. One of the alternative conceptions revealed in a learner's comments was that particles group themselves and move to the side of the container, explaining why ice cubes become hollow. Generally, learners did not make comments on this item, so that there is no clarity on why learners considered the statement to be false.

6.2.2. Learners' responses to states of matter

6.2.2.1 Classification

Table 6.7 (a) summarises the results of learners' classification of substances as solids, liquids or gases as derived from their responses in the questionnaire (Appendix A).

Table 6.7 (a) Classification of substances (N = 110)

FREQUENCY		
	NUMBER	%
SUBSTANCES	SOLID LIQUID GAS I DO NOT KNOW	SOLID LIQUID GAS I DO NOT KNOW

	MISSING	MISSING
A. Table salt	93 3 8 4 2	86 3 7 4
B. Oil	2 108 0 0 0	2 98 0 0
C. Water	0 110 0 0 0	0 100 0 0
D. Lipstick	100 3 2 5 0	91 3 2 4
E. Vaseline	82 19 3 6 0	75 17 3 5
F. Rubber	109 1 0 0 0	99 1 0 0 0

G. Sponge	110 0 0 0 0	100 0 0 0 0
H. Tooth paste	74 27 1 8 0	67 25 1 7
I. Porridge	62 38 10 0 0	56 35 9 0
J. Sugar	93 8 2 5 2	86 7 2 5
K. Body spray	2 37 70 1 0	2 33 64 1
L. Steel	106 1 2 1 0	96 1 2 1
M. Body powder	80 10 14	73 9 13

	5 1	5
N. Maize meal	90 4 2 14 0	82 3 2 13
O. Air	1 1 105 2 1	1 1 96 2
P. Margarine (butter)	79 22 1 7 1	72 20 1 6

DISCUSSION

Table 6.7(a) displays the results of learners' description of solids, liquids and gases. For this sub-item, item 1 of part B (refer to Appendix A), learners were asked to classify different substances under different states. The general performance in this question was good, since the overall percentage of learners that gave acceptable responses was 78%. This question was from a scientist's point of view the best responded to in the whole questionnaire. In two items all learners (100%) answered correctly. These are items C and G (refer to Appendix A). An interesting result is that most of the learners in this study did not have a problem with classifying powders such as body powder (73 % correct) and maize meal (82 % correct) as was found by Ryan (1990:175-177).

The two substances, porridge and body spray, were classified incorrectly by almost one third of the group. Body spray, was classified by 34% as a liquid. Their answer was actually understandable and not necessarily incorrect, since body spray is a liquid inside its container (this can be proved by shaking the container with body spray and listening). There were no comments on this substance. In the case of porridge, 38% respondents classified it as liquid. A possibility could be that learners were thinking of soft porridge, which has properties of a liquid, for example, it flows and takes the shape of the container. So, based on these reasons, the classification of these two substances cannot necessarily be taken as alternative conceptions.

The item following the one on classification (Table 1 of part B of Appendix A) in the questionnaire was: *"How would you describe to a friend what a solid substance, a liquid or a gas is?"* Table 6.7 (b) gives the results of learners' descriptions of solids, liquids and gases.

Table 6.7 (b) Learners' description of solids, liquids and gases (N = 110)

DESCRIPTION BASED ON	NUMBER OF RESPONSES	PERCENTAGES
Microscopic entities/ properties	28	25
Macroscopic entities/ properties	13	12
Combination of microscopic and microscopic properties	66	60
Other descriptions	3	3

Table 6.7(b) displays the results of the learners' description of solids, liquids and gases. In response to that item, 97% answered it correctly from a scientific point of view, although the descriptions differed widely. Some descriptions were based on the macroscopic properties (models), some were based on the

microscopic properties (models), and some combined both microscopic and macroscopic properties. The remaining 3% gave incorrect answers.

Table 6.7(c) summarises the examples of the types of descriptions of learners.

Table 6.7(c) Learners' descriptions of states of matter (N = 110)

DESCRIPTION BASED ON	EXAMPLES OF LEARNERS' ANSWERS		
	SOLIDS	LIQUIDS	GASES
Microscopic entities/ properties	Consist of particles that are closely packed in an orderly pattern and that vibrate around a fixed position.	Substance made of small particles further apart than that of a solid. Particles glide over each other and its movement is disorderly.	It consists of small particles that are in continuous disorderly movement. Particles are in continual, random and rapid motion.
Macroscopic entities/ properties	Has a definite shape, volume and is incompressible	Maintains its volume, but assumes the shape of the container and flows.	Has no definite volume nor shape and fills its container. Can be compressed.
Combination of microscopic and microscopic properties	Has a definite shape and volume. It consists of particles that are closely packed in an orderly pattern.	Fixed volume, but no fixed shape, flows. Made of small particles further apart than that of a solid. Particles glide over each other and its movement is	Does not have a fixed shape or volume and fills its container. Consists of small particles that are in

		disorderly.	continuous disorderly movement.

