An investigation into how two Natural Science teachers in the Khomas Region mediate learning of the topic of atoms and molecules in Grade 7: A case study

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Narenda Hoepfner

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DECLARATION OF ORIGINALITY

I, NARENDA HOEPFNER declare that this research is my original work and has not been submitted in any other form to another university. Where use was made of the work of others, it has been duly acknowledged in the text.

Signature: Hoepfner Date: 15 NOVEMBER 2014

ABSTRACT

The teaching of abstract concepts requires higher cognitive thinking skills and thus presents a challenge for most subjects in the curriculum, in particular, science subjects. Teachers often complain that they struggle to develop higher cognitive skills in learners in such topics. As a result, learners fail to understand science concepts and then complain that science is boring and hence lose interest in the subject.

The main reason for this study was to investigate how Grade 7 Natural Science teachers mediate the learning of abstract topics, in particular, atoms and molecules which are regarded as the building blocks in chemistry. This study further sought to develop a teaching unit of work on atoms, molecules and the Periodic Table in partnership with the participating teachers, in order to help improve teaching and learning of the topic.

The study is located within an interpretive paradigm. Within this paradigm, a qualitative case study approach was adopted whereby two Grade 7 Natural Science teachers in the Khomas Region were the research participants. This approach enabled me to seek for answers beyond the obvious classroom experiences by using document analysis, semi-structured interviews and classroom observation (which were video-taped and transcribed).

The theoretical frameworks underpinning this study focused on mediation of learning and social constructivism as expounded by Vygotsky, in conjunction with Shulman's pedagogical content knowledge. Hence, emphasis was placed on the teaching strategies used by teachers, such as elicitation of prior knowledge during the lessons, language used, interaction of learners and ways how teachers deal with the challenges faced by them in the mediation of learning. An inductive analysis to discover patterns and themes was applied during the data analysis process. The themes were further turned into analytical statements to interpret the data.

The validation process was achieved by using a variety of data gathering techniques. I watched the videotaped lessons with the observed teachers and I made use of member checking in the form of stimulated recall interviews and transcripts of the interviews. Thus, a summary of discussions were given back to the respondents to verify their responses and check for any misinterpretations. Different chapters of my study were given to colleagues to read through as a

means of the validation process. Herein lies the importance of a critical friend in qualitative research.

The findings of the study revealed that concepts of high cognitive demand should not be oversimplified when introduced to learners, as learners might find it difficult to define and conceptualise concepts as they do not have proper insights into the concepts. The findings further illuminated that teachers should develop a strong subject content knowledge as well as pedagogical content knowledge to have the best strategies in place to mediate learning of this topic. The study concludes, with Phase 2, that the exposure of and cooperation between teachers plays an indispensable role in their professional development. Essentially, this enables teachers to make use of different teaching styles as they scaffold learners in the process of making sense of, in particular, abstract science concepts.

Finally, this study recommends that teachers need to engage in on-going professional development opportunities and be equipped with suitable learning support and other necessary physical resources, as a way of motivation and to be in a position to deal with all the many challenges they have to face during the mediation of learning.

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DEDICATION

This research is dedicated to my parents and role models, Henning and Rina van Wyk, who encouraged me to always work hard, follow my heart and to never stop making my dreams to become reality.

LIST OF ABBREVIATIONS AND ACRONYMS

BETD:	Basic Educational Teaching Diploma
I-T1:	Interview with Teacher 1
I-T2:	Interview with Teacher 2
L:	Learner
LL:	Two learners
LLL:	Group of learners answering in a chorus
LCE:	Learner centred education
LTSM:	Learning and teaching support material
MEC:	Ministry of Education and Culture
M ED:	Masters' in Education
NIED:	National Institute for Educational Development
NSHE:	Natural Science and Health Education
O-T1:	Lesson observation with Teacher 1
O-T2:	Lesson observation with Teacher 2
PBL:	Problem-based learning
PCK:	Pedagogical content knowledge
SATs:	Standardised Achievement Test
SMK:	Subject matter knowledge
TIMSS:	Trends in International Mathematics and Science Study
T1:	Teacher 1
T2:	Teacher 2
ZPD:	Zone of proximal development

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DEFINITION OF CONCEPTS

The following key concepts are referred to in this study:

Abstract topics: Topics in the sciences that have no concrete realities to illustrate concepts for better understanding.

Learner centred education (LCE): A teaching approach where learners play an active role in their own learning through interacting with peers, teachers and subject content in order to develop critical, problem solving skills.

Learning and teaching support materials (LTSMs): prepared materials used to support teaching and learning that may be in the form of textbooks, computer software or prepared materials in the form of worksheets, posters and practical activities, to name but a few.

Mediation: a form of intervention in the form of interaction between teacher and learner to facilitate effective learning.

Pedagogical content knowledge (PCK): knowledge of the best strategies to facilitate learning of specific topics to make them comprehensible to the learners and to clear up certain misconceptions learners may have about a topic.

Prior knowledge: experiences and knowledge, either scientific or non-scientific, that learners bring with them to the classroom.

Scaffold: Various forms of guidance given by the teacher to learners as way of mediating abstract concepts, to increase their ability to develop their own inquiries and concepts.

Social constructivism: The process whereby learners construct their own knowledge within social interaction with peers and assistance of more knowledgeable people.

Subject matter knowledge (SMK): knowledge of the basic content of the subject.

Teaching strategies: Different methods that the teacher uses during teaching and learning to help learners access the content to be taught and make sense of the topic.

Zone of proximal development (ZPD): The difference between what a learner can do without help and what he or she can do with help.

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CHAPTER ONE: RESEARCH CONTEXT

> *The concept of the atom is one of the building blocks of science education. Although the concept is a foundation for students' subsequent learning experiences, it is difficult for students to comprehend because of common misconceptions and its abstractness (Cokelez, 2012).*

1.1 INTRODUCTION

The teaching of abstract concepts require higher cognitive thinking skills and thus presents a challenge for most subjects in the curriculum, in particular, science subjects. This study sought to investigate how Grade 7 Natural Science teachers mediate the learning of abstract topics, with emphasis on the topic of atoms and molecules. I focused on the methods that teachers use to scaffold learners in order to show how they deal with the challenges that they and their learners face in making sense of the concepts underlying the subject of atoms and molecules. This study further sought to develop a teaching unit of work on atoms and molecules in partnership with the participating teachers, in order to help improve teaching and learning of the topic. In order to do this, I made use of the data gained from my observations, interviews and document analysis,

This chapter thus introduces the reader to the research study and presents the background of the study as well as the motivation for the research, the research goal, problem statement, and the significance of the study. Finally, the structure of the thesis is outlined. The chapter ends with some concluding remarks.

1.2 RESEARCH BACKGROUND

The Trends in International Mathematics and Science Study (TIMSS) is an international document that highlights and compares the findings on Mathematics and Science performance in 46 countries world-wide. According to this report (Kirkham, 2013), grade 9 learners were asked to identify the diagram representing a water molecule. Although 83% of Finland's grade 9 learners were able to identify the correct diagram, only 42% of New Zealand and 39% of learners in England could answer correctly. Unlike some other African countries, Namibia does not participate in the TIMSS review. Instead, the Standardised Achievement Tests were implemented in Namibia in 2010 to analyse and compare the performance of learners from different schools according to specific science questions.

Nationally, the Standardised Achievement Tests (SATs) were implemented to monitor the progress of schools, especially in Mathematics, Natural Science and English, and identify content areas where teachers and learners would need extra support to improve their performance (Shaakumeni, 2012). The SATs Report for Grade 7 Science indicated that in 2010 only 21% of Grade 7 learners nationwide were able to classify elements into metals and non-metals; 44% of learners were able to state that elements have a name and a symbol (Namibia. Ministry of Education and Culture [MEC], 2011), (see Appendix E).

The Namibian education system has been undergoing reform since its independence in 1990. In order to achieve this, the Ministry of Education of Namibia implemented the learner-centred education (LCE) approach to enhance the quality of learning to improve learning with understanding and to develop the cognitive skills of learners. The National Curriculum for Basic Education (2010) in Namibia seeks to create a knowledge-based society where learners can learn how to "apply new knowledge creatively and innovatively" (p. 5). It further aims to provide a foundation from which to develop the cognitive skills of the learners in order for them to be able to:

> …think critically, to enquire, (to) research, explore, generate, try out and develop ideas; to analyse; compare; evaluate; plan solutions and solve problems; to take decisions; to use the imagination and think creatively, laterally, flexibly and reflectively; to understand situations, inter-relationships and systems; and to think innovatively (p. 12).

Similarly, the Natural Science and Health Education Syllabus for Grades 5-7 (2007) promotes the development of a:

> lively, questioning, appreciative and creative intellect to enable learners to discuss issues rationally, and to make careful observations and analysis, to think scientifically, solve problems and apply them to task (p. 2).

According to Nyambe (2008), LCE refers to an approach where the teacher allows the learners to play an active role in their own learning. In other words, during teaching and learning the learners interact with each other, the teachers, as well as with the subject matter in order to develop critical thinking skills. Hence, the teacher, as the facilitator and mediator, still has the responsibility to ensure that the learners become familiar with the curriculum content. Furthermore, the teacher has the role of building bridges between the learners' interests, knowledge and any skills the learners should acquire regarding the curriculum and society (Nyambe, 2008). Rowell (1995) has elaborated on this view of the teacher as follows:

> In a learner-centred pedagogy, the role of the teacher becomes that of mediator of learning experiences in which the learners generate meaning rather than one of transmitter of knowledge to learners (p. 7).

Unfortunately, not all teachers have been able to adapt to this way of teaching, especially in teaching abstract topics such as atoms and molecules which is why this is the focus of this study.

As noted earlier, the teaching of abstract concepts is a challenge for all subjects. A range of strategies, some subject specific, has been developed to aid the teaching of these concepts. As Burns and Hamm (2011) point out, in mathematics for example, abstract topics such as fractions can be concretised through the use of concrete objects such as blocks and geometric shapes of different colours (manipulatives). Science also consists of many abstract topics that pose a challenge to teachers and learners alike. In some instances strategies for making concepts more concrete would be the most appropriate route to take.

The understanding of and approach to the teaching of abstract concepts is however nuanced and in itself complex and may not be always solved through merely concretising the idea. According to Kiekebusch and Nghipandelwa (2010), research done at the Polytechnic of Namibia asserts that primary as well as secondary learners are often taught by rote learning and repetition, resulting in under-development of cognitive skills. Often teachers exhibit a low proficiency in subject content knowledge in critical subjects such as science, in particular. Findings from this report also accentuate the fact that Namibian tertiary students demonstrate a lack of abstract reasoning and critical thinking.

1.3 MOTIVATION FOR THE STUDY

My interest in exploring which strategies teachers could use to mediate the learning of abstract topics that require higher cognitive thinking skills in learners goes back as far back as 2002, when I started to lecture at the former Windhoek College of Education. For instance, during visits to schools when student teachers were doing their school based studies, I realised that they struggled to teach these 'abstract topics' in a creative and clear way, making use of concrete models and examples to explain concepts. Even experienced teachers complained that they struggled to develop the required skills in learners as prescribed in the National Curriculum for Basic Education in Namibia (2010). I also found that teachers (as well as student teachers) tend to teach the way they were taught in school and find it difficult to make the paradigm shift to effective learner centred education (LCE) as described in Section 1.2 above. Instead, teachers tend to depend on rote learning and fail to teach creatively and to develop the higher cognitive skills of learners. As a result, learners then fail to understand the complexities of science and complain that science is difficult and boring and subsequently lose interest in the subject.

To support this concern, a recent report was compiled by Scott and Uahengo (2013) regarding the teaching practice experience of student teachers at the University of Namibia. In this report, they note the point of concern that some student teachers doing their School Based Studies in schools have no in-depth subject knowledge and therefore do not incorporate real-life examples in the mediation of learning in the classroom. Stears, Malcolm and Kowlas (2003) found that learners in the Western Cape differentiate between "school science" and "out of school science" (p. 110) and therefore experience difficulties in conceptualising science content and making it part of their everyday experience. In other words, learners tend to differentiate between what they learn in the science classroom and what they experience in their everyday lives. This is exacerbated by the fact that student teachers often set tasks of poor quality for the learners and they are not creative in their use of teaching aids (Scott & Uahengo, 2013).

Following this line of thought, Shulman (1986) asserts that in addition to content knowledge, teachers should also have pedagogical content knowledge (PCK). This form of knowledge would empower teachers to make a subject comprehensible to their learners in the way they present the content. All these areas of concern can be barriers to the development of, not only the cognitive skills of learners, but also the affective and psychomotor domains as part of LCE.

Thus, I have decided to locate my investigation within one topic, namely, the mediation of learning of the topic of atoms and molecules in Grade 7. I have chosen to do my research on this topic for the following reasons: Firstly, this topic is one of the first abstract topics, with high conceptual demands, in the Natural Science and Health Syllabus, Grades 5-7 (2007) where learners do not have concrete examples to refer to.

Teachers' scaffolding of the subject, as introduced by Wood, Brunner and Ross (1976), plays a crucial role in conceptualising these concepts to enable learners to "solve problems beyond their unassisted efforts" (cited in Goos, 2004, p. 260). Goos (2004) contributes to the definition of scaffolding when she claimed that from research done in the mathematics classroom, peer interaction and argumentation, with the teacher controlling these interactions, may challenge learners to use their own experiences in understanding more abstract concepts. So, in this study I sought to find out how (and if) teachers in Namibia scaffold learners effectively for them to make sense of the topic on atoms and molecules.

Secondly, in discussions with teachers and student-teachers, I found that learners, as well as teachers, often experience difficulties in understanding the concepts of atoms and molecules and this might lead to misconceptions about the topic. For instance, research conducted in Australia confirms that learners tend to believe that they will be able to see atoms through a microscope; soft substances consist of soft molecules; non-living things consist of atoms and living things of cells; atoms are the colour of the substance it is part of, and learners express different opinions about the shape of atoms (Harrison & Treagust, 1996). I have found that the same misconceptions are often experienced at primary level in Namibian schools in that primary school learners experience difficulty in distinguishing between an atom and a molecule.

Thirdly, this topic forms the foundation for the chemistry syllabus in secondary school. Although the Grade 7 Natural Science curriculum requires that this topic should only be introduced in Grade 7 and no detail of the structure of atoms are required, knowing this would provide a baseline for future more in-depth topics related to atoms and molecules covered in Grades 8 to 12 Chemistry, such as: Nature of matter, periodic table, bonding, chemical reactions, stoichiometry and organic chemistry (Namibia. MEC. Physical Science Syllabus, Grades 8-10, 2010; Physical Science Syllabus, Ordinary Level, Grades 11-12, 2010).

In my position as a teacher educator at the University of Namibia, I gave a test to my Physical Science students to determine what their background knowledge of this topic was. It is evident from the test that often students who enter university to study teacher education with a C symbol in Grade 12 Physical Science, for example, lack some basic knowledge of atoms, molecules and elements (See Appendix D1). This motivated me to find out more about the teaching and learning of this topic.

1.4 RESEARCH GOAL

The main goal of this study was to investigate how Grade 7 Natural Science teachers mediate the learning of the topic of atoms and molecules.

The following questions were asked in order to achieve this goal:

Main research question

How do Grade 7 Natural Science teachers mediate the learning of the topic of atoms and molecules?

Sub-questions:

(1) How do Grade 7 Natural Science teachers scaffold learners to make sense of the concepts of atoms and molecules?

(2) (a) What challenges do Grade 7 Natural Science teachers experience in mediating the topic of atoms and molecules?

(b) In what ways do they deal with the challenges that learners face in making sense of the concepts underlying the topic of atoms and molecules?

(3) In what ways can Grade 7 Natural Science teachers be supported with mediation of learning of the topic of atoms and molecules?

1.5 SIGNIFICANCE OF THIS STUDY

This study will be a baseline study where I plan to identify strategies on how to improve the mediation of learning of abstract topics, especially at primary school level, focusing in particular on the topic of atoms and molecules.

I hope that this study will lay the foundation for further work that could include improvement on teaching aids developed during Phase 2 of this study (see Appendix H) in the form of more creative worksheets, lesson plans and practical activities to assist teachers in their mediation of learning of other topics in the Grade 7 Natural Science syllabus and might also reveal improved strategies to teach other abstract concepts in science at this level.

With the information gained from this study, I thus envisage contributing to primary school Natural Science teachers' as well as student teachers' effective mediation of learning of abstract topics. Secondly, I hope to assist textbook writers and curriculum developers in developing learning and teaching support materials (LTSMs) for teachers' use in the mediation of learning, as Czerniewicz, Murray and Probyn (2000) subscribe to the fact that LTSMs are an indispensable part of teaching and learning. Furthermore, the study could provide useful insights for potential researchers in the field of the mediation of learning at primary school level.

Last, but not least, I hope that this study will help to improve my own practice as a lecturer of science education to primary school student teachers. I hope to equip my student teachers with the necessary knowledge and skills to become competent teachers in science education.

1.6 STRUCTURE OF THE THESIS

This thesis consists of six chapters including the introduction.

Chapter 1 introduces the study by discussing the background to and motivation of the research study, the research goal and research questions and provides definitions of key main concepts used during this study. This chapter concludes by outlining the overview of the study.

In **Chapter 2**, a review of literature relevant to the study is discussed. The theoretical framework underpinning the work is provided in detail and different mediational tools to be used in the mediation of learning are explored.

Chapter 3 describes the research methodology; clarifies the goal of the study, explains how the data were gathered and analysed and how the ethical aspect of the study was considered. It also deals with validity and trustworthiness as well as the limitations of the study.

Chapter 4 contains the presentation and analysis of data gathered through interviews, lesson observations and document analysis, coupled with stimulated recall discussions. Several direct quotes are included in the presentation of the data. Data gathered during collaboration between the researcher and research participants to develop a detailed teaching unit of work of this topic is included in this chapter.

Chapter 5 engages with interpretation of the analysed data in terms of analytical statements developed from the emerging themes regarding mediational tools teachers use to teach the topic as well as challenges teachers experience and overcome. Insights from the literature review chapter underpin the analysis and interpretation.

Finally, in **Chapter 6** conclusions are drawn with respect to: the implications of the findings for learners, teachers, researchers and teacher educators; suggestions for the teachers in the light of these findings; limitations of the study; the need for further research and recommendations as well as lessons learnt from the study. Lastly, reflections and a brief account of my research journey as well as the conclusion of the study are provided.

1.7 CONCLUDING REMARKS

This chapter presents an outline of the research study such as the research background and context. The statement of the problem as well as the significance of the study is also clarified. The chapter ends with a list of definitions of key concepts and an overview of the research chapters.

In the next chapter, I present the literature relevant to my study, and review it in relation to science teaching and the learning of the topic on atoms and molecules.

CHAPTER TWO: LITERATURE REVIEW

> *Pedagogy is the act of teaching together with its attendant discourse. It is what one needs to know, and the skills one needs to command, in order to make and justify the many different kinds of decisions of which teaching is constituted (Alexander, 2004, p. 11).*

2.1 INTRODUCTION

For learners to learn chemistry, they need to be able to link macroscopic, microscopic as well as symbolic representations (Wu, 2002). In trying to find answers to how teachers mediate the learning of abstract topics in science at primary school level, this chapter highlights the expectations of the Namibian Curriculum for the topic of atoms and molecules in Grade 7. Furthermore, this chapter uses the following lenses as conceptual and mediational tools in this study: relevant prior knowledge of learners and teachers, the use of models in the mediation of learning and the role of language in science classrooms.

The theoretical framework underpinning this study focuses on the social constructivist framework of Vygotsky as well as the pedagogical content knowledge of the teachers involved in this study.

2.2 NAMIBIAN CURRICULUM

The Namibian Natural Science and Health Education syllabus for Grade 7 requires learners to study atoms and molecules under the theme 'building blocks of matter' (topic 3.3.1, p. 38) where the "learners should be able to:

- state that atoms are the smallest building blocks of matter;
- explain that all matter consists of elements or combinations thereof;
- state that the Periodic Table is a classification of all existing elements;
- classify elements into metals and non-metals; and
- state that every element has a name and a symbol (know at least the first 10 elements, as well as U, Cu, Au, Fe, Ag, Al, Pb, Cl.

Furthermore, as noted in Section 1.2, the Natural Science and Health Curriculum for Grade 5-7 advocates for the "development of a lively, questioning, appreciative and creative intellect to enable learners to discuss issues rationally, to make careful observations and analysis, to think scientifically, to solve problems and apply these skills to tasks" (p. 2). "Learners need to develop higher cognitive skills of analysis, interpretation and evaluation to use information effectively" as well as "the ability to think critically in solving problems and apply these skills to tasks" (Namibia. MEC. Natural Science and Health Education Grade 5-7, 2006, p. 2).

2.3 THE SIGNIFICANCE OF LEARNING ABOUT ATOMS AND MOLECULES AT PRIMARY SCHOOL LEVEL

This topic is one of the first abstract topics with high conceptual demands in the Natural Science and Health syllabus, Grades 5-7 (2006) where learners do not have concrete examples to refer to due to the extremely small size of an atom and molecule. Because of this, teachers' scaffolding (Wood, Bruner & Ross, 1976; Vygotsky, 1978, both cited in Goos, 2004) plays a crucial role in visualising and understanding these concepts to enable learners to solve problems of higher conceptual demands (Goos, 2004).

Knowledge of atoms and molecules forms the foundation for chemistry topics in secondary school. Although the Grade 7 Natural Science curriculum requires that this topic is only introduced in Grade 7, it does provide a baseline for future more in-depth topics related to atoms and molecules covered in Grades 8 to 12 chemistry, such as: nature of matter, detail on the periodic table, bonding, chemical reactions, stoichiometry and organic chemistry (Namibia. MEC. Physical Science Syllabus, Grades 8-10, 2010; Physical Science Syllabus, Ordinary Level, Grades 11-12, 2010). Clarity on the concepts behind atoms and molecules may also enhance learning of the topic Nutrients in the Biology Syllabus Ordinary Level, Grades 11-12 (2009).

Science teaching and learning, according to the Natural Science and Health Curriculum (2006), is focused on learning experiences to promoting teaching and learning for understanding. Thus, it is important that mediation of learning in the science classroom assists learners to develop knowledge and skills which will foster their "understanding of the interaction of human being and the environment in order to satisfy human needs" (Namibia. MEC. Natural Science and Health Education Syllabus Grade 5-7, 2006, p. 1).

2.4 THE CHALLENGE OF MEDIATING THE TOPIC OF ATOMS AND MOLECULES

> *Chemistry learning involves establishing conceptual relationships among macroscopic, microscopic and symbolic representations… Because of the abstract and content-based nature of chemical representations, teachers' scaffolds are crucial to facilitate the construction of links between chemical representations and observable phenomena (Wu, 2003, pp. 868, 887).*

Science is rife with abstract concepts, representations of reality that are constructed from elements that often cannot be seen individually due to its extremely small size. Furthermore, science uses words that may look similar to everyday language but have a unique meaning, and hierarchies of knowledge structures and classifications; much of which can never be directly seen as they are either simplified representations of reality or are too small to see. Hence, learners often experience difficulties in learning these concepts not only due to the microscopic nature of the concepts, but also due to misconceptions and distorted ideas in the mind of the learner as concepts are not properly linked to everyday-experiences of the learner (Wu, 2003).

Cokelez (2012), amongst others, claims that some of the most common misconceptions that learners may have about atoms and molecules relate to the size and shape of the atom as well as differentiating between concepts of an atom, molecule and element. An atom is often qualified as a hard, solid ball that can be seen under the highest magnification of a microscope. Students often have problems interpreting the mass of an atom and believe that an atom can be measured in grams or milligrams (ibid.).

When teaching concepts of such a microscopic nature, Wu (2003) argues, it may be effective to use macroscopic observations as a starting point. When developing concepts of atoms and molecules, Wu (2003) suggests that it may be more effective to use, for example, the burning of a candle as starting point. The carbon atoms of the wax will combine with the oxygen molecules of the air to form carbon dioxide molecules (ibid.).

Pozo (2001) subscribes to this viewpoint when she states that studies done in Spain with learners at different levels indicated that learners tend to relate microscopic concepts to observable features of substances (macroscopic level). Thus, she proposes that mediation of learning of microscopic concepts (atoms and molecules) should start from a macroscopic perspective (compounds and mixtures).

Duschl (2008) also agrees with Pozo (2001), when he reflects on a change in science education to take place from "one that embraces a shift from teaching about *what* to teach to teaching about *how* and *why*" (p. 270). It is thus important not to confront learners with a lot of content without there being corresponding comprehension.

The point made by all these researchers is that, during the mediation of learning, learning experiences should be refined and restructured for learners to make sense of abstract science content. Learners should be actively involved in learning activities and take equal responsibility for their own learning. However, teachers as well as learners should be properly educated and trained to do so.

2.5 THEORETICAL FRAMEWORK

This study will use three main perspectives to assist in both its design and in its analysis, viz. mediation of learning (from Vygotsky and developed by Feuerstein), social constructivism (as expounded by Vygotsky), which includes scaffolding of learning (Brunner) within Vygotsky's zone of proximal development (ZPD) of the learner and finally, pedagogical content knowledge (as developed by Shulman). The rationale for the use of each of these standpoints is explained in the following sections.

2.5.1 Mediation of learning

2.5.1.1 Overview

The concept of mediated learning was introduced by Vygotsky (1978) as a result of his interest in the social activity of learners and how it influences their learning process. Mediation of learning, according to Presseisen and Kozulin (1992), is the "subtle interaction between teacher and learner in the enrichment of the student's learning experience" and an "important key to survival and success" (p. 1). Mediation therefore refers to the full understanding of knowledge in sharing experiences with each other as well as the organising of concepts in the minds of the learners (ibid.). Verenikina (2003) agrees with Presseisen and Kozulin (1992) when she argues that the concept of 'intersubjectivity', where learners and knowledgeable adults share common understandings, is central to mediation of learning.

For Vygotsky, mediation plays a major role in thinking of learning as a social act. According to Presseisen and Kozulin (1992), Vygotsky proposed the following types of mediators when mediating learning: human beings using different tools in the form of material tools as well as psychological tools. To begin with, Vygotsky argued that resource material such as posters, models, technology and the chalkboard, to name but a few, would have an indirect effect on the other tools used. The psychological tools used to mediate learning include the use of language as a mediational tool (Thompson, 2013). Thompson (2013) agrees with Vygotsky when he argues that speaking and writing in a specific language is crucial for the cognitive development of a learner.

Finally, and as important as the others, is the role of individuals in higher cognitive development (Presseisen & Kozulin, 1992). These individuals may include the teacher or any other knowledgeable person, or it may refer to the construction of new knowledge within the child (ibid.). To summarise Vygotsky's view of mediated learning, in the words of Thompson (2013): "mediated, social activity is the key to both learning and to cognitive development" (p. 250).

2.5.1.2 The role of the teacher in mediation of learning

In the mediation of learning, the teacher's role is mainly to stimulate learners' interest in science learning, by linking their everyday experiences to science concepts studied in the classroom (Sulaiman, Suan, Abdullah, Politeknik & Tinggi, 2007). Especially at primary school level, teachers not only need to prepare learners for understanding science at secondary level, but primarily learners should be 'fascinated' to learn science (ibid.). Sulaiman, et al. (2007) further argue that, to achieve this, teachers should be creative and imaginative in their teaching of science by using, for example, games, analogies, simulations and technology when planning for a lesson.

Furthermore, teachers should actively involve learners and encourage them to take initiative in hands-on activities such as constructing their own models, doing projects, making drawings, role-play, doing practical activities in the laboratory or doing problem-based learning (PBL). In PBL learners will have to get answers to real-life problems, guided of course by the teacher (Martin, 2012). Herein lies the importance of mediation of learning as espoused by Vygotsky. Teachers should also encourage learners to engage in dialogue and discussions with teachers as well as with their peers, to be able to link their everyday context with school science. By doing this, teachers can develop learners' curiosity about scientific concepts around them and build an exploratory attitude (ibid.).

Teachers should also be skilled in applying different teaching strategies such as inquiry, constructivism and demonstration approaches according to the lesson objectives. Therefore, as has been noted in the epigraph in this section, teachers as pedagogues, should be knowledgeable not only about the content, but also about the most effective way to stimulate learners to become interested in science and in this way enable learners to make more sense of scientific concepts (Alexander, 2004).

2.5.1.3 Prior knowledge as a mediational tool

The Namibian school curriculum implemented the learner centred approach by linking science learning to everyday context in science education (Kasanda, Lubben, Gaoseb, Kanjeo-Marenga, Kapenda & Campbell, 2005). According to the Namibian MEC policy documents,

> (a) The starting point is the learner's existing knowledge, skills, interests and understandings, derived from previous experience in and outside school.
>
> (b) The natural curiosity and eagerness of all young people to learn to investigate and to make sense of a widening world must be nourished and encouraged by challenging and meaningful tasks.
>
> (c) Learners should be empowered to think and take responsibility not only for their own, but also for one another's learning and total development.
>
> (d) Learners should be involved as partners in rather than receivers of educational growth (Ministry of Basic Education and Culture, 1993, p. 60).

In short, this approach advocates that learners' everyday knowledge should be nourished and learners should be empowered to be actively involved in their own educational growth, with the assistance of more knowledgeable others. Therefore, the importance of using prior knowledge in science as a mediational tool is clear and summarised by Roschelle (1995) who states that "curiosity, caring and exploration begin with what you know now" (p. 19).

However, the role of prior knowledge in assisting the understanding of new ideas and concepts is widely debated within education circles today. For instance, research has shown that, to be able to construct new concepts in science, a learner needs prior knowledge and experiences, or to be able to find appropriate links to their everyday experiences. Although it is true that learners are more able to construct abstract concepts in science when they draw from prior knowledge, Rochelle (1995) argues that science learning is often mediated in irrelevant ways, totally disconnected from learners' everyday experiences. Furthermore, science knowledge is seen as theoretical, structural and abstract (ibid.).

In contrast with these views, prior knowledge is seen as familiar, superficial and concrete (Roschelle, 1995). These dichotomies lead to the opinion of some researchers that science knowledge and prior knowledge are incompatible. Learners tend to differentiate between what they learn in the science classroom and what they experience in their everyday lives (Stears, Malcolm & Kowlas, 2003). However, a research study conducted in the Western Cape by Stears, et al. (2003) indicated that in classes where learners were more actively involved in the lesson and where they could relate to the content and share their experiences more freely, they achieved better marks in science.

It is therefore important that learners should, with the necessary assistance, be able to 'border cross' between every day science and school science (Kasanda, et al., 2005, p. 1806). In other words, in the mediation of learning, teachers should assist learners in making links between their own experiences and the concepts studied in the science classroom. This, however, requires a conceptual change that needs to take place in teachers as well as learners – a slow, transformative, unpredictable and difficult process, restructuring prior knowledge into scientific content (Roschelle, 1995).

As a result of these differences, a barrier is often created between what is learned as scientific knowledge at school and the scientific knowledge used in the community (Rennie, 2011). Rennie stresses that, to eliminate such barriers, teachers will have to find ways to integrate at least some parts of the curriculum with other interdisciplinary issues.