In the second part of this section of the questionnaire learners were asked whether there were substances that were not on the list that could not be classified under three states of matter. Those who responded with 'yes', were asked to name the substance. 46% of the respondents ticked off 'no', 11% did not respond and 43% ticked off 'yes' (see Table 6.7(d)). The majority of those who ticked off 'yes', gave a variety of answers. There were also some individual interesting answers such as "earthquake", "electricity", "sky" and "fire". The learner who wrote "sky" stated: '*sometimes it is a gas, and sometimes it is a solid.*' In the case of "earthquake", a possibility could be that learners see it as fire (which does not fall under any of the mentioned states of matter). Some 53% of learners wrote "fire". It was not clear what they meant or visualised about electricity. 9% wrote maize meal, sugar and body powder (all powders). These answers indicated that there were a small number of learners who still did not know where to classify powders.

Table 6.7(d) displays the results of learners' responses to the second part of item 1 of part B of the questionnaire (refer to Appendix A)

Table 6.7(d) Responses of learners classifying the substances that are not on the list and cannot be classified as solid, liquid or gases by responding with a "Yes" or "No"

	YES	**NO**	**MISSING**
Number	47	51	12
Percentage	43	46	11

It is interesting to note that 47 of 110 respondents indicated that there were substances that they were unable to classify as solids, liquids or gases. The substances they mentioned are listed in Table 6.7(e)

Table 6.7(e) List of substances learners could not classify as a solid, liquid or a gas (N = 47)

SUBSTANCES	NUMBER OF LEARNERS	% OF LEARNERS
Earthquake	5	11
Electricity	4	8
Sky	3	6
Fire	15	32
Body powder	3	6
Maize meal	5	11
Table salt	6	13
Sugar	5	11
Plastic	1	2

6.2.2.2. Statement about solids

Item 1 of part B of the questionnaire dealt with statements about solids. The assignment was to classify a statement as true or false, or to indicate when the respondent was unsure about it. The results of this item are summarised in Table 6.8.

Table 6.8 Classification of statements on solids (N = 110)

	STATEMENT	NUMBER	%
2.1	ALL SOLIDS.............	TRUE FALSE UNSURE MISSING	TRUE FALSE UNSURE MISSING
A.	consist of atoms/molecules.	109 1	99 1

		0 0	0
B.	are hard.	75 34 0 1	69 31 0
C.	cannot flow.	81 25 4 0	74 23 3
D.	have a fixed shape.	100 8 0 2	93 7 0
E.	can be melted if heated sufficiently.	88 16 4 2	81 15 4
F.	have atoms or molecules that stay in more or less the same position.	80 21 8 1	73 19 6
G.	have atoms that vibrate around a fixed position	104 4 1 1	95 4 1
H.	can be smelled.	36 49 22 3	34 46 20
I.	melt always at the same temperature, but the melting temperatures are	81 23 6	74 21 5

	different for different solids.	0	
2.2 A	particles such as that of rubber are soft.	59 46 4 1	54 42 4
B	a solid cannot change directly into a gas without becoming a liquid first	38 70 2 0	34 64 2

DISCUSSION

The results indicate learners' understanding of what a solid is. Generally, it can be concluded that 70% of learners seem to have a good perception of what a solid is, since they gave acceptable responses from a scientist's point of view. The percentage that was correctly answered for all items was relatively high. There was one item to which learners gave an unacceptable response, namely item B. Some 31% of the learners disagreed that all solids are hard. Their comments were that there are soft solids such as sponge, rubber and plastic. Some 69% agreed that solids are hard, for example, table salt.

6.2.2.3. Statements about liquids

In item 2 of part B of the questionnaire learners were requested to classify statements about liquids. The results are summarised in Table 6.9

Table 6.9 **Classification of statements on liquids (N = 110)**

	STATEMENT	NUMBER	%
2.	**ALL LIQUIDS …**	**TRUE** **FALSE** **UNSURE** **MISSING**	**TRUE** **FALSE** **UNSURE** **MISSING**
A.	can flow	104 5 1 0	95 4 1
B.	always take the shape of the container it is in	106 3 0 1	97 3 0
C.	consist of atoms/molecules	104 4 1 1	95 4 1
D.	can freeze (if sufficiently cooled)	99 7 3 1	91 6 3
E.	can evaporate if sufficiently heated)	100 6 3 1	92 5 3
F.	will boil at a fixed temperature if heated sufficiently	89 17 4 0	81 15 4
G.	have atoms/molecules that always stay at the	28	26

	same position in the liquid	77 4 1	70 4

DISCUSSION

The learners' responses to this item (Table 6.9) about liquids indicated that liquid is a concept that is well understood, as was the case with solids (refer to paragraph 6.2.2.2). Of all the items in the test, this was the one learners performed best in. No less than 90% of learners' responses matched the scientist's point of view. It is interesting to note that no alternative conception regarding the liquid state could be identified in the literature review (refer to Table 3.1)

One learner made an interesting comment. The comment was that 'A *liquid fills in any container*.' The interpretation is that the learner wanted to state that liquids take the shape of any container.