Skamp (2009) asserts that many concepts which have a high conceptual demand (e.g., atoms and molecules – which is the focus of this study) are rarely used in the everyday language of learners. To effectively mediate learning of these topics, the teacher must identify relevant prior knowledge and assess its potential role for teaching the specific concept. The first step of introducing matter at primary level should be, according to Adbo and Taber (2009), only to name different objects and indicate for example, what one can do with these objects. The next step would be to develop more abstract concepts such as separation of parts, before moving to linking the macroscopic level with the microscopic.

In exploring how curriculum documents have addressed this matter of prior knowledge, it was found that Grade 5 Natural Science learners are exposed to the fact that, although air cannot be seen, it is made up of matter and consists of smaller particles. Different activities should then be done to concretise this abstract concept, for example, to show that although it cannot be seen, air has mass and it takes up space (Namibia.MEC. Natural Science and Health Education Syllabus for Grades 5-7, 2007).

With this prior knowledge, it is argued, topics such as 'states of matter' and 'atoms and molecules' can then be introduced (Adbo & Taber, 2009), as is the case in the Namibian curriculum. Skamp (2009) supports the idea of introducing atoms and molecules at primary level, but stresses that the relationship between the different chemical symbols, for example types of bonding, should be discouraged at this level.

It should be recognised, however, that prior knowledge comes in different forms and plays an indispensable role in the way teachers and learners react to learning (Roschelle, 1995). Learners' everyday knowledge can be used effectively in different ways and phases of the teaching and learning process to improve learning. Stears, et al. (2003) suggest that prior knowledge can be used as a "starting point for learning science, as a reference point for thinking about the nature of science, and as a context for applying scientific ideas and skills". Each one of these phases allows space for critical thinking so that the learners can effectively integrate their prior experience to improve their learning.

Kasanda, et al. (2005) elaborate on the importance of using everyday knowledge in the science classroom to mediate learning when they report on the inclusion of everyday knowledge in the science classroom throughout several countries in Africa. The drive for implementing prior knowledge as a mediational tool to improve science learning, they argue, is threefold. The first argument is to build on "socio-cultural achievement" (p. 1806) in the sense that learners will increase their conceptual abilities, have a greater competence to make science-based decisions as well as improved understanding of the nature of science (ibid.).

Secondly, integrating learners' prior knowledge will empower them to take control of their own learning. Learners will more easily participate and be involved in classroom activities (Kasanda, et al., 2005). According to Stears, et al. (2003), learners are inclined to engage more freely with the teacher and their peers when they have experiences to share. However, learners have different ways in which they learn science and will contribute differently towards the science content. Kasanda, et al. (2005) support this view and highlight the importance of the teacher in recognizing each individual method of constructing scientific knowledge when mediating learning in the science classroom.

Finally, a context based curriculum would also widen learners' access to education (Kasanda, et al., 2005), preparing learners to take on the challenges of the outside world. To improve science learning, everyday knowledge of the learners may be used in different pedagogic strategies, as proposed by Kasanda, et al. (2005). Everyday context forms an integral part of explaining an idea, usually done by the teacher. In the mediation of learning process, teachers as well as learners can effectively rely on their prior knowledge to contextualize the science content when asking questions or providing explanations. Prior knowledge can be used for setting an assessment task as learners find it easier to relate to their own experiences than to draw responses from abstract non-conceptualised content.

For prior knowledge to be used as a mediational tool effectively in improving science teaching and learning, it is of utmost importance that teachers should be sensitive to the prior knowledge that learners have (Roschelle, 1995). Despite the importance of prior knowledge in the teaching and learning of science, it thus remains a challenge to apply it effectively. Factors making the effective use of prior knowledge difficult may include a science curriculum that is not really focused on active learner participation and is irrelevant to learners' everyday experiences (Rennie, 2011). The school curriculum is blamed for being too complex and difficult to understand by learners. In this way the curriculum unfortunately caters only for the minority of learners who pursue further studies in science (ibid.). Secondly, teachers may often feel unsure of how to handle the prior knowledge of learners in a classroom when it emerges unexpectedly and requires a change of mind-set by the teacher.

To this end, Rennie (2011) raises a concern that teachers will have to improve their content knowledge in order for them to bring real-life experiences into the science classroom for effective mediation of learning. Similarly, learners coming from different cultural, social and economic backgrounds may have different prior knowledge and may also experience conflicting interpretations of science knowledge, as emphasised by Rennie (2011).

Guided by lesson observations and interviews, it was important for me as a researcher in the context of this study to find out how Grade 7 teachers engage with prior everyday knowledge as a teaching and learning strategy in the mediation process. Hence, I discuss these below.

2.5.1.4 Use of models as a mediational tool

> *What 'truth' can we show with models of atoms and molecules? This question should never be far from us as we use models to help explain and predict chemical changes. A model cannot represent fully the thing modelled, and it may even mislead us if we imagine that the thing modelled must behave as predicted with the model (Keenen, Kleinfelter & Wood, 1980, p. 188, as cited in Harrison & Treagust, 1996, p. 511).*

As highlighted earlier, the teaching of chemistry relies on three levels – a macroscopic, microscopic and a symbolic level. In mediating learning, Wu, Krajcik and Soloway (2001) proposed different teaching strategies such as the conceptual change model, practical activities, the use of concrete models as well as the use of technologies (including 3-dimensional animations of models) to enhance conceptual understanding of abstract concepts in chemistry. eChem for example, is a computer-based program where learners are able to build models of molecules and make translations among chemical representations (Wu, et al., 2001). Taking different teaching strategies into consideration, Wu, et al. (2001) assert that the use of concrete models and technologies are the most effective methods for the teaching and learning of abstract science concepts.

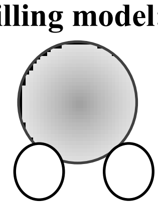
This study did not focus on the use of practical activities and technologies as teaching strategies, as learners in many schools in Namibia do not have access to practical equipment, computers and the internet. Instead, it focused on the use of models, as the use of models may be an effective way to simplify complex concepts and explain abstract entities in a more visible way (Justi & Gilbert, 2010). From a constructivist perspective, Justi and Gilbert (2010) argue that teachers should not only use models in their own teaching, but also encourage learners to engage in the use of models. However, for the effective use of models in the science classroom, Justi and Gilbert (2010) advocate that teachers must have the right skills to use the models.

One of the major difficulties in learning about matter, according to Adbo and Taber (2009), are the learners' macroscopic ways of thinking. These scholars believe that due to the microscopic nature of chemistry, it should be taught by means of models. For example, Swedish teachers make use of teaching models to simplify scientific knowledge. Wooden or plastic models, or even role-play, can be used to demonstrate the abstractness of the model of matter on a concrete, macroscopic level (Skamp, 2009).

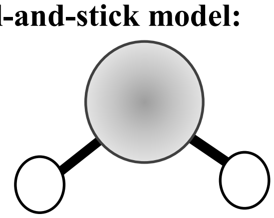
Analogical models used to represent the building blocks of matter

Harrison and Treagust (1996) postulate seven possible models to introduce most science concepts, namely: scale models, analogical models, mathematical models, chemical formulae, theoretical models, maps and diagrams, as well as a model or standard to imitate a process such as a physical and chemical change. Of these seven categories, chemical formulae and analogical models would be most appropriate to teach the topic of atoms and molecules. By comparison, chemical formulae (e.g. H_2O) will model the composition of molecules, whereas analogical models will be used to illustrate abstract patterns and relationships between atoms (e.g. space-filling models and ball-and-stick models) (ibid.). Examples of analogical models and chemical formulae of a water molecule as demonstrated by Harrison and Treagust (1996, p. 513):

(a) Space-filling model:



(b) Ball-and-stick model:



(c) Structural formula model: **(d) Lewis structure:**

Figure 1: Four types of analogical models used to illustrate molecules

Harrison and Treagust (1996) warn the reader that the use of models to explain a concept, may be confusing and challenging to many learners, especially those learners who still struggle to reason in an abstract way. They point out the importance of the model being as familiar and accurate as possible. To add value to the current argument, results of a study done on Grade 8 – 10 learners in Western Australia, claimed that 76% of the learners preferred the space-filling model to indicate the structure of a water molecule. Their responses were that it was closer to reality, as atoms are joined together with no spaces between them (ibid.). Adbo and Taber (2009) applaud this viewpoint by claiming that teachers need to discuss with learners the limitations and specific role of using models. If not, learners may tend to form their own distorted mental models about concepts and may see the model as part of reality. This may be confusing to the learners, resulting in difficulty to achieve higher mental functions.

Limitations of using models in mediation of learning

According to Adbo and Taber (2009), when primary school learners view microscopic concepts from a macroscopic perspective, it may provide opportunities to enhance the conceptual development of the learners. However, Adbo and Taber (2009) warn that models of the content are often presented by teachers without proper acknowledgement of the fact that it is only a representation of the actual concept. This may cause confusion amongst learners. Limitations arise when learners tend to form 'mental models' of the content, using their own individually created knowledge (ibid.). With these often distorted mental models, learners develop alternative concept formation that may be problematic in understanding future chemistry topics. This is more so if prior knowledge is lacking or learners already hold a very different view (ibid.).

Role of the teacher in using models

As has been noted, teachers may use models as effective ways during the mediation of learning to conceptualise abstract concepts in a more visible way (Justi & Gilbert, 2010). However, for the teacher to be truly effective Justi and Gilbert (2010) argue that teachers should have the ability to develop useful and relevant teaching models. Therefore, teachers should build on the prior knowledge of the learners when constructing models. In this way teachers will first have to understand the mental models constructed by the learners, enabling them to deal with possible distortions of these models formed by the learners. Finally, teachers should know "when, how and why" models should be introduced in a classroom (p. 1274). To summarise, models should "demonstrate the dynamic interplay of thought and actions in science" (ibid., p. 1274).

2.5.1.5 Use of language as a mediational tool

> *Language creates the possibility of thought, organises the thinking process and both reflects and shapes the human society in which it is used (Hodson & Hodson, 1998, p. 36).*

Moving on to the role of social constructivism when mediating learning of science concepts, it is important for the teacher to create optimal opportunities for learners to talk and write about their experiences in science, in order to develop insights into science as a subject integrated into their everyday lives (McRobbie & Tobin, 1997). In other words, for the cognitive growth of learners it is very important that they need to communicate by means of speaking, being spoken to as well as writing, even in the science classroom.

Lemke (1990) raises the importance of 'learner talk' and urges teachers to use teaching strategies that encourage learners to ask questions, instead of teachers asking the questions and learners merely responding. Informal small-group discussions, especially in the laboratory, may also give learners an opportunity to talk science without being pressured to do so in a formal classroom situation (ibid.).

Unfortunately, poor English proficiency due to the fact that the medium of instruction in Namibia is English, although it is usually neither the learners' nor the teachers' home language, has a huge impact on the education of the learner and may lead to poor academic achievement. The question now arises how linguistic support can be given to second language learners in the mediation of learning in the science classroom.

Teaching strategies to deal with second language learners and learning science

Although learners should be challenged cognitively, Probyn (2004) emphasises the importance of linguistic support to second language learners in order for effective teaching and learning to take place in the science classroom. Probyn (2009) draws our attention to the fact that many learners cannot express themselves in English, leading to high failure rates which could make them feel inferior. Probyn (2009) therefore advocates for the use of code-switching in the mediation of learning, where concepts will be explained in the vernacular of the learners. When using their mother tongue, learners can more easily understand certain concepts and it will assist in "reducing the alienation of the subject matter" so that learners can relate to own experiences (ibid., p. 133). As well as code-switching, teachers should use a range of different teaching strategies to mediate learning of abstract topics for second language learners. Such teaching strategies may include the question and answer method; repetition of new words; demonstrations and practical work; analogy; role-play; use of examples from learners' own experience and the using the chalkboard (Probyn, 2004).

The chalkboard can be utilized effectively by writing down new terminology so that new words are not only heard by the learners but seen as well. Students should be encouraged to create their own glossary of new terminology at the end of the topic. It is, however, crucial in the classroom that although teaching and learning activities should focus on the learners, it should still be facilitated by the teacher in such a way that effective learning can take place (Bencze, 2000).

Teaching and learning in schools is moving towards a view of learning whereby learners are no longer seen as spectators of the process, but are viewed as having the responsibility to be actively involved in the learning process (Hodson & Hodson, 1998). Through interaction with peers and teachers, learners will be able to create their own understanding of concepts and become competent participants of a sociocultural environment.

2.5.2 Social Constructivism

> *Although learning environments are necessarily personal, each individual's constructions are mediated by the actions of others in a social setting and characteristics of the culture in which learning is situated (McRobbie & Tobin, 1997, p.194).*

2.5.2.1 Overview

Mc Robbie and Tobin (1997) use this quote to emphasise the importance of social interactions in humans while learning. Jones and Brader-Araje (2002) note that the term *constructivism* acts as an umbrella term for several concepts and meanings. Individual constructivism, in the theories of Piaget (1967), focused on the individual while ignoring the influences of the socio-cultural context of which may be part of the learner (cited in Jones & Brader-Araje, 2002). In other words, individual constructivism focuses on the individual alone to build up a cognitive network of knowledge, irrespective of his or her social interactions.

On the other hand, Vygotsky (1978) as cited in Hodson and Hodson (1998) advocate the importance of the social interactions of learners when constructing new knowledge instead of focusing on the individual. This notion forms the basis of social constructivism. Moll (2002) complemented Hodson and Hodson (1998), by explaining that Vygotsky's theory of social constructivism is a process whereby learners construct their own knowledge with the assistance of more knowledgeable others – and in the context of this study, the Grade 7 Natural Science teachers.

Hodson and Hodson (1998) emphasise the importance of teachers in assisting learners to develop a perspective where the science content learned in the classroom is integrated with their own everyday experiences. Therefore, a shift from focusing on individual learners, towards highlighting the construction of knowledge within a social community should take place.

However, according to Hodson and Hodson (1998), teachers should bear in mind that learners are not all on the same level of development and are therefore functioning in different ways and requiring different amounts of teacher intervention. Certain structures, such as the zone of proximal development (ZPD) of a learner and scaffolding of learning from the teacher, according to Vygotsky (1978) should therefore being taken into consideration for social constructivism to be applied successfully in the science classroom (cited in Hodson & Hodson 1998). I now discuss these below.

2.5.2.2 Maintaining the ZPD of the learner

Vygotsky's theory on the zone of proximal development is defined by Goos (2004) as "the distance between a child's problem-solving capability when working alone and with the assistance of a more advanced partner, such as a teacher or peer tutor" (p. 262). Goos (2004) contributes to this definition when she claims from research done in a mathematics class, that peer interaction and argumentation, with the teacher controlling these interactions, may assist in creating a collaborative ZPD.

Similarly, Levykh (2008) argues that a child will develop faster psychologically when solving problems initially beyond his or her capabilities with the aid of a knowledgeable adult. The zone of proximal development is thus "not only about learning", Levykh (2008) argues, but also "about development" (p. 89).

Teachers should thus determine the ZPD of individual learners in order to challenge them to achieve greater levels with tasks beyond their actual level of development, but assist them in such a way that they will be able to reach that new level of development. As has been noted in Section 2.3.1, Vygotsky suggested different tools to use in the mediation of learning and establishment of the ZPD of a child (Levykh, 2008). He did not only suggest human artefacts such as models or art, but also emphasised the importance of psychological tools such as language and human emotions in the development of a child.