6.2.2.4. Statements about gases

Item 3 of part B of the questionnaire dealt with statements about gases. The results are summarised in Table 6.10

Table 6.10 Classification of statements on gases (N = 110)

	STATEMENT	NUMBER	%
3.	**ALL GASES ...**	**TRUE FALSE UNSURE MISSING**	**TRUE FALSE UNSURE MISSING**
A.	can be liquefied (made a liquid).	56 51 2	52 47 1

		1	
B.	consist of rapidly moving atoms/molecules.	105 5 0 0	95 5 0
C.	are invisible.	52 53 5 0	47 48 5
D.	can melt if cooled sufficiently.	32 71 6 1	29 65 6
E.	will condense at a fixed temperature.	70 34 4 2	65 31 4
F.	can be smelled (comment on this statement).	73 26 8 3	68 24 8

DISCUSSION

Overall, the performance on the classification of statements on gases yielded 52% correct responses. There was a conceptual problem with regard to item F, since only 24% of learners answered it correctly. The statement was: "*All gases can be smelled'* (respondents were requested to comment on this). Only 7% of the learners were not sure, while 68% gave incorrect answers. The comments were from those who answered correctly and who probably wanted to support their answer. These learners gave examples of gases that could be smelled and gases that could not be smelled. They gave reasons as to why it could not be smelled.

Among one of the most frequent examples given was "air", the reasoning being that air was in the atmosphere and was inhaled, but could not be smelled. Some gave the example of oxygen, nitrogen and argon that made up a large percentage of the air in the atmosphere and could not be smelled. Some 25% respondents answered that water vapour was a gas that could not be smelled. These learners concluded that it was not true that all gases could be smelled. Those who answered incorrectly gave examples of gases that could be smelled. The conclusion drawn by the researcher is that these learners could not think of gases that do not smell.

A sub-item that needs focus is number A, which states that all gases can be liquefied. Only 52% ticked off the correct answer, some 1% ticked off "unsure", while 47% answered incorrectly. The comments of some respondents that answered incorrectly included examples of gases that learners thought could not become a liquid. A wide range of incorrect answers, including "air", was given.

In item C it was stated that all gases are invisible. The respondents were requested to respond to this statement. Some 47% answered incorrectly, 5% was unsure, while 48% was correct in their responses. Those who answered incorrectly supported their answers by mentioning only gases that are invisible, without thinking of the ones that are visible. Those who answered correctly gave examples of both visible and invisible gases.

6.2.2.5. Statements about states of matter

Item 4 of part B of the questionnaire requested classification of statements on matter and states of matter. The results are noted in Table 6.11.

TABLE 6.11 Classification of statements on matter and states of matter (N = 110)

	STATEMENT	NUMBER	%
4.		**TRUE** **FALSE** **UNSURE** **MISSING**	**TRUE** **FALSE** **UNSURE** **MISSING**
A.	Solids, liquids and gases all consist of particles.	110 0 0 0	100 0 0
B.	Particles only appear during transition (for example when a liquid evaporates or a solid melts.	30 75 3 2	28 69 3
C.	Water is a mixture of hydrogen and oxygen.	100 6 3 1	92 5 3
D.	The particle theory and the kinetic theory are only applicable to gases.	11 97 2 0	10.00 88 2
E.	The particle theory (kinetic theory) is only applicable to liquids.	16 91 1 2	15 84 1
F.	The particle theory (kinetic theory) is only applicable to solids.	18 90	16 83

		1 1	1
G.	A gas has weight.	98 10 1 1	90 9 1
H.	A gas is a material substance.	29 68 6 7	28 66 6
I.	A glass contains ice water. Small droplets of water form on the outside of the glass, because the glass leaks.	26 77 2 5	25 73 2
J	When water boils, the H_2O molecules are destroyed.	16 90 4 0	14 82 4
K.	When water boils, the H_2O molecules break up to form hydrogen and oxygen.	57 47 6 0	52 43 5
L.	Matter is something that is concrete and solid.	1 107 2 0	1 97 2
M.	If a block of ice is melted in a jug, the water in the jug will weigh less than the ice before melting.	39 69 2 0	35 63 2
N.	Powders are liquids because they can be poured.	24 82 4	22 74 4

		0	
O.	When water has evaporated from a jug, it is completely lost after evaporation.	28 76 4 2	26 70 4
P.	When water is boiling, it throws off a gas that is inside the water.	51 51 4 4	48 48 4
Q.	If a solid substance such as iron//butter/ice melts, its particles also melt.	16 90 4 0	14 82 4
R.	If water is hot, its particles (the H_2O molecules) are also hot.	69 29 12 0	63 26 11
S.	The molecules of a soft substance are soft.	44 62 4 0	40 56 4
T.	The molecules of a hard substance are also hard.	66 40 4 0	60 36 4
U.	A soft substance cannot be made of hard particles.	32 70 8 0	29 64 7

DISCUSSION

The 100 % correct response to item 4A shows that, after instruction, all learners accepted the basic assumption of the particle theory that all matter consists of particles. This is supported by the high percentages correct responses to items 4B, D, E and F. A relative small percentage (28 %) of the learners displayed in 4B the alternative conception found by Anderson (1990:23), namely that particles appear temporarily, especially during a transition. More than 80% of the learners did not reveal in D, E and F the alternative conception reported by Stavy (1988:559-560), namely that the particle theory is only applicable to gases and not to liquids or solids.

A total of 92% of the respondents gave an incorrect answer to sub-tem C. This percentage clearly shows that there is confusion about what a compound and what a mixture is. The same concept was also probed in item K. Learners think of a compound as being a mixture that can be separated.

In item H (gas is a material substance), 28% of the learners ticked off the correct answer (from a scientist's point of view), and 66% ticked off the incorrect answer. The problem here could be the term used. Learners are used to the term '*matter*', not '*material substance*' and it might have confused them.

Items S and T tested the same concept and were dominantly incorrectly answered. It is related to the previous alternative conception and is referred to in discussions in 6.2.1.2 and 6.2.1.3. The items were asked in different ways but tested the same concept. The consistency in learners' responses on the two items indicates the validity of the questionnaire.

Item R, which asked if particles of hot water were also hot, was incorrectly answered by most of learners (63%). Some 26% answered correctly, these learners believed that particles gained kinetic energy and did not become hot. Only 11% was not sure. This problem can be solved by more attention to the kinetic molecular theory in teaching.

The last item to be discussed is P (*When water boils, it throws off gas, which is inside water*). Nearly half of the respondents (48%) responded correctly, and nearly half (also 48%) incorrectly, with 4% unsure. This alternative conception is in line with the findings of Fermin (1997:70-72) as discussed in paragraph 3.2.3. The respondents had no clear idea about conservation of mass or change of state. Most of the learners' comments were that the gas that was thrown off is water vapour. If they knew that the gas was water vapour, the problem might be rooted in language. Water vapour is not thrown off, water just changes from a liquid to a gas (phase change).

6.3 LEARNERS' OVERALL RESPONSE TO QUESTIONNAIRE

Table 6.12 summarises learners' responses to the items in the questionnaire (Appendix A). It also gives average percentages of part A (*phase change*) and B (*states of matter*). This displays a general performance on a sub-topic, and a general understanding of the topic as a whole.

Table 6.12 displays the results of items in terms of learners' general performance. The items of Part A include: condensation, freezing, melting, evaporation, boiling and sublimation. The results of part B include: classification, solids, liquids, gases and classification of matter into different states.

Table 6.12 Overall response of items (N = 110)
Overall percentage of correct responses for Parts A & B

Part A

Item	Variable	percentages
1	Condensation	68
2	Freezing	57
3	Melting	53
4	Evaporation	48
5	Boiling	72

6	Sublimation	66

Part B

Item	Variable	percentages
1	Classification	78
2	Solids	69
3	Liquids	89
4	Gases	52
5	Classify	65

Overall percentage correct responses. Parts A and B

Variable	percentages
Part A	67
Part B	71

DISCUSSION

Table 6.12 summarises learners' overall achievements in the questionnaire. Part A dealt with phase changes and part B with states of matter. The overall percentages of correct responses were respectively 67% and 71%. Although not outstanding, it indicates a good general performance. The performance can be improved by giving more attention to the identified alternative conceptions.

A concept not well understood is evaporation. The overall performance was only 48 %. The other topics for which the percentage was below 60% were melting, freezing and the gas state. The liquid state is best understood with a percentage of 89% (refer to paragraph 6.2.2.3).

6.4 COMPREHENSIVE DISCUSSION OF THE RESULTS

Objectives of this study were to determine learners' alternative conceptions about the states of matter and phase changes after teaching of these topics and to propose strategies to deal with those alternative conceptions (see paragraph 1.4). During this study, learners were taught about the topic. Modern teaching strategies recommended in the outcomes-based approach were employed. After instruction information on learners' knowledge of the states of matter and phase changes were probed into by means of a questionnaire (Appendix A). Alternative conceptions were identified in the responses. One hundred and ten (110) learners completed the questionnaire, and an analysis of the results was made. This chapter presents the results and analysis.

From the analysis of the results, it became clear that learners still had alternative conceptions about states of matter and phase changes after instruction by means of modern strategies currently in use in South African schools. The alternative conceptions identified in the analysis are summarised below.

GENERAL ALTERNATIVE CONCEPTIONS HELD BY LEARNERS IDENTIFIED IN THIS STUDY

1. The temperature of a liquid when it freezes is higher than that of the frozen substance.
2. The temperature of a solid increase when it melts.
3. Liquid particles become hard when freezing, and solid particles become soft when melting.
4. Particles of soft substances are soft, and those of hard substances are hard.

5. Soft solids are made up of soft particles.
6. When a substance melts, it occupies a bigger space, which means a bigger volume.
7. The temperature of a solid increases when melting, and that of a liquid decreases when freezing.
8. Liquids only evaporate at their boiling points.
9. When a liquid boils, the temperature does not remain the same (constant), the liquid temperature changes to the gas temperature.
10. Not all liquids can evaporate or freeze, e.g., oil.
11. Not all gases can be liquefied, e.g., smoke, air.
12. All gases can be smelled.
13. Water is a mixture of H_2 and O_2.
14. Water breaks up to form H_2 and O_2 when boiling.
15. When water boils, it throws off a gas that is inside the water.
16. Ice cubes become hollow in a freezer because particles group themselves and move to the side of the container.
17. If water is hot, its particles (the H_2O molecules) are also hot.