According to Levykh (2008), the ZPD focuses on long term successes. Therefore, it is important to establish and maintain the ZPD of a child for the following reasons: Firstly, functioning within the ZPD of a child can make the child feel safe and comfortable in his or her environment. Within this safe environment, the child can now develop intellectual knowledge (ibid.). Maintaining the ZPD of a learner can also assist in the effective learning process, for example, building on communicative skills such as new vocabulary and listening skills. An established ZPD may also enhance the memorisation of bigger amounts of knowledge at one time and transfer this newly acquired knowledge to the long-term memory of the learner (ibid.).

Verenikina (2003), amongst others, claims that the ZPD of a learner makes up the core of the scaffolding of learning to take place. This is the link between the concepts of ZPD and scaffolding. However, she argues, the ZPD can only qualify as scaffolding when the learning event enables a learner to carry out specific tasks with assistance of a knowledgeable adult or peer. The intention of the learning activity should be to allow the learner to eventually complete the task on his or her own and then there should be evidence that the learner achieved a greater level of independence after the completion of the activity on his or her own (ibid.).

This however, requires the teacher to be sensitive to each learner's level of understanding, in order to be able to know when to let the learner becomes more independent and no longer needs the teacher for assistance. Put in simple terms, the scaffolds are removed. By interacting and talking to learners, teachers can lead learners to new levels of conceptual thinking by interacting with them according to their own cultural understandings (Hodson & Hodson, 1998).

2.5.2.3 Scaffolding of learning within the Zone of Proximal Development of the learner

Although the term 'scaffolding' was originally introduced by Wood, Bruner and Ross (1976), elaborating on the important role of proper knowledgeable guidance in order for learners to solve problems beyond their unassisted performance, it became commonly associated with Vygotsky's notion of ZPD (cited in Goos, 2004). According to Jacobs (2001), scaffolding of learning will take place when "teachers or peers supply students with the tools they need in order to learn" (p. 125). The scaffolding of learning therefore is characterised by the teacher-learner dialogue that takes place to co-construct knowledge, the effectiveness of the specific activities used to construct knowledge, as well as the tools used in the mediation of learning (Verenikina, 2003). This means that the teacher can create a ZPD by scaffolding learning by creating opportunities for learners for higher cognitive development (Hodson & Hodson, 1998).

Despite the importance of scaffolding, however, it often can be seen as a one-way process where the teacher or knowledgeable adult gives the instruction and the learner is only a passive recipient of knowledge (Verenikina, 2003). Verenikina (2003) therefore asserts that effective interaction between learners and adults should take place when learning is scaffolded. As has been noted, language plays an indispensable role in this process (Probyn, 2004).

Various teaching strategies may be used to scaffold learners' understanding of science concepts. Akerson, Flick and Lederman (1999) discuss the following three teaching strategies as effective in scaffolding of learning: Firstly, they highlight the learning cycle, where learners' misconceptions (as described in Section 2.3.2) will be cleared up. Students will then participate in classroom activities and discussions to co-construct new knowledge and have the opportunity to compare this new knowledge with existing ideas. Learners will then be able to apply their new knowledge to everyday experiences (ibid.). During this process, teachers can break down concepts into smaller bits for learners to manage the content more easily. Teachers may also make use of demonstrations, guidelines and relevant examples to support learners in conceptualising new concepts.

Wright (2003) suggests the use of everyday contexts to illustrate atoms and molecules such as everything we touch is made of atoms; although we cannot see atoms, we can feel them, using gases to explain this concept; and the difference between liquids and solids can be used to illustrate the fact that atoms and molecules 'stick' to one another (p. 20).

The next teaching strategy proposed by Akerson, et al. (1999) is the use of analogies to help learners develop their own scientific ideas. In this regard, learners can find something known to them to assist in understanding new concepts and ideas (ibid.). For instance, they suggest that the use of LEGO-blocks may be used as an effective analogy to explain the building blocks of matter at a primary level. More examples of analogies may be to compare atoms and molecules with letters in a word, or even a sports team having players moving around (Wright, 2003).

Similarly, Akerson, et al. (1999) emphasise the importance of language and communication in the scaffolding of learners' perceptions. Teachers may scaffold learners' ideas through oral discussions and written activities and encourage learners to share their ideas with one another (ibid.).

Due to the abstract and microscopic nature of chemistry, Wu (2003) accentuates the importance of effective scaffolding from the teacher to facilitate learners in constructing a link between the macroscopic, observable, everyday science and the microscopic, chemical representations.

Finally, directing learning within the unique ZPD of each learner may "facilitate a positive learning experience and an appreciation for the subject being taught (Levykh, 2008, p. 99). It is recognised, however, that this requires a strong pedagogical content knowledge (PCK) on the part of teachers which I now discuss below.

2.5.3 Pedagogical content knowledge of teachers

> *What ideas do students already have about the topic? What representations, examples, and illustrations would be most suitable for these students in this context? What curriculum materials and teaching strategies would be most appropriate in light of the curriculum aims and objectives? (Geddis, Onslow, Beynon, & Oesch, 1993, p. 580).*

2.5.3.1 Overview

Teachers may have excellent content knowledge of a subject, say at an undergraduate or post-graduate level, but that does not mean they can necessarily teach or explain this content to students at a lower level. Thus, teachers should possess, what has come to be known as pedagogical content knowledge (PCK) which "goes beyond knowledge of subject matter *per se* to the dimension of subject matter knowledge for teaching" (Shulman, 1986, p. 9). According to Shulman, teachers need to have knowledge of the best strategies on how to mediate learning of specific topics to make it comprehensible to the learners and to clear up certain misconceptions learners may have about a topic. Bucat (2005) confirms this when claiming that there is a vast difference between having content knowledge and having the skills to teach that content effectively.

Although originally proposed by Shulman (1986), a number of authors elaborated on Shulman's notion of PCK, for example, Grossman (1990), Marks (1990), Veal and Makinster (1999), and Banks, Leach and Moon (2005), to name but a few (cited in Kind, 2009). This study will focus on Shulman's interpretation of PCK, with reference to some of the other interpretations where appropriate.

According to Shulman (1987), PCK refers to "the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students" (p. 15). To be able to achieve this, Shulman proposed seven categories of knowledge that teachers should possess to promote comprehension among learners (ibid.).

2.5.3.2 Categories of knowledge base for teachers

The first three categories of knowledge base for teachers include content knowledge of the subject, pedagogical content knowledge, as well as knowledge of the curriculum - all content based knowledge (Van Driel, Verloop & de Vos, 1997). According to Shulman (1986), subject content knowledge refers to the "amount and organization of knowledge per se in the mind of the teacher" (Shulman, 1986, p. 9). This in essence means that the teacher should not only know the basic content of the subject, but the 'why' behind the argument as well, showing deeper insight into the subject content matter. As has been noted in Section 2.5.1.3, the use of prior everyday knowledge of the teacher in the mediation of learning plays an indispensable role in this content based category of knowledge base for teachers.

Pedagogical content knowledge will imply appropriate examples, illustrations, analogies and explanations used by the teacher, as highlighted in scaffolding learning, to make the subject content accessible and comprehensible to the learners (Shulman, 1986). Curriculum knowledge, on the other hand, will embrace the material and programs developed for a specific subject and grade, to assist in the comprehension of the subject. However, knowledge on other topics taught at the same time may also allow for cross-curricular teaching (Shulman, 1986, 1987).

Shulman (1987) then goes on to include another four categories of knowledge base for teachers in the form of more general educational aspects such as general pedagogical knowledge, for example, strategies for effective classroom management to promote the transformation of subject content to learners (ibid.). The next category will be knowledge of the learners, their background and their characteristics will enable teachers to clear out prior knowledge preconceptions and misconceptions learners may bring with them at different ages (Shulman, 1986). As has been noted by Kasanda, et al. (2005), integrating learners' prior knowledge will again empower them to take control of their own learning. Thirdly, teachers will thus need to have knowledge of educational contexts such as the governance and financing of the school and the culture and character of the community as well as knowledge of the educational purposes and values as final bodies of knowledge to teaching (Shulman, 1987).

Shulman (1987) further argues that, among those seven categories, PCK is central in blending subject matter content and pedagogy. Of all categories, only PCK is unique to the teacher as the teacher now needs to combine the subject matter content with specific teaching strategies and additional knowledge base as has been mentioned above (Kind, 2009). Grossmann (1990) follows Shulman's line of thought by putting PCK in the centre of importance, surrounded by general PCK and knowledge of subject matter and context (cited in Van Driel, et al., 1997). Marks (1990) goes on to assert that PCK may even be so intertwined with subject matter and general pedagogical knowledge, that it sometimes may be impossible to distinguish between these three knowledge bases (cited in Van Driel, et al., 1997).

2.5.3.3 PCK in the context of science teaching and learning

As mentioned in the epigraph, Geddis, Onslow, Beynon, and Oesch (1993), amongst others, claim that subject matter knowledge first needs to be transformed into teachable content knowledge to make it accessible for learners, without giving up the reliability of the content. This is possible by demonstrating knowledge of not only possible misconceptions learners bring with them to class, but also knowledge of teaching strategies on how to clear out these misconceptions as well as alternative representations of the content. In other words, teachers need pedagogical content knowledge to transform subject content into teachable content. The teaching of concepts and complexities of modern science to children at the primary and high school levels poses many challenges. Thus, in the sciences especially, having PCK to mediate learning of science content effectively seems especially necessary.

Geddis, *et al*. (1993) summarise the model of pedagogical reasoning and action proposed by Shulman (1987) when they highlight at least four areas where PCK can play a role in order to effectively transform subject content. The first area they identify, prior knowledge of the learners, subscribes to the notion of Shulman (1986) that learners do not come to class as empty vessels. However, teachers need to know about the possible preconceptions and misconceptions about a topic to be "fruitful in reorganising the understanding of learners" (Shulman, 1986, p. 10).

Secondly, Geddis, et al. (1993) stress the importance of PCK in effective teaching strategies to transform subject content during the mediation of learning. As has been noted in scaffolding learners' understanding of science concepts, these teaching strategies may include conventional methods such as lecturing, demonstrations or recitation, or it may include more alternative and hands-on methods such as dialogue, projects, use of models and analogies and excursions outside the classroom (Shulman, 1987). Furthermore, according to Geddis, et al. (1993), alternative representations of subject matter, especially in abstract chemistry, play an indispensable role in transforming content knowledge, for example the use of chemical symbols, molecular formulae, electron configuration or even physical models to demonstrate abstract concepts. Teachers need to use examples as close as possible to the everyday experiences of learners to simplify complex, abstract concepts for better learner understanding (ibid.).

Finally, Geddis, et al. (1993) argue that teachers should have sound knowledge of the importance of the topic relative to the overall science curriculum – a concept known as "*curricular saliency"* (p. 583). Considering the curricular saliency may have an effect on the amount of time spent on a specific topic, regarding the importance of the topic as it fits into the whole curriculum. In other words, curricular saliency may be extremely important in "teaching for understanding" instead of "covering the curriculum" (ibid., p. 589).

Shulman (1986) summarises the effectiveness of having a sound knowledge of PCK to foster proper conceptual understanding of subject matter in learners with the following: *"Those who can, do. Those who understand, teach"* (p. 14).

2.6 CONCLUDING REMARKS

In this chapter I explored the literature that relates to the effective mediation of learning of abstract topics that require high cognitive demand.

Critical issues that emerged from the literature included the need for considering prior knowledge of learners and teachers, selective use of models and language as mediational tools in the teaching and learning of science concepts. This work was explained in the context of the social constructivist theory of Vygotsky, including scaffolding within the ZPD of each learner in conjunction with the notion of PCK. In the next chapter I discuss the methodology and methods that I used to investigate the Grade 7 teachers' mediation of learning of the topic of atoms and molecules.

CHAPTER THREE: RESEARCH METHODOLOGY

> *A qualitative case study is an approach to research that facilitates exploration of a phenomenon within its context using a variety of data sources. This ensures that the issue is not explored through one lens, but rather a variety of lenses which allows for multiple facets of the phenomenon to be revealed and understood (Baxter & Jack, 2008, p. 544)*

3.1 INTRODUCTION

The main goal of my research study was to investigate how primary school teachers mediate learning of the topic of atoms and molecules. Atoms and molecules is an abstract topic that requires higher cognitive thinking skills of learners. What follows in this chapter is an outline of the research design and orientation that I used to generate, analyse and interpret the data (Section 3.2). This chapter also includes in Section 3.3 the research goal and questions that guided the data gathering process. Section 3.4 outlines the research site and sampling. I follow this with a discussion of different data gathering techniques (Section 3.5) used to generate data. The data analysis process is described in Section 3.6, while Sections 3.7 and 3.8 deal with issues of validation, trustworthiness and ethical considerations taken into account before, during and after the fieldwork. This chapter concludes by giving a summary of what emerged in Section 3.9.

3.2 RESEARCH DESIGN AND ORIENTATION

Research design forms the foundation of the research process. According to the purpose of the research, the research question and the philosophical position of the researcher, the researcher will select the design with which to answer the research question (DePoy & Gitlin, 2011). Thus, my research is a qualitative case study, located within the interpretive paradigm.

3.2.1 Interpretive paradigm

In an attempt to understand how teachers mediate learning of the abstract topic of atoms and molecules to primary school learners, this study was informed by an interpretive paradigm. According to Cohen, Manion and Morrison (2011), an interpretive paradigm focuses on the individual as the subject of the research and tries to "get inside the person and to understand from within" (p. 17). Morehouse (2012) supports this viewpoint when he describes interpretive research as a process that focuses on individual parts to understand the bigger picture. This approach therefore enabled me to seek for answers beyond the obvious classroom experiences by using interviews, observations and data analysis.

3.2.2 Case study

Within the interpretive paradigm, I carried out a qualitative case study. Check and Schutt (2012) define a case study as "the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (p. 190). As this case study focused only on the mediation of learning of a single topic in the Grade 7 Natural Science syllabus, I tried to gain some insights and understanding of how teachers effectively intercede in the learning of atoms and molecules. In this study, my case was two Grade 7 Natural Science teachers' practice, teaching atoms and molecules. My unit of analysis was mediation of learning.

The research was qualitative in approach, which, according to Boudah (2011), entailed conducting a systematic study with a focus on rich descriptions to "conduct a systematic study of a case or cases to give a rich description of the object of inquiry" (Boudah, 2011, p. 127). The qualitative researcher, according to Check and Schutt (2012), makes use of what is said, as well as what can be seen, to identify certain patterns in the collected data that could result in "narrative interpretations that create meaning" (p. 10). The qualitative case study therefore allowed me to use the information generated to provide an in-depth description and explanation of the mediation of learning in the science classroom.

3.3 RESEARCH GOAL AND QUESTIONS

3.3.1 Research goal

The main goal of this study was to investigate how Grade 7 Natural Science teachers mediate learning of the topic of 'atoms and molecules'.

To achieve this goal, the study was guided by the following questions:

3.3.2 Main research question

How do Grade 7 Natural Science teachers mediate learning of the topic of atoms and molecules?

Sub-questions:

(1) How do Grade 7 Natural Science teachers scaffold learners to make sense of the concepts of atoms and molecules?

- To answer this question, I analysed documents such as the learners' notebooks and workbooks, as well as the lesson plans of the teachers. I also did some observations and the lessons were videotaped (See Section 4.5).

(2) (a) What challenges do Grade 7 Natural Science teachers experience in mediating the topic of atoms and molecules?

(b) In what ways do Grade 7 Natural Science teachers deal with the challenges that learners face in making sense of the concepts in the topic of atoms and molecules?

- To answer this question, I observed lessons which I videotaped and analysed. I also interviewed the two teachers (See Section 4.4). Although I made use of a 'successful' teacher, I anticipated that he experienced the same challenges as any other teacher, with the only difference being that he might be able to provide ideas on how to overcome these challenges.