Some of the alternative conceptions in this survey indicated that alternative conceptions on the topic "states of matter and phase changes" is extensive among learners, as a large percentage of learners had these conceptions. This topic has been investigated in many countries, as stated in the literature review (Chapter 3, paragraph 3.3). Some of the alternative conceptions that were noted in the literature review were also identified in this study. The references given in brackets after the alternative conceptions noted above relates to the similar alternative conceptions in literature. Generally, the alternative conceptions identified in the literature study (Chapter 3) were also identified in the empirical survey of this study. It was found that there are pattern of alternative conceptions among learners that are globally held. These cross-cultural, internationally reported alternative conceptions are tabulated below in Table 6.14.

Table 6.14 General alternative conceptions

ALTERNATIVE CONCEPTIONS IN THIS STUDY	ALTERNATIVE CONCEPTIONS FROM THE LITERATURE REVIEW (REFER TO CHAPTER 3).
1. Particles of soft substances are soft, and those of hard substances are hard.	Paragraph 3.2.1, paragraph 4 and 6
2. Water is a mixture of H_2 and O_2.	Paragraph 3.2.1, paragraph 8
3. When water boils, it throws off a gas that is inside water.	Paragraph 3.2.3, paragraph 7
4. When water is hot, its particles are also hot.	Paragraph 3.2.3, paragraph 8
5. Learners do not know where to classify powders.	Paragraph 3.2.2, paragraph 2

This paragraph dealt with the alternative conceptions about the states of matter and phase changes held by learners who participated in this survey and relate to some of the alternative conceptions to literature. The next paragraph summarises the analysis and discussions.

6.5 CONCLUSIONS

The findings as mentioned in the discussion of the results indicate that learners still have alternative conceptions after instruction by modern interventional strategies. This verifies the hypothesis that was stated in paragraph 1.2, namely that: *"Grade 11 learners studying physical science have alternative* *conceptions about the states of matter and of phase changes after instruction*." Even with the overall performance of learners in the questionnaire yielding 70%, the alternative conceptions in paragraph 6.3 confirm that learners' knowledge of these topics is far from perfect. Teaching strategies employed in this topic still need to be improved.

The next chapter, Chapter 7, gives a summary of the study and the recommendations based on the results of the study. Attention is paid to how to deal with problems associated with the understanding of states of matter and phase changes that learners experience in teaching.

CHAPTER 7

SUMMARY AND RECOMMENDATIONS

7.1 INTRODUCTION

The previous chapter, Chapter 6, gave the results of the empirical study and a discussion thereof. This chapter constitutes a summary of the study as well as recommendations based on the results of this study. It is envisaged that these recommendations would be helpful in alleviating problems associated with the understanding and conceptualisation of states of matter and phase changes. Paragraph 7.2 summarises the chapters of the dissertation, while paragraph 7.3 presents the recommendations of the research. The comprehensive conclusion drawn from the investigation is given in 7.4.

7.2 SUMMARY

A summary of the different chapters of this study is presented in 7.2.1 – 7.2.6. The summary is in line with the objectives stated in paragraph 1.4 and the aim given in paragraph 1.4 of Chapter 1.

7.2.1 Chapter 1

Chapter 1 presented an orientative introduction. A comprehensive motivation for the study was given. It stated the research problem, research hypothesis, aims and objectives of the study and the method of research. A descriptions of terms related to states of matter and phase changes were also included in this chapter.

7.2.2 Chapter 2

This chapter reported on the literature study, dealing with concepts related to the particle nature of matter, states of matter and phase changes. An overview was given on concepts related to matter, which included the constituents of matter and the processes related to phase changes that are relevant to the investigation, based on objective 1.4.1.

7.2.3 Chapter 3

Since this study is concerned with learners' alternative conceptions about the states of matter and of phase changes, alternative conceptions commonly held by learners as were revealed in the literature, were discussed in this chapter to form the basis for the investigation of learners' conceptualisation. Chapter 3 gave an overview of alterative conceptions about states of matter, phase changes and the particle nature of matter. The aim of this study is to reveal the knowledge learners possess regarding the states of matter and phase changes (paragraph 1.3). This chapter laid the foundation for investigations, since alternative conceptions among school learners are extensive. Chapter 3 therefore surveyed alternative conceptions on the states of matter and phase changes held by learners as reported in literature.

7.2.4 Chapter 4

This chapter reviewed different teaching strategies employed in the natural sciences. This review was done because the investigation conducted in this study focused on the impact of the interventional strategies on the teaching and learning of science with specific reference to states of matter and phase changes. The purpose of this section of the study was to investigate the common obstacles in the learning of natural science and to survey teaching strategies that could be recommended for the teaching of the states of matter and phase changes as implicated in objective 1.5.3. Chapter 4 was devoted to a discussion of constructivism, cognitive conflict, practical work, co-operative learning and visualisation. It should be noted that these are not the only teaching strategies used in natural science. An overview on conceptual change was also given, since the investigation was also based on how to effect conceptual change from alternative conceptions to scientific conceptions. The interventional strategies, its uniqueness and purpose of use at secondary level and its benefits were reviewed in this literature study.