(3) In what ways can Grade 7 Natural Science teachers be supported with mediation of learning of the concepts on the topic on atoms and molecules?

- To answer this question, I had an informal discussion with the teachers while watching the videos with them. Developing lessons on the specific topic together with the teachers involved (phase 2), also helped me to answer this question (See Appendix H).

3.4 RESEARCH SITE AND SAMPLING

In selecting research participants I targeted only a particular group, as only two teachers were the focus of my research. Despite the disadvantages of this type of sampling, in the sense that data collected cannot be generalised, it is less expensive and less complicated to collect the data needed (Cohen, *et al*., 2011).

Hence, for this study, sampling was done purposively and conveniently, as the qualitative researcher seeks “maximum variation, rather than a random sample” (Morehouse, 2012, p. 74). Two teachers, teaching Grade 7 Natural Science and Health Education in two different schools in the Khomas Region were ‘hand-picked’. One of the teachers chosen as a research participant had graduated from the former Windhoek College of Education as an Integrated Natural Science student. The other research participant is known to me due to the fact that he successfully organises the annual science fairs at the school where lecturers and students of the University of Namibia act as judges.

Originally my approach was to identify two teachers in the Windhoek region who are both known for using a variety of approaches in the mediation of learning of abstract topics in Science Education (Thomson & Sefton-Green, 2011). As I am not directly involved in primary schooling, it was difficult to get hold of the teachers as they were quite busy with activities at their respective schools. One of my research participants was promoted to acting principal with a very busy schedule so I had to allow him to withdraw from the project. A third research participant, who was keen to improve her teaching skills, was then included. Although I had to change my approach slightly, I still made use of a ‘successful’ teacher, as mentioned in Section 3.3.1, I believed that a ‘successful teacher’ experiences the same difficulties as any other teacher, the difference being that he could give insights into how to overcome these challenges. The schools were chosen based on convenience as both were close by and easily accessible. Although Site 1 is a private school and Site 2 is a government school, these schools were not compared with one another as such but rather used to get some insights into how this topic is taught.

3.5 DATA GATHERING TECHNIQUES

The data in this study was gathered in two phases. Phase one aimed at answering research questions (1) and (2) while phase two aimed at answering research question (3).

Phase 1

According to Boudah (2011), there are mainly three sources of data used in qualitative research: document analysis, interviews and observations. Boudah further states that although these are the three principal methods, the researcher can be extremely flexible in collecting the data (ibid.). For the purpose of this study, I made use of all three data gathering techniques for triangulation purposes.

3.5.1 Document analysis

According to Lambert (2012), scrutinising different documents may allow the researcher to collect rich data to be used in the research process. Therefore, the first part of my research design was to analyse official curriculum documents such as the National Curriculum for Basic Education (2010) and the Natural Science and Health Education Syllabus Gr 5-7 (2005). The National Curriculum for Basic Education allowed me to gauge the importance of cognitive development of learners as well as the approaches to follow in the mediation of learning in the science classroom. From the syllabus, as well as the Grade 7 Natural Science textbook and other teaching material, I was able to get clarity on the prescribed content and pedagogy of the topic on atoms and molecules. After analysing the basic competencies in the syllabus, I realised that I should also include mediation of learning of elements and the periodic table in my study. I also gathered rich data through analysing the workbooks of learners to reveal the active participation of the learners in constructing knowledge as part of LCE. Test scripts of learners on the topics of atoms and molecules as well as elements and the periodic table were also analysed to discover any misconceptions learners might have as well as to look into learners' conceptual understanding of the topic.

The Standardised Achievement Tests (SATs) results for Grade 7 Natural Science countrywide were analysed to examine the performance of learners in application questions, especially the topic of atoms and molecules, as these questions often relate to a higher level order of thinking.

3.5.2 Interviews

According to Cohen, et al. (2011), interviews enable the interviewer as well as interviewee to "discuss their interpretations of the world in which they live, and to express how they regard situations from their own point of view" (p. 409). I conducted semi-structured interviews with two selected Grade 7 Natural Science teachers from two different schools in the Khomas Region. Open-ended questions (see Appendix F1), which were specific in their intent, were asked to allow for individual responses (McMillan & Schumacher, 2006).

Due to ethical considerations, interview questions were given to research participants beforehand. This however proved to be not effective as Teacher 1 then did not respond to the questions, instead, he started talking about his experiences and problems that may arise in the science classroom generally. The interview then adopted an informal discussion approach, complicating the analysis process (see Appendix F2).

All interviews were audio-recorded and transcribed verbatim to allow capturing of important detail and to ensure that an accurate record of what was verbally communicated was reported. After conducting the interviews I realised that I had to modify the research questions slightly as I noticed that teachers were facing obstacles that they did not know how to deal with, such as lack of resources, textbook and syllabus issues. I therefore had to add research question 2(a). These obstacles will be dealt with in more detail in Section 4.

3.5.3 Observations

To gather 'live' data that otherwise might be taken for granted or go unnoticed, my third data gathering technique was observations (Cohen, et al., 2011). Check and Schutt (2012) contend that observations should also be used to complement data collected from the interviews and document analysis.

Cohen, et al. (2011) clarify two types of participants when making observations; participant- and non-participant observers. As a non-participant observer, I stayed aloof from the classroom situation that I observed (ibid.). Observations done in the classrooms allowed me to see how teachers scaffold learners to help them make sense of the concepts on atoms and molecules. To be able to achieve this, a semi-structured observation schedule was used as a guideline (see Appendix G3), with "an agenda of issues, but will gather data to illuminate these issues in a far less predetermined or systematic manner" (Cohen, et al., 2011, p. 457). In brief, an observation schedule was used only as basic guideline, as useful data, not included in the observation schedule, might have emerged from the observations.

I observed three lessons of Teacher 1with the same class to enable me to gather data on most aspects of mediation of learning of the topic. As Teacher 2 completed the topic in two lessons, I only managed to observe two of her lessons. Thus, I was able to observe how teachers mediate learning while introducing, presenting, concluding and assessing the topic through the use of prior knowledge, analogies and different forms of learner support material. I was also able to observe student-teacher interactions. Teacher 2's lessons were video-recorded by a critical friend, but due to time constraint and the busy schedule of my critical friend, all lessons for Teacher 1 were video-recorded by me. All of the lessons were then transcribed and analysed. As only one video camera was used for recording, I was able to make short field notes throughout the recording of the lessons of Teacher 2.

Due to many long weekends and public holidays during the school term, teachers were about a month behind their planning. This caused a delay in my observation schedule.

3.5.4 Piloting of interview questions

The interview questions were piloted with two other MEd (science) students during a contact session at the beginning of 2014. This enabled me to refine the interview questions in order to be able to gather a rich amount of data from my research participants.

<u>Phase 2</u>

Development of a teaching unit of work on atoms and molecules Grade 7

This phase aimed at answering the third research question. Specifically, in what ways can Grade 7 Natural Science teachers be supported with mediation of learning of the concepts on the topic on atoms and molecules?

In order to assist the teaching of the topic, I developed a teaching and learning unit of work on atoms and molecules together with the participating teachers, using the reflections of my observations, interviews and document analysis. Both teachers had some learning support materials on this topic. Teacher 2, however, felt that her teaching resources were not up to standard and by improving them, she could enhance learners' understanding of the topic. Both teachers expressed the wish to have more links to You-tube video clips, practical activities or other interesting facts included in the unit of work.

As the three of us are stationed at different places, it was awkward for all of us to meet at the same time. To overcome this, I met with the teachers separately. The comprehensive set of material developed by Teacher 1, gave me an effective starting point. In addition, the collaborations with my participants helped all three of us to develop professionally as teachers.

I designed two lessons as part of this unit of work and presented them during a contact session at NIED to the B Ed (science) honours students, as a pilot for the final unit of work. The aim of this unit of work is to assist learners to grasp the content, as it consists of strategies for the teachers to use on how to introduce, present and discover the topic of atoms and molecules at primary school level. The unit of work also facilitates discussions and reflections on how to enhance mediation of learning of this topic.

The following table summarises the different stages of my research.

Table 1: Showing the tools and methods used, and the purpose for the gathering of information:

Stage	**Methods used to gather data**	**Data gathered**	**Purpose**
PHASE 1 **Stage 1**	Document analysis of Curriculum documents	1. Science curriculum: What curriculum documents say about development of	To get some insight on the aims of the curriculum regarding creative thinking and development of

		cognitive skills of learners? 2. Syllabi: (a) NSHE Syllabus Gr 5-7: Content to be covered on topic of atoms and molecules in Grade 7. (b) Physical Science Syllabi Grade 8-10 and Ordinary Level Gr 11-12: Content to be covered building atoms and molecules as foundation. 3. Gr 7 Natural Science textbook 4. Workbooks of learners and lesson plans of teachers	cognitive skills of learners. To find out information about the content to be covered for the topic of atoms and molecules in Gr 7 as well as practical suggestions. To find out which topics in secondary chemistry build on atoms and molecules as foundation. To investigate how much assistance teachers get from textbooks in the mediation of learning of the topic. To scrutinize how teachers scaffold learners in the mediation of learning.
Stage 2	Pilot	I piloted my research questions as well as interview questions on two other M Ed students not involved in my research process.	To pilot my data gathering tools so that I can improve on them so that the research process runs smoothly
Stage 3	Interviews: I interviewed two Gr 7	Teachers' perceptions of mediation of learning of	To gain insight into the strategies of teachers in

	science teachers.	abstract topics.	scaffolding learners. To get clarity on challenges experienced in teaching of abstract topics. To investigate possibilities of intervention to improve the mediation of learning.
Stage 4	Lesson observations of Grade 7 science lesson introducing topic of atoms and molecules	How teachers mediate learning of the topic of atoms and molecules	To study the strategies of teachers in scaffolding learners. To explore possibilities of intervention to improve the mediation of learning.
Stage 5	Structured recall interviews	As follow-up on stages 3 and 4, this was conducted with the research participants to clarify any misinterpretations.	To ensure validity and to investigate the participants' views of understanding
Stage 6	Transcribing audio and video recorded data	To get information from interviews and classroom observations.	For data analysis
PHASE 2	Development of a module together with participating teachers	Strategies and examples on how to introduce, present and discover the topic of atoms and molecules at primary school level.	To answer research question 3: Ways to support teachers with mediation of learning of the concepts atoms and molecules.

3.6 DATA ANALYSIS AND FRAMEWORK

Cohen, et al. (2011) claim that qualitative data analysis is a way to make sense of data by organising it into themes and categories. Any emerging patterns and consistencies are then noted and are used to facilitate the interpretation of the data.

When analysing the data that I gathered, I made use of the five stages of qualitative data analysis outlined by Check and Schutt (2012):

(1) **Documentation of the data and the process of data collection:** This was done by transcribing data collected from interviews, observations and document analysis.

(2) **Organisation/Categorisation of the data into concepts:** Thematic analysis enabled me to categorise my data into themes, such as identifying different teaching strategies i.e. prior knowledge applied, learner support material and analogies or models used as well as problems faced and how teachers overcame them in the mediation of learning of the topic. Each theme was colour coded with a different colour, to identify similar information (Cohen, et al., 2011).

(3) **Examining relationships to show how one concept may influence another:** Finding relationships in the different themes allowed me to find explanations of “why things happened the way they did” (Check & Schutt, 2012, p. 304). I highlighted all text relating to a particular concept with the same colour. Similar concepts were then grouped together to form themes by cutting and pasting them into a document in order to create analytical memos.

(4) **Authenticating conclusions by evaluating alternative explanations, confirming evidence, and searching for negative cases:** The themes that emerged from the data was interpreted and discussed. Data analysis was thus **inductive** in approach, as categories and patterns emerged from the raw data collected, rather than being imposed by structured research objectives (Thomas, 2003).

(5) **Reflexivity:** By reflecting on the “development of the evidence” of my study, it enabled me to evaluate my findings and make sense of how my perceptions could have influenced my conclusions and findings (Check & Schutt, 2012, p. 308).

3.7 VALIDATION AND TRUSTWORTHINESS

Hamilton and Corbett-Whittier (2013) define validation as: how accurate the findings of the research are to reality.

Different steps were taken to strengthen the validity of the findings.

Firstly, methodological triangulation was employed as I used different techniques, such as interviews, observations and document analysis, to gather data. Cohen, et al. (2011) describe triangulation as comparing and checking of data gathered through different data collection methods.

Secondly, interview questions were piloted with fellow master students to establish validity. The unit of work prepared in Phase 2 was piloted with honors science education students to ensure the effectiveness and reliability thereof.

Follow-up interviews as well as stimulated recall interviews of video recorded lessons were conducted with the research participants to clarify any misinterpretations. Lyle (2003) advocates for this process in interviews with research participants to "stimulate recall of their concurrent cognitive activity" (p. 861).

Finally, validity was also enhanced through member checking (Hamilton & Corbett-Whittier, 2013). That is, research participants were provided with a copy of the transcripts and were given the opportunity to confirm or deny the researcher's conclusions.

3.8 ETHICAL CONSIDERATIONS

According to Hamilton and Corbett-Whittier (2013), ethics refer to the "norms of conduct that distinguish between acceptable and unacceptable behaviour" (p. 64). Various authors have alluded to the ethical dilemmas that a qualitative researcher is often confronted with as a result of human participation.

Therefore, I adhered to the four basic ethical priorities as described by McMillan and Schumacher (2006):

Prior to the research, I sought permission from the Regional Director in the Khomas Region, as well as school principals of the identified schools and the teachers. This was done in writing where the aim of the research was explained clearly (see Appendix A).

Throughout the study research participants were guaranteed confidentiality. Only I had access to the participants' information (DePoy & Gitlin, 2011). The research participants were also guaranteed anonymity, as pseudonyms were used for schools (School 1 and School 2) as well as for the participants (Teacher 1 and Teacher 2) so that no information could be linked to the research participants' identity (ibid.).

Negotiations took place with research participants so that they understood their power in the process. Interview questions were discussed beforehand with both research participants. Furthermore, I explicitly indicated that lessons and interviews would be video- and audio-taped for the purpose of the study only. Participants were urged to be truthful as the outcome of the study would not only benefit me, but also them and could inform important interventions to the advantage of others. Informed consent takes place when individuals decide whether they still want to participate in an investigation or study after they were informed of all aspects that could have an impact on their participation (Cohen, et al., 2011). Therefore, participants were informed that participation was voluntary and withdrawal at any point would be allowed.

3.9 CONCLUDING REMARKS

This chapter focused on the research design and methodology of the study. My emphasis was on document analysis, interviews and observations as the main tools used to generate data in order to answer my research questions. The research methods as well as coding methods used to analyse the data are outlined in this chapter. Furthermore, this chapter explained the triangulation methods and ethical considerations and concluded with the limitations of my study.

The data that informed this study are presented in the next chapter.

CHAPTER FOUR: DATA PRESENTATION AND ANALYSIS

> *Data analysis is a systematic search for meaning. It is a way to process qualitative data so that what has been learned can be communicated to others. Analysis means organizing and interrogating data in ways that allow researchers to see patterns, identify themes, discover relationships, develop explanations, make interpretations, mount critiques, or generate theories (Hatch, 2002, p.148)*

4.1 INTRODUCTION

This chapter deals with the presentation and interpretation of two sets of data gathered during my research. The first section refers to Phase one of the study and the second section to Phase two. In this chapter, I report on findings from data gathered via lesson observations, interviews with teachers which were reinforced with stimulated recall interviews and document analysis. As indicated in the epigraph above, I present my data in themes that emerged from the data gathering process that were influenced by my research questions.

I start by describing how the samples of each data set were chosen. I then outline the teachers' profile information, which I consider crucial for proper contextualising of the data due to huge disparity between the profiles of the teachers. Thereafter, findings are presented as per the given situation generated from different data-gathering techniques used.

4.2 THE SELECTION OF THEMES FROM EACH DATA SET

In order to answer my research questions, the samples of data sets were chosen according to the following themes:

- Application of prior knowledge;
- Use of models and analogies;
- Other learning and teaching support material used;
- Teacher-learner interaction;
- Challenges faced by teachers in mediation of learning the topic; and
- How do teachers deal with the challenges when teaching the topic?

4.3 TEACHERS' PROFILES

Two teachers from different schools were involved in this study. Both schools are situated in an urban area in Windhoek in Namibia. As explained in Section 3.4, the teachers were 'handpicked', on the one hand to gain insight from an experienced teacher, and on the other to find out more about the problems that teachers have to deal with on a daily basis.

Teacher 1 (T1) is situated at School 1, which is a private school with many resources available and only twenty learners per class. The learners as well as the teacher speak Afrikaans as their mother tongue with English as a second language. Teacher 1 is an experienced teacher with a doctorate in Plant Science and seven years teaching experience, some as a lecturer at a university in South Africa, lecturing Biology education. Currently he is teaching Natural Science and Health Education to two Grade 7 classes. He is confident in using learning and teaching support materials (LTSMs), for example, information technology such as the smart board, white board and computer.

Teacher 2 (T2) teaches at School 2, a government school with few resources and up to thirty-five learners per class. Although the learners are all from one cultural group, speaking Herero as mother tongue with English as a second language, the teacher's mother tongue is Oshivambo but she speaks English fluently even though it is her second language. She has a basic educational teaching diploma (BETD), obtained from a College of Education in Namibia and has 4 years teaching experience. Currently she is busy with an advanced certificate in Mathematics and English and is keen to improve her teaching skills. She teaches Natural Science and Health Education for two Grade 7 classes, as well as two Grade 6 classes. I present data from Phase one below.

PHASE 1

4.4 DOCUMENT ANALYSIS

The first data gathering technique used in this study was to analyse documents including the Natural Science and Health Education Syllabus Grades 5-7, two textbooks mainly used by teachers, the SATs report as well as workbooks of some of the learners. I did this hoping to gather rich data (Section 3.5.1), as well as for the purpose of triangulation (Section 3.7).

4.4.1 Natural Science and Health Education Syllabus Grades 5-7

The syllabus is systematically divided into three columns, indicating the theme/topic, learning objectives and basic competencies for each topic. Theme 3.3 – Building blocks of matter is then subdivided into:

3.3.1 - Atoms and molecules;
3.3.2 – Elements and compounds and
3.3.3 – Mixtures and solutions.

For the purpose of this study, I will only focus on 3.3.1 and 3.3.2 as elements are closely related to atoms. Based on my analysis of the syllabus, the basic competencies could be confusing as it does not mention any detail on molecules, yet this is in the topic. The basic competencies are oversimplified, by only requiring concepts to be stated. No detail of the structure of the atom is required, although concepts such as protons and electrons are required in Topic 6.1 as part of static electricity. This may cause confusion, especially for the novice teacher, into how much detail should be done to equip learners with enough prior knowledge for chemistry topics to be studied later (see Section 2.3). A statement made in the learning objectives of 3.3.2 is also not correct as atoms combine to form molecules and not compounds as stated in the syllabus. This may cause confusion by teachers.

The figure below gives the layout of the basic competencies of this topic in the syllabus:

Figure 4.4.1: Basic competencies for the topic on atoms and molecules as laid out in the Natural Science and Health Education syllabus for Grade 7

THEMES AND TOPICS	LEARNING OBJECTVES: Learners will:	BASIC COMPETENCIES: Learners should be able to:
3.3 Building blocks of matter		
3.3.1 Atoms and molecules	• Know that every element has a name and symbol (know at least the first 10 elements, as well as C, O, U, Cu, Au, Fe, Ag, Al, N, Pb, Cl)	• State that atoms are the smallest building blocks of matter • Explain that all matter consists of elements or combinations thereof • State that the periodic table is a classification of all existing elements • Classify elements into metals and non-metals • State that every element has a name and a symbol (know at least the first 10 elements, as well as C, O, U, Cu, Au, Fe, Ag, Al, N, Pb, Cl)
3.3.2 Elements and compounds	• Know that atoms combine to form compounds, which are the building blocks of matter (an extension of the particle model) • Understand the difference between an element and a compound	• State that elements combine together chemically to form compounds (e.g. water, H_2O and carbon dioxide, CO_2) • Name practical examples of most common elements, compounds and mixtures found in everyday life, the Earth's crust, the atmosphere and water

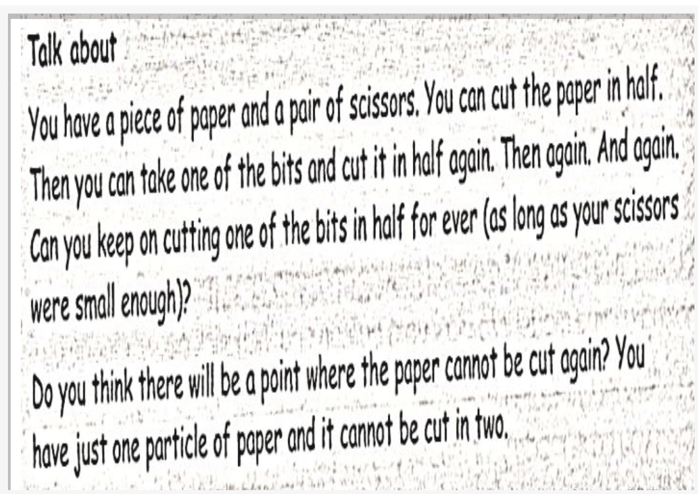
It is encouraging to find that the basic competencies require contexualisation of common elements found in everyday life.

4.4.2 Textbook 1: Natural Science and Health Education Grade 7 (Elphick, Olivier, Tyson, & Beljon, 2005)

This textbook introduces the topic of atoms and molecules with a possible activity to arouse interest and direct the learners to the content. Insertions encourage active interaction and dialogue between learners and the teacher as an approach to the mediation of learning of the topic. Examples are given below:

Figure 4.4.2 (a) and (b) show activities to encourage active interaction and dialogue (p. 10; p. 12)

(a)

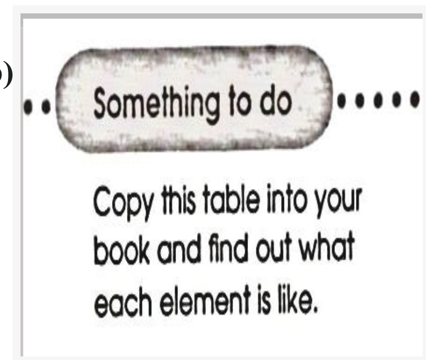


Talk about

You have a piece of paper and a pair of scissors. You can cut the paper in half. Then you can take one of the bits and cut it in half again. Then again. And again. Can you keep on cutting one of the bits in half for ever (as long as your scissors were small enough)?

Do you think there will be a point where the paper cannot be cut again? You have just one particle of paper and it cannot be cut in two.

(b)



Something to do

Copy this table into your book and find out what each element is like.

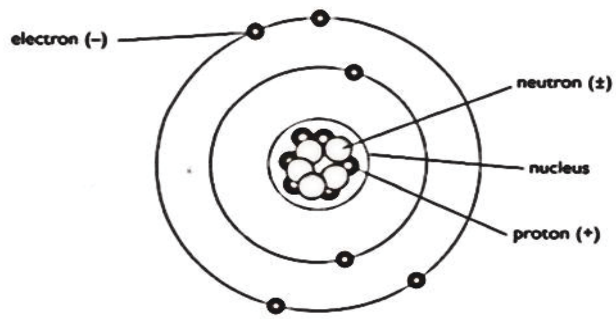
Although no analogies are used in the textbook, two different analogical models of a molecule are presented, in the form of a space-filling model and the ball-and-stick model (Section 2.5.1c).

The limitation of this textbook, however is, that the content is written in a simplistic format, highlighting only main points from the basic competencies of the syllabus. This might lead to a lack of coherence between the concepts. The absence of a glossary of terms or activities to test the learners' conceptual understanding of the basic competencies in the syllabus makes the textbook less user-friendly.

4.4.3 Textbook 2: Natural Science and Health in Context Grade 7 (Clegg, 2007)

Based on my analysis of the textbook in relation to my study, this textbook has adopted a user-friendly approach. Detailed definitions, relation of concepts to each other and labelled diagrams guide learners to a higher cognitive level than required in the syllabus (See example below).

Figure 4.4.3.1 shows diagrams guiding learners to a higher cognitive level (p. 46)



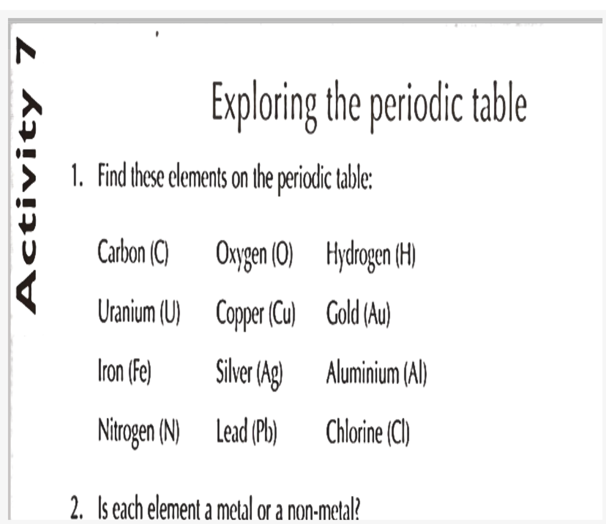
The structure of an atom.

No glossary of terms is given for this topic, and activities to test the learners' conceptual understanding of the basic competencies in the syllabus do not really allow for consolidation of concepts, especially on atoms and molecules.

The following inserts show the only examples of activities on atoms, molecules and elements in Textbook 2:

Figure 4.4.3.2 (a) and (b) show the only activities to encourage active interaction and dialogue on atoms and molecules in Textbook 2 (p. 47; p. 49).

(a)



Activity 7

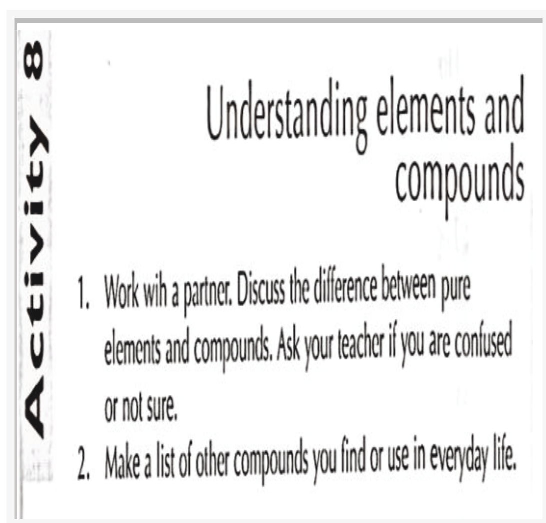
Exploring the periodic table

1. Find these elements on the periodic table:

Carbon (C)	Oxygen (O)	Hydrogen (H)
Uranium (U)	Copper (Cu)	Gold (Au)
Iron (Fe)	Silver (Ag)	Aluminium (Al)
Nitrogen (N)	Lead (Pb)	Chlorine (Cl)

2. Is each element a metal or a non-metal?

(b)



Activity 8

Understanding elements and compounds

1. Work wih a partner. Discuss the difference between pure elements and compounds. Ask your teacher if you are confused or not sure.
2. Make a list of other compounds you find or use in everyday life.

Although the concepts of 'atoms' and 'molecules' are the primary concepts for learners to master, none of the activities access understanding of these concepts. Furthermore, the concept of elements is not related to the Namibian context, for example, explaining where some of the elements are mined in Namibia. This might lead to concepts being mediated in irrelevant ways, totally disconnected from learners' everyday experiences (Section 2.5.1.3).

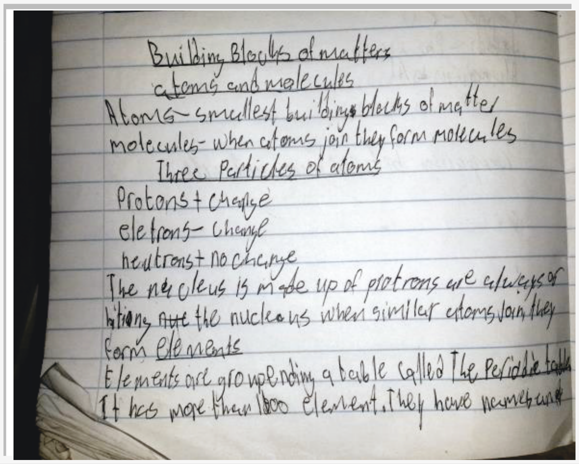
4.4.4 Workbooks of learners in School 1

In School 1 learners do not make use of the prescribed textbooks. Each learner has his/her own set of notes prepared by the teacher. A separate workbook is used to complete activities. At the time of collecting the data, it was the start of examinations at School 1. Learners therefore had completed the topic, yet there was no time to complete activities in their workbooks or write the test. However, I managed to look at other activities done. A variety of questions were posed and it was often expected that learners would apply their new knowledge to everyday experiences. Activities were marked regularly and learners had the opportunity to correct mistakes. As Teacher 1 did not feel comfortable sharing his study guide and workbook that he prepared, I had to respect his feelings due to ethical reasons.

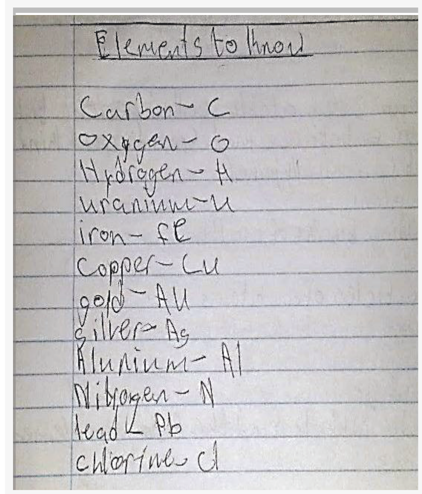
4.4.5 Workbooks of learners in School 2

As learners in School 2 do not have their own textbooks, they have to use their workbooks for writing down summaries from the chalkboard as well as to complete activities. Even though the summaries were given correctly, as can be seen, often the summaries made were not of a high standard, messy and mistakes were made. Figure 4.4.5 (a) and (b) give an indication of some of the summaries made by learners. Learners often used, for example, capital and small letters wrongly when writing symbols of elements. This may result in confusion when writing formulae of molecules.

Figure 4.4.5 (a) and (b) show summaries written down from the chalkboard by learners on concepts discussed in class.