7.2.5 Chapter 5

Chapter 5 sets out the research methodology followed in the execution of the empirical part of this study. The questionnaire as a research tool was discussed. In this chapter an outline of the method and procedure used in the empirical research was given. Specific reference was made to the questionnaire, its design, sampling, procedure, the population, data collection and data analysis.

7.2.6 Chapter 6

This chapter reported on the empirical survey and a discussion of the results was given. The analysis of results was summarised in tables 6.1 to 6.13. A discussion of the results were summarised after each table. The sequences of the numbers and percentages of learners who gave a particular response were indicated. This chapter also summarised alternative conceptions held by learners that were identified during the analysis.

7.3 RECOMMENDATIONS

In conclusion, it can be stated that the aims and objectives of this study were achieved. The study verified the hypothesis: "*Grade 11 learners studying physical science have alternative conceptions about the states of matter and of phase changes after instruction*". The test revealed problems that learners continue to have, even after instruction. This verified the hypothesis. Based on the results of the research, a need for recommendations became an important part of this study. This need is expressed in objective 1.4.3. The paragraphs that follow attend to these recommendations.

It is recommended that further research through the use of interventional strategies be conducted to deal with alternative conceptions held by learners. Proposed interventional strategies for further research include practical work, visualisation, constructivism as well as the method of relating learning to real-life situations. These are some (but not all) of the strategies that are recommended to bring learners to an understanding of the topic and remove the alternative conceptions identified in this study. The paragraphs that follow provide a discussion of the recommended strategies.

7.3.1 Practical work

Based on the general alternative conceptions identified in this study, practical work is recommended to address the alternative conceptions on matter and the states of matter held by learners. Most of the alternative conceptions identified in this study (refer to paragraph 6.3 of Chapter 6), need simple experiments, for example on temperature change, where only a thermometer and water are needed. This study showed that the concept of constant temperature during a phase change was not well understood, because such simple experiments were ignored. Some concepts are not as obvious as the educator might think. Practical work is recommended to enhance or establish these concepts and to substitute or change alternative concepts held by learners.

7.3.2 Visualisation

It is recommended that visualisation be used more in order to improve the understanding of states of matter and phase changes. This strategy is highly recommended for the learning of the kinetic molecular theory, which serves as foundation for the understanding of states of matter and phase change. This recommendation is based on the alternative conceptions about the particle nature and kinetic molecular theory that were identified in this study (refer to 6.3). There is confusion about the particle nature of matter in the different states. Learners, for example, think that when substances change from one phase to the other, its particles either hardens or softens. Based on these alternative conceptions, the kinetic molecular theory needs to be well understood. This can be accomplished with the help of interventional strategies such as visualisation and practical work. Educators need to bring learners to an understanding of the concepts of matter from a microscopic point of view. This actually needs learners to develop the abilty of visualisation. Illustrations and models (analogies) are proposed to help learners visualize.

7.3.3 Other recommended teaching / learning strategies

It is recommended that everyday situations should be related to phenomena associated with the phases of matter and phase changes. Explanations should be in terms of the particle model and the kinetic molecular theory. Linkages should be made between macroscopic observable phenomena and the underlying sub-microscopic entities and processes. Alternative conceptions revealed in this study, such as: "*Liquids only evaporates at boiling point*", are observed on a daily basis, but because learning is not related to real-life situations, learners separate the two situations. For example, a hot cup of tea can that evaporation takes place even if is not boiling. Learners observe this almost every day, but to them it seems to be a totally different situation from what is learned about boiling and evaporation in class. Based on this discussion the recommendation is to relate learning to real-life situations.

The above-mentioned does not exhaust all effective teaching strategies that could be recommended for the learning of the states of matter and phase changes. Recent research strongly recommends the use of the constructivist approach in dealing with alternative conceptions. This approach was discussed in detail in Chapter 3. To summarise, it is recommended that the aspect of dealing with alterative conception be investigated further, since it is very important and fundamental to scientific reasoning. It is also recommended that educators apply the teaching strategies and skills imparted to them in the day-to-day teaching activities.

7.4 CONCLUSION

Recommendations in this chapter do not offer a permanent solution to effective learning of the states of matter and phase changes, but merely presents suggestions on how to deal more effectively with alternative conceptions in teaching. The suggestions are based on the fact that this research showed that learners still had alternative conceptions after instruction. This confirmed the hypothesis (refer to paragraph 1.2).

As was already mentioned, it was impossible to include all the recommended strategies for the learning of states of matter and phase changes. Only those strategies that are considered to be effective and relevant to the situation were discussed. However, these strategies do not offer final solutions nor do they constitute a perfect method for effective learning. The situation in which one finds himself/herself, determines which strategies would be suitable. Efforts have to be made to find the approaches that are most effective, compatible with the situation at hand and can be executed in the time and with facilities available.