(a) 

Building Blocks of matters
atoms and molecules
Atoms – smallest buildings blocks of matter
molecules – when atoms join they form molecules
Three Particles of atoms
Protons + charge
eletrons – charge
neutrons + no charge
The nucleus is made up of protrons are always or
~~ntte~~ the nucleus when simller atoms join they
form elements
Elements are groupending a table called The Periodic table
It has more than 100 element. They have number and

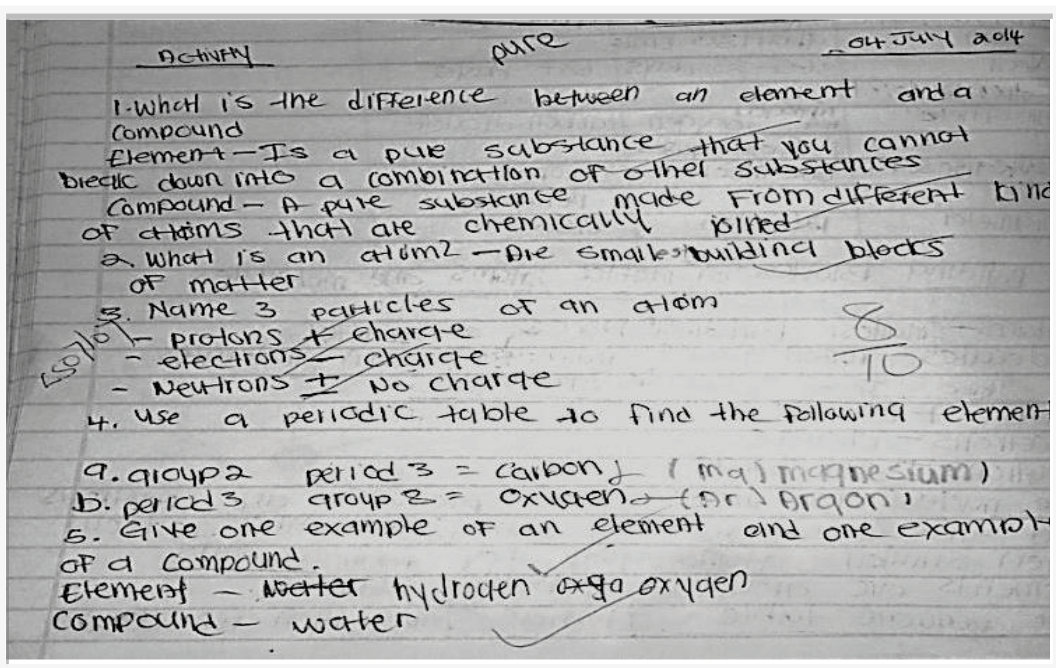
(b) 

Elements to know
Carbon – C
oxygen – O
Hydrogen – H
uranium – U
iron – fE
Copper – Cu
gold – AU
silver – Ag
Alunium – Al
Nitrogen – N
lead – Pb
chlorine – Cl

During the informal discussion with Teacher 2, it was clear that she does not have the time to check the accuracy of the summaries.

Activities were given to consolidate concepts discussed and the questions asked cover different levels of cognitive demand and are marked regularly by the teacher. As illustrated in Figure 4.4.5 (c) below, I noticed that Teacher 2 corrected mistakes as this is also a source of information for learners as they do not have their own textbooks.

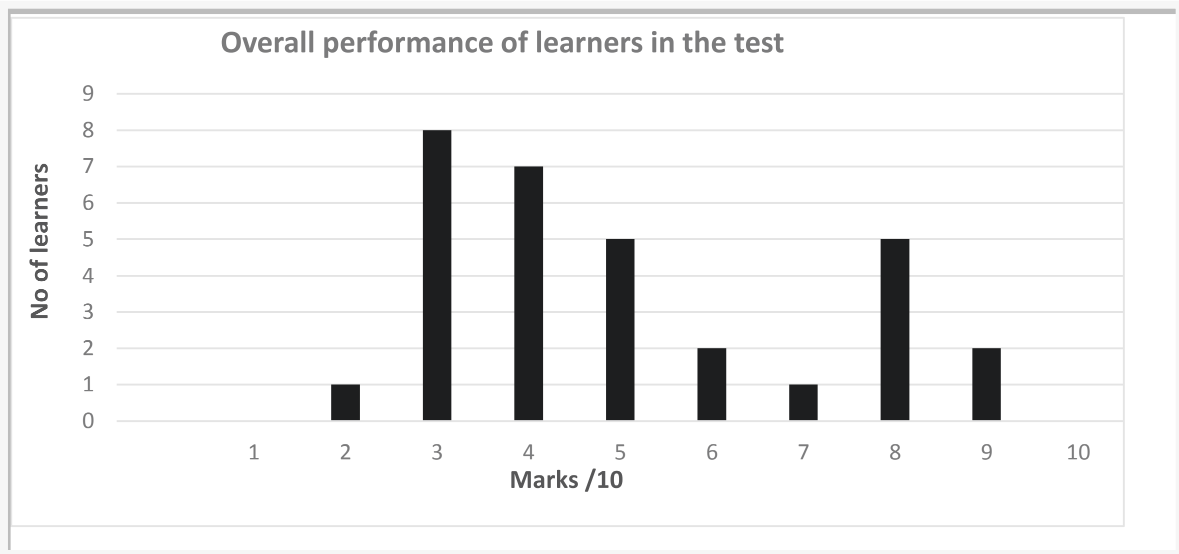
Figure 4.4.5 (c) shows a class activity done by learners in consolidation of concepts



Activity pure 04 July 2014
1. What is the difference between an element and a compound
Element – Is a pure substance that you cannot break down into a combination of other substances
Compound – A pure substance made from different kind of atoms that are chemically joined
2. What is an atom? – Are smallest building blocks of matter
3. Name 3 particles of an atom
– protons + charge
– electrons – charge
– Neutrons + No charge
8/10
4. Use a periodic table to find the following element
a. group 2 period 3 = carbon (mg) magnesium)
b. period 3 group 8 = oxygen (Ar) Argon)
5. Give one example of an element and one example of a compound.
Element – ~~water~~ hydrogen ~~oxg~~ oxygen
Compound – water

A test was written at the end of the topic with question items requiring learners to not only apply knowledge, but to analyse and compare as well (see Appendix D2). The graph below indicates the overall scores of the 31 learners.

Graph 4.4.5 indicates the overall performance of learners in the test on atoms and molecules in School 2.

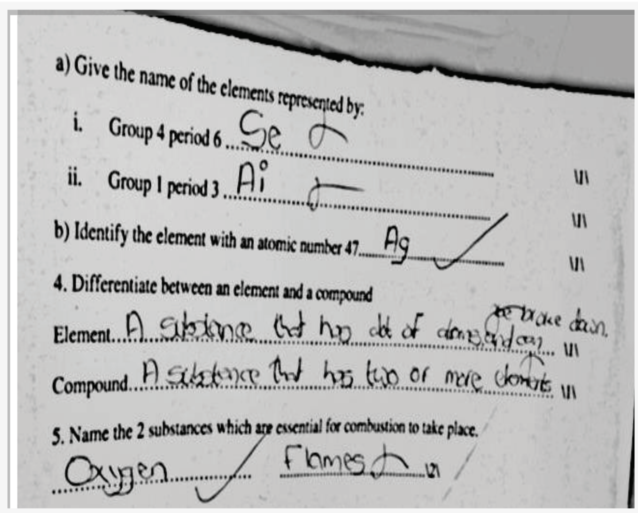


From the graph, it was clear that 21 out of 31 learners do not have more than 50% knowledge and understanding of the topic on atoms and molecules. Almost everyone was able to identify the atom as the smallest building block of matter, but more that 60% of them had no insight at all about the definitions of other concepts. It was clear from analysing the tests, that even though the definitions were given in the summaries, the majority of learners still were not able to compare elements with compounds.

The following extracts in Figures 4.4.5 (d) and (e) indicate some of the answers given by learners:

Figure 4.4.5 (d) and (e) show answers given by learners during a test on atoms, molecules and elements.

Figure 4.4.5 (d)


a) Give the name of the elements represented by:

i. Group 4 period 6 ... Se

ii. Group 1 period 3 ... Ai

b) Identify the element with an atomic number 47 ... Ag

4. Differentiate between an element and a compound

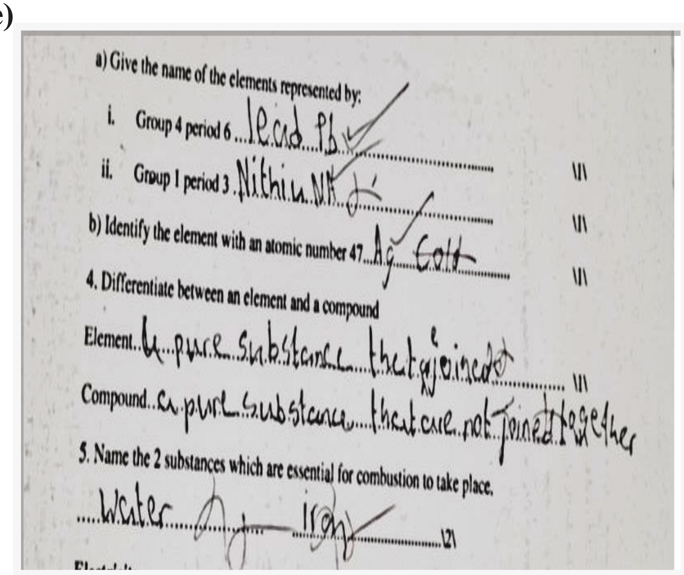
Element ... A substance that has ...

Compound ... A substance that has two or more ...

5. Name the 2 substances which are essential for combustion to take place.

Oxygen ... Flames

(e)


a) Give the name of the elements represented by:

i. Group 4 period 6 ... lead Pb

ii. Group 1 period 3 ... Nithiu NA

b) Identify the element with an atomic number 47 ... Ag

4. Differentiate between an element and a compound

Element ... a pure substance that ...

Compound ... a pure substance that are not joined together

5. Name the 2 substances which are essential for combustion to take place.

... Water ...

It was noticed that in extract 4.4.5(e), an answer that was marked wrong by the teacher when the symbol for the element sodium was written as NA, was corrected by the Head of Department who moderated the test papers.

4.5 INTERVIEWS

The second data gathering techniques I used was to conduct interviews with each of the two teachers at their respective schools. The purpose of conducting the interviews was firstly, to find out the positive and negative experiences of the teachers with teaching the topic of atoms and molecules, and secondly, to ensure validity.

4.5.1 Interview with T1 (I-T1)

The interview with Teacher 1 was in the format of an informal discussion of the interview questions. For Teacher 1 the continuous use of prior knowledge is indispensable throughout teaching and learning of this topic. In his own words: "*you need to trigger the child's perception of 'I want to know more' and 'how does this thing work*" (Appendix F2; I-T1: 8).

In the words of Teacher 1: "*In my first lecture I will show them the video 'Planet Earth and Living things'. Do you know why? Because when you talk about atoms on day 1 and you talk about atoms six months later, the child has heard about it somewhere already" (*Appendix F2; I-T1:203).

The use of prior knowledge takes an interesting turn as Teacher 1 believes that the levels of organisation in organisms are most important in the topic of atoms and molecules. The teacher indicated in his own words: *"So the Levels of organisation for me is more or less the most important prior knowledge and then of course Form and Function"*. On prior knowledge, Teacher 1 also emphasised the importance of starting every lesson with the concepts discussed in the previous one.

During the interview it became clear that Teacher 1 makes use of different models and analogies in scaffolding learners to make sense of the topic of atoms, such as the ball-and-stick model; use of different magnets to illustrate the proton/neutron; school building made up of bricks; and then in his own words:

> "*For example, you can take a Mc Donald's burger. If you eat too much of this you will get fat. Why? And then we can take that burger and break it down till we get to the building blocks of atoms. What is inside the burger? Meat, flour, sugar. What does all these things consist of? Then you end up with carbon, oxygen, hydrogen – different elements, atoms"* (Appendix F2, I-T1: 242).

When asked about learning support materials and other ways of scaffolding learners to make sense of this abstract topic, Teacher 1 responded that they are fortunate to have a smart board in the classroom which he makes use of to show video clips. "*I will show them physically a video of exactly how the protons are fixed and the electrons are running around it"; and "I will show them videos on the internet that indicates how atoms combine physically*". Furthermore he plays games such as 'musical chairs' to illustrate the structure of the atom; repeats content at least 3 times in different ways; and then makes use of different examples that the learners can relate to in their own environment. He explained as follows:

> "*they know Uranium, they know the Rössing mine. They know it, but how can we bring it in connection with what we are doing? We have power stations in Japan; we have Koeberg in South Africa. This is how I keep science relevant. And the Uranium the kid reads about on the front page of 'Die Republikein (*Namibian newspaper*), is the same he*

sees on the periodic table and could bring it back to protons, neutrons, electrons" (Appendix F2; I-T1:163).

Another important aspect of scaffolding, according to Teacher 1, is interactive sessions between learners and the teacher. He explained:

> "*The next morning it will be like a fire alarm. I will for example say: Pieter, come to the front and explain to us this or that*", or "*I will say "let's take water today". We will discuss the structure and then we will take another molecule, for example Sodium hydroxide. So I will say: Right, there you go! Go and find out more about sodium hydroxide. So the next morning I will put up sodium hydroxide on the board and then ask kids to come to the front. I will ask them to draw the atom of sodium"* (Appendix F2; I-T1:133; 138).

Although Teacher 1 is confident in teaching, and teaching this topic specifically, he discussed a few trials that he has to face in assisting the learners to make sense of the topic of atoms and molecules. These will be dealt with in Table 4.5.1 below.

Table 4.5.1: Summary of challenges faced by the teacher in the mediation of learning of the topic of atoms and molecules to grade 7 learners as identified by Teacher 1 during an interview

Identified challenges faced by teacher	Effect on teaching and learning	Ways in which teacher deals with the challenges
(a) Teachers and learners Concept of atoms very abstract	Learners fail to conceptualise abstract concepts. Learners lose interest in topic.	Use of video clips, games, relevant examples to conceptualise concepts.
Concepts not taught in understandable ways	Learners fail to contextualise abstract concepts. Lose interest in topic.	Teacher makes associations with everyday experiences
Interpretation of questions in examination	Poor performance in examination	Start with scientific method as prior knowledge "*what is inside the scientific method as a whole and how do you approach a problem or questions inside the sciences. If they understand this, they can interpret a lot"* – T1. Explain science terminology to

		learners. "*kids must know the origin of a word and the meaning of it as a lot of information is contained in a word*" - T1.
(b) Textbook issues Examples not relevant to present	Learners fail to make connections	"*Russia is threatening to 'nuclear' the Ukraine. I will always bring it back to what is happening now*". "*It is the responsibility of the teacher to keep it alive and recent*" - T1.
(c) Syllabus issues Level of content oversimplified	Confusion and misconceptions in the minds of learners	Incorporate some basic competencies of grade 8 Do many extra examples " *to capture a concept, rather than to oversimplify it* - T1"

4.5.2 Interview with T2 (I-T2)

This interview started with the teacher being asked how she experiences teaching the topic of atoms and molecules. She indicated that this topic is really difficult to teach as it is the first time the learners have faced a topic like this. In her own words she said: *".... they give me this look like – wow, what's going on here? Is this Physical Science, or what? They not really enjoy it. It's just... I don't know."* (See Appendix F3; I-T2:15).

The biggest challenge Teacher 2 faces in teaching this topic, is that she does not feel comfortable with it topic. She says:

> *"just the fact that you have to explain something that I find a challenge myself. I understand it, but I don't understand it so fully – you know like any other topic. Yes, I do research, but then it's quite challenging trying to explain something, trying to make it **fun**, you know, but they don't really see it in.*" (Appendix F3; I-T2:129).

Some other obstacles she experiences are given in Table 4.5.2 below.

Table 4.5.2: Summary of obstacles faced by teacher in mediation of learning of the topic of atoms and molecules to grade 7 learners as identified by Teacher 2 during an interview

Identified challenges faced by teacher	Effect on teaching and learning	Ways how teacher deals with challenges
(a) Teachers and learners: Lack of prior knowledge	Learners cannot fit content into other prior knowledge	
Topic abstract and no analogies or everyday experiences to compare with – "*These are not things they relate to in everyday life, for example the human body" – T2*	Learners fail to contextualise abstract concepts. Lose interest in topic.	
Lack of learning support material	Topic stays abstract and learners fail to understand or make sense of topic	Teacher prepares her own posters of the periodic table as well as on structure of atoms.
Information technology (IT) not sufficient and ineffective	No use of OHP or video clips to make learners to visualise abstract concepts better –"*I want to show learners how those electrons are moving in the atomic structure – T2".*	Teacher makes use only of chalkboard and posters
Language used – second language English speaking learners (Learners Herero-speaking while teacher is Oshivambo-speaking - therefore no code-switching could take place).	Lack of comprehension. Wrong spelling of terms. Poor classroom interactions.	
Overcrowded classrooms – not enough chairs for everybody to sit on	Learners not focused. Need to write on their laps	
(b) Textbook issues: (described in detail under Section 4.6.2 and 4.6.3 Limited resources	3 or 4 learners sharing a textbook in class. Time consuming as learners need to make summaries from chalk board	Writes summaries on chalk board for learners to copy

	Wrong spelling of terms lead to content wrongly studied	
Summative – not enough detail and not linked with prior knowledge	Difficult to conceptualise concepts and seeing the broader picture	
Content oversimplified -"*The learners want more. Not a lot of information, they just want to link things to 'why do these things happen*?' " – T2.	Confusing to learners as well as teachers with not enough prior knowledge	Summaries made using two textbooks as well as the internet Teacher does some research on the internet, but "*it's more based on the United States" – T2*
Not enough activities given – "*there is only one and that's it!"*	Learners not actively involved in activities, therefore do not enjoy learning about the topic	
Examples given in textbook not relating to Namibian context	Learners struggle to link science concepts to real life experiences (see Section 2.5.1c). May lead to learners not performing in this topic – "*their overall performance in this topic is not so good comparing to others" – T2.*	
(c) Syllabus issues: (described in detail under Section 4.6.1 Not clear enough	Concepts are oversimplified when being taught, leading to misconceptions.	
Not enough detail – "*some things are not in the syllabus, like molecules".*	Confusing to teachers on depth of content and what concepts to be covered.	Teacher goes into more depth than required from syllabus, by doing research in two textbooks as well as using internet at home.

Regarding the elicitation of prior knowledge, Teacher 2 mainly focuses on what the learners have done in Grades 5 and 6 on the topic matter. No other everyday experience is taken into consideration. When being asked about the teaching strategies used to scaffold learners in the classroom to make sense of this topic, Teacher 2 indicated that there isn't really much she can use as "*there isn't a lot in there and they are not really involved in this.*" She did however identify strategies used in teaching and learning of atoms and molecules, such as the use of prior knowledge, use of posters and mainly the chalkboard. On prior knowledge, she said that it assists in conceptualising the rather abstract topic of atoms and molecules as:

> "*water is a molecule, because it is made up of hydrogen and oxygen. That they are familiar with. In grade 6 there are matter – and they are also talking of the three states of matter. So matter they know is anything that can occupy space and has mass*". *The use of concrete examples, such as: "a table, your desk, you, even us humans – all have atoms in our bodies" (Appendix F3; I-T2:24).*

After watching the video of recorded lessons with the teacher, we discussed the hindrances that emerged from the video. During an informal discussion, she was asked to reflect on what she could have done differently. She identified better use of learning and teaching support materials (LTSMs); spreading the content over more days to prevent jumping between concepts; more effective conceptualisation of concepts as well as allowing more time to guide learners properly in writing summaries.

From data gathered via interviews, I gained insight into the teachers' view of scaffolding learners in the mediation of learning of the topic on atoms and molecules. Teachers also managed to indicate some of the problems they faced in teaching this topic. In the next section I elaborate on lesson observation as the third and last data gathering technique used.

4.6 LESSON OBSERVATION

Observation was used to gather 'live' data that otherwise might be taken for granted or go unnoticed (Section 3.3.3). I therefore used observation to complement the data generated from the interviews and document analysis as it enabled me to answer my research questions.

For Teacher 1 three lessons were observed, of which one was a double period, and videotaped. Each lesson lasted about 30 minutes. For Teacher 2, however, I was only able to observe 2 lessons of 30 minutes each, as she completed the topic in only two lessons. I identified this as a possible reason for the fact that she struggles with this topic. During all the lessons, a critical friend videotaped the lessons on my behalf, so I was able to make some field notes on an observation schedule during the presentations.

Being in the classroom I was able to observe different teaching strategies used by the teachers in scaffolding the learners to make sense of the topic. It also enabled me to experience some of the difficulties faced by the teachers and learners as discussed during the interviews and observed how teachers dealt with some of them. After the lessons observed with Teacher 2, she was given the opportunity to reflect on the lessons while watching the videos with her. Feedback was then given to her in anticipation that this would assist in improving her teaching skills.

4.6.1 Teacher 1 (O-T1)

Lesson 1 and 2 (double period)

This lesson (double period) was only on the concept of atoms. The lesson started with the teacher giving the objectives of the lesson. He said:

> *"we are going to do the section in your books on atoms – the structure of atoms, a bit of the functions of atoms in relation to what you guys have done up to now. And we are going to start off with this picture. (Teacher puts on Smart-board and shows the picture of the Levels of Organisation in the biosphere to the learners)".*

The purpose was to prepare the learners for what was expected from them in this particular topic and connecting this with previous concepts discussed. The teacher used an interesting approach to prevent the topic from being isolated from other topics using the Levels of Biological Organisation as elicitation of prior knowledge. He then positioned the atom according to the rest of the Universe, for the learners to be able to better construct these new concepts. In his words he said:

T: *So if we look at the whole Universe, it all relates back to atoms. Atoms basically allow for the whole Universe to stay together. This is because the atom is structured in a specific way which I am going to show you this morning. It's because the atom is the atom that the whole world can stick together and stays together. And it is continuously … what? (Teacher makes vibration movements with his hands)*

LLL: *Vibrating!*

T: *Yes, the whole Universe is continuously vibrating and I am going to show you this as well. And when we start touching on molecules I just give you the example when we did the digestive system about three weeks ago what happens to the building blocks of carbohydrates for example. So I'm gonna show you also where an atom fits into a loaf of bread which we eat every day. Okay, is it fine?*

The lesson was presented in the form of power point slides although the teacher only used the summary as well as diagrams on the smart board to guide teacher-learner interactions. The classroom interaction was mainly a discussion between the learners and the teacher. The teacher often posed well-structured questions of higher cognitive demand. Clarity was then sought by posing follow-up questions. To illustrate, the teacher started the discussion with the question (Appendix G1; O-T1: 35). The following example gives an indication of the interaction between the teacher and learners:

T: *Who can tell me, how do we know that gas has mass?*

L: Because you can buy it in a bottle

T: So everything in the whole Universe has mass. If anything is composed of particles, it will have mass. Even a dust particle, even the lightest gas in the world! Who knows what the lightest gas in the world is? Can you guess?

L: Hydrogen

T: Yes! And we will go to why hydrogen is the lightest gas. So now we know that a brick has mass and a pencil have mass and takes up space. And the very important one that many of you did not know before a week ago, is that even air has mass! Right, now, uhm….. can you think of anything that is not considered as matter?

L: (No response)

T: Hierdie masjien (indicating to the projector light in the roof) doen dit ook. (Freely translated: "This machine does it as well").

L: Lig! (Freely translated: "Light"!)

Lig! So there are physicists in the world who actually think that if you look at light and the Universe – for light to exist, there must be some form of matter involved. So the normal answer that people will give you is that light is not matter. Can you capture light and cool it and condense it so that it can have mass?

LL: No!

T: *So that is one thing! Het "n mens se asem massa? (Freely translated: "Does human breath have mass"?) Yes! Why? (Teacher breathes out against his hand). What is in your breath?*

L: *Water vapour*

When the teacher wanted to clarify a point or have a spontaneous discussion with the learners, he would code-switch from English to Afrikaans (Appendix G1; O-T1: 81). When he explained the importance of using a model for abstract concepts, he said:

> *"I am now going to talk in Afrikaans so that everybody understands – Baie keer kan ouens nie altyd 'n ding sien nie, maar hulle maak 'n teorie van hoe hulle dink dit moet lyk. Nou as ons 'n reaksie met daai ding maak en die resultaat is wat ons verwag het dit moet wees, dan is die model reg. Verstaan julle"?*

He then immediately translated it into English as this was the medium of instruction.

> "*So millions of experiments have been done since 1930 in every single lab across the world up until this day and they still prove the model of the atom is the right one! So the atomic bomb that you see is the result of the function of the atomic structure. So even though we cannot see the atom we know that the atom model fits into the function of the atom. Okay? "He* further said: *"En daai lekkertjies wat mens so suig – is glucose! (Freely translated: "And that sweets that we all suck – is glucose!").*

The teacher then used an activity to support learners' understanding of the size of an atom. Learners started to do the activity without knowing the outcome and the teacher guided them throughout the activity. This led them to explore and be excited about the outcome. They responded as follows:

L1: Dis onmoontlik! (Freely translated: "It's impossible!")

L2: Meneer, ek is al by 8! (Freely translated: Sir, I am already at number 8!)

L3: Ek is al by 11! (Freely translated: I am already at 11!)

Equally important as doing a practical activity to involve learners, it could be concluded that the teacher was trying out other teaching methods to mediate learning of the topic, such as prior everyday knowledge, analogies and interactive diagrams as an attempt to help learners make sense of abstract concepts such as atoms. The teacher managed to relate the size of the atom to the learners' every day experience by relating it to the thickness of aluminium foil; amount of atoms in a human cell, and in a grain of table salt. It was clear that this strategy kept the learners interested and actively involved in the lesson at all times. The use of the smart-board for three-dimensional and interactive diagrams and the white board to write on assisted in keeping the lesson alive and interactive. The teacher used an athletic track surrounding a field (a concept well-known to all the learners) as analogy to explain the structure of the atom.

It was clear that the content explained by Teacher 1 was of a higher cognitive demand as required from the syllabus. Concepts such as sub-particles, atomic mass, atomic number, orbits and the stability of an atom, were clearly explained to the learners to establish a proper conception of the concept of an atom. According to learners' answers in response to questions asked by the teacher, as well as questions asked by some learners, it was clear that the conceptual development of most learners was on a par with the content covered and it was clear that most learners had proper insight in the topic. Questions asked by some learners were as follows:

L1: Sir, what is the biggest atom?

L2: In an atom, is the protons and neutrons in the same amount?

L3: If hydrogen has no neutron, is that what makes it so unstable?

L4: Meneer, maar hoeveel ringe is daar? (Freely translated: Sir, how many orbits are there?)
T: Seven. Up to seven orbits, but you guys only need to know the first two.

L: So al 118 pas perfek in die sewe in? (Freely translated: So all 118 fit in perfectly in that seven"?).

In contrast with questions indicating higher cognitive understanding, a question such as: "*Meneer, is 'n atoom 'n organisme?"* (*Freely translated: Sir, is an atom an organism?),* made it clear that not all learners were on the same level of understanding and that the teacher should be sensitive to each learner's level of understanding.

Lesson 3

This lesson was a continuation of the previous lesson, but focused more on elements, molecules and the periodic table. The teacher again made effective use of power point slides on the smart-board. The lesson started with ample time spent on elicitation of prior knowledge and consolidation of basic concepts discussed during previous lessons. This took place mainly in the form of the question-answer method as well as active participation through discussion between teacher and learners. The teacher posed well-sequenced questions, guiding learners to a new level of understanding. Clarity was sought by posing follow-up questions. There was a good balance between teacher talk and learner talk.

Effective use of the white-board enhanced learner participation. Individual learners were asked to come to the white-board to complete the structure of different atoms. An example of a learner completing the structure of sodium is shown below.

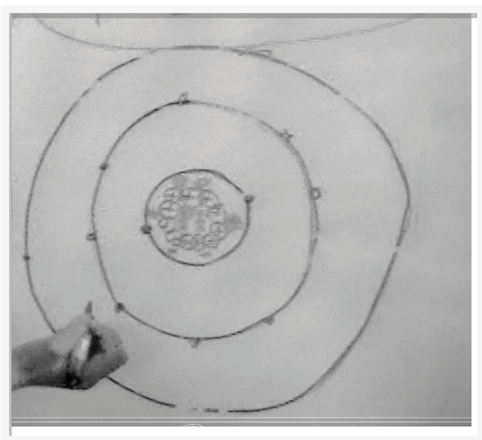


Figure 4.6.1 shows an example of learner participation in activities on the white board

This gave the teacher the opportunity to evaluate learners' conceptual understanding of the concepts so that he could clear up any misconceptions or incorrect mental models made by the learners.

Peer interaction and argumentation, with the teacher controlling these interactions, assisted in creating a collaborative ZPD as discussed in Section 2.5.2.2. Teacher 1 involved learners actively in line with their cognitive abilities. It was clear that he was scaffolding learners in order to challenge them to new levels with tasks beyond their actual level of development, but assisting them in such a way that they could reach that new level of development as discussed in Section 2.5.2.2.

An example of scaffolding from the teacher was observed when he said: (Appendix G1; O-T1: 70) "*Now what I want you to do is – I want you to come to the white-board and we are going to draw those 5 elements on the smart-board. Who wants to come first? Come Gerhard, I will help you! (Learner comes to the front).*

T: Okay, you will take sodium for us – I will help you! So sodium has 11 protons and 12 neutrons. So let's take the blue for the protons and then you can just make a plus (+). We use the green for neutrons that is a neutral colour – just make a dot (●) for the neutron. And the electrons? Red! We do it like this (e^-).

T: Okay, I will read for you to make it easier (teacher reads from smart-board). So there is Sodium and it has 11 protons. How many orbits do we need to fill in? The first one has …?

L: 2

T: Second one?

L: 8

T: That gives us 10. So we need to draw a third one as well. So fill in the 11 protons with plusses.

T: Okay Gerhard, dan vat jy vir ons die groen en hy moet 12 neutrons hê. Maak net sirkeltjies (freely translated: Okay, Gerhard, then take the green and it should have 12 neutrons. Only make little circles). (Teacher observes that learner is making Θ to indicate neutrons.) Okay, onthou hulle het nie 'n lading nie, so jy maak net 'n kolletjie. Anders as jy dit so maak lyk dit of hy 'n negatiewe lading het (freely translated: Remember, they do not have any charge, so you only make a dot. If you do it like this, it will be as if it has a negative charge.) (Teacher assists in correcting boy's diagram). Remember, a neutron has NO charge! The electrons have the negative charge!

Another interesting example of scaffolding was when a learner was confused about the three circles around the nucleus. Teacher 1 did not explain on the spot, but gave the learner the opportunity to come up with her own conclusion after guiding her throughout the activity. And, as has been noticed in the previous lessons, Teacher 1 would switch to the vernacular in order to clarify concepts. For example, to ensure that the concept was clear, he said the following:

> "*And there we have all the electrons! Verstaan jy nou waar kom die drie vandaan, Alicia? Jy maak eers die eerste vol met twee in die eerste orbit – dis 'n universal law on the atom model – the first orbit has two electrons, dan's hy vol! The second orbit has 8, dan's hy vol. And in the case of Sodium, there is only one left, so the third orbit will take that one, dan is daar nog sewe plekke oop".(freely translated: "Do you understand where the three comes from, Alicia? You fill up the first with two electrons, then it is full – it is the universal law on the atomic model – the first orbit has two electrons, then it's full! The second orbit has 8, and then it's full. And in the case of Sodium, there is only one left, so the third orbit will take that one, and then there are still seven places open"). Do you understand now, Alicia"?*

Teacher 1 explained new concepts while continuously