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APPENDIX A

QUESTIONNAIRE

NAME:	SCHOOL:
CLASS:	GENDER:

A. PHASE CHANGES

MAKE A TICK (√) IN THE APPROPRIATE BLOCK. CLASSIFY THE STATEMENTS BELOW AS TRUE OR FALSE. EACH ITEM MUST BE MARKED, IF YOU ARE UNSURE TICK THE UNSURE BOX

1. **CONDENSATION (GAS – LIQUID)**

	STATEMENT	TRUE	FALSE	UNSURE
	What happens when a gas condensates to form a liquid?			
A.	The volume of the gas decreases when it liquifies			
B.	The gas gives off energy (heat) when it forms a liquid			
C.	The gas takes up energy to form a liquid			
D.	The particles move slower when it liquifies			
1.2.A	The gas can change to a liquid at any temperature			
B	The gas can change to a solid if the gas temperature is below the boiling point of the liquid it forms			

If you have a remark on any of the statements above, or are not sure if the answer is true or false, please say what you think (comment) in the space below. Clearly indicate which statement the remark is on.

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2. FREEZING (LIQUID – SOLID)

	STATEMENT	TRUE	FALSE	UNSURE
	What happens when a liquid freezes?			
2.1.A.	The volume of the solid is more or less the same as that of the liquid			
B.	The temperature of the liquid when it freezes is higher than that of the frozen substance			
C.	The particles move slower in the frozen substance than in the liquid			
D.	The particles move faster in the frozen substance than in the liquid			
E.	The liquid particles become hard			
2.2.A	When freezing heat is given off by the liquid			
B	While freezing the temperature of the liquid is the same as that of the frozen substance.			

If you have a remark on any of the statements above, or are not sure if the answer is true or false, please say what you think (comment) in the space below. Clearly indicate which statement the remark is on.

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3. MELTING (SOLID – LIQUID)

	STATEMENT	TRUE	FALSE	UNSURE
	What happens when a solid melts?			
A.	The volume of the solid increases			
B.	The temperature of the solid increases			
C.	The particles of a solid moves faster when it changes to a liquid			
D.	The particles of a solid becomes soft			
E.	The solid takes up heat to melt			
F.	The temperature of a solid remains the same at its melting point			

If you have a remark on any of the statements above, or are not sure if the answer is true or false, please say what you think (comment) in the space below. Clearly indicate which statement the remark is on.

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4. EVAPORATION (LIQUID – GAS)

	STATEMENT	TRUE	FALSE	UNSURE
	When a liquid evaporates to form a gas the ...			
A.	volume of the liquid increases (gas has more volume than liquid)			
B.	liquid gives off energy (heat) when it forms a gas			
C.	particles move slower in the gas that forms than in the liquid			
D.	temperature of the liquid is always the same (in other words: a liquid evaporates only at a specific temperature)			
E.	liquid must boil (in other words: a liquid evaporates only at the temperature where it boils)			
F.	liquid particles disappear completely (in other words: the particles cease to exist)			

If you have a remark on any of the statements above, or are not sure if the answer is true or false, please say what you think (comment) in the space below. Clearly indicate which statement the remark is on.

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5. **BOILING (LIQUID – GAS)**

	STATEMENT	TRUE	FALSE	UNSURE
	When a liquid boils the ...			
A.	temperature remains the same (constant)			
B.	liquid particles are destroyed			
C.	particles goes into the gaseous phase but remains the same as in the liquid			
D.	speed of the particles change. The particles move faster in the gas than in the liquid			

If you have a remark on any of the statements above, or are not sure if the answer is true or false, please say what you think (comment) in the space below. Clearly indicate which statement the remark is on.

6. **SUBLIMATION (SOLID – GAS)**

	STATEMENT	**TRUE**	**FALSE**	**UNSURE**
A.	It is possible for a substance to change directly from a solid into a gas.			
B.	Dry ice (steam ice) melts to form a liquid.			
C.	Ice cubes in a freezer becomes hollow because water molecules leave the ice (without becoming a liquid first).			

If you have a remark on any of the statements above, or are not sure if the answer is true or false, please say what you think (comment) in the space below. Clearly indicate which statement the remark is on.

B. STATES OF MATTER

1. CLASSIFICATION

Make a tick (√) in the appropriate block to indicate what the substance in the first column is (at room temperature)

SUBSTANCES	SOLID	LIQUID	GAS	I DO NOT KNOW
A. Table salt				
B. Oil				
C. Water				
D. Lipstick				
E. Vaseline				
F. Rubber				
G. Sponge				
H. Tooth paste				
I. Porridge				
J. Sugar				
K. Body spray				
L. Steel				
M. Body powder				
N. Maize meal				
O. Air				
P. Margarine (butter)				

Are there substances that are not on the list that you cannot classify as a solid, a liquid or a gas?

Yes ☐ No ☐

If yes name the substance ______________________________

____

How would you describe to a friend what a solid substance, a liquid or a gas is?

Write down the description you would give in the space provided.

A solid ....
....
....

A liquid is ....
....
....

A gas ....
....
....

2. . **MAKE A TICK (√) IN THE APPROPRIATE BLOCK. CLASSIFY THE STATEMENTS BELOW AS TRUE OR FALSE. EACH ITEM MUST BE MARKED, IF YOU ARE UNSURE TICK THE UNSURE BOX**

	STATEMENT	TRUE	FALSE	UNSURE
2.1	**ALL SOLIDS............**			
A.	consist of atoms/molecules			
B.	are hard			
C.	cannot flow			
D.	have a fixed shape			
E.	can be melted if you heat it sufficiently			
F.	have atoms or molecules that stay in a more or less the same position			
G.	have atoms that vibrate around a fixed position			
H.	can be smelled			
I.	melt always at the same temperature, but			

	the melting temperatures are different for different solids			
2.2A	particles such as that of a rubber are soft			
B	a solid cannot change directly into a gas without becoming a liquid first			

If you have a remark on any of the statements above please write it down in the space provided below. Indicate clearly which statement the remark is on

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3. CLASSIFY THE STATEMENTS BELOW AS TRUE OR FALSE. MAKE A TICK (√) IN THE APPROPRIATE BLOCK

	STATEMENT	TRUE	FALSE	UNSURE
	ALL LIQUIDS ...			
A.	can flow			
B.	always take the shape of the container it is in			
C.	consist of atoms/molecules			
D.	can freeze (if you can cool it sufficiently)			
E.	can evaporate if you heat it sufficiently			
F.	will boil at a fixed temperature if you heat it sufficiently			
G.	have atoms/molecules that always stay at the same position in the liquid			

If you have a remark on any of the statements above please write it down in the space provided below. Indicate clearly which statement the remark is on

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4. **CLASSIFY THE STATEMENTS BELOW AS TRUE OR FALSE. MAKE A TICK (√) IN THE APPROPRIATE BLOCK**

	STATEMENT	TRUE	FALSE	UNSURE
	ALL GASSES ...			
A.	can be liquefied (made a liquid)			
B.	consist of rapidly moving atoms/molecules			
C.	are invisible			
D.	can melt if you cool it sufficiently			
E.	will condense at a fixed temperature			
F.	can be smelled (comment on this statement)			

If you have a remark on any of the statements above please write it down in the space provided below. Indicate clearly which statement the remark is on

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5. CLASSIFY THE STATEMENTS BELOW AS TRUE OR FALSE. MAKE A TICK (√) IN THE APPROPRIATE BLOCK

	STATEMENT	TRUE	FALSE	UNSURE
A.	Solids, liquids and gasses all consist of particles			
B.	Particles only appear during transition (for example when a liquid evaporates or a solid melts			
C.	Water is a mixture of hydrogen and oxygen			
D.	The particle theory (kinetic theory) is only applicable to gasses			
E.	The particle theory (kinetic theory) is only applicable to liquids			
F.	The particle theory (kinetic theory) is only applicable to solids			
G.	A gas has weight			
H.	A gas is a material substance			
I.	A glass contains ice water. Small droplets of water form on the outside of the glass, because the glass leaks			
J	When water boils the H_2O molecules are destroyed			
K.	When water boils the H_2O molecules break up to form hydrogen and oxygen			
L.	Matter is only something that is concrete and solid			
M.	If a block of ice is melted in a beaker the water in the beaker will weigh less than the ice before melting			
N.	Powders are liquids because they can be poured			

O.	When water has evaporated from a beaker it is completely lost after evaporation			
P.	When water is boiling it throws off a gas which is inside the water			
Q.	If a solid substance like iron//butter/ice melts, its particles also melts			
R.	If water is hot its particles (the H_2O molecules) are also hot			
S.	The molecules of a soft substance are soft			
T.	The molecules of a hard substance are also hard			
U.	A soft substance cannot be made of a hard particles			

If you have a remark on any of the statements above please write it down in the space provided below. Indicate clearly which statement the remark is on

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APPENDIX B

Example of a worksheet

PART A: States of matter

Introduction

1. Group discussion

Write down your answers on the worksheet

1.1 Name the three states of matter can occur in? ....

1.2 Give examples of matter in each state..

1.3 Are the following substances examples of matter? Mark 'Yes' or 'No'.

a. Water Yes / No
b. Air Yes / No
c. Lead Yes / No

1.4 Can water exist in all three states? Name the states. ....

1.5 Can air exist in all three states? Yes / No

1.6 Can lead exist in the three states? Yes / No

1.7 Answer Yes or No

a. Matter has mass in any state it may be in. Yes / No
b. Matter has volume (occupy space) in any state it may be in. Yes / No

Experiment 1

Aim: Has air mass?

Apparatus: Air pump, ball without air (flat ball), mass meter (scale).

Method:
Determine the mass of the flat ball.

Mass of flat ball ....

Inflate the flat ball with a pump until it is hard. Determine mass again

Mass of inflated ball ....

Compare the masses of the flat and inflated ball. What is your conclusion?
....

Can you deduce from this experiment that air is matter? Yes / No
Motivate your answer...
....

Experiment 2

Aim: To investigate if water can exist in a liquid and a solid form.

Apparatus: Glass, ice cubes, cold water.

Method: Pour iced water in an empty dry glass. Leave it for some time and observe what happens inside the glass.

Observation: Inside the glass……………………………………………………..

Explanation:……………………………………………………………………………
………………………………………………………………………………………

Complete: In this experiment water changed from the ………… state to the ………… state.

The process is called…………………………………………………………

What is needed for ice to melt?……………………………………………………

What happened on the outside of the glass? …………………………………..
………………………………………………………………………………

Explanation…………………………………………………………………………
………………………………………………………………………………………
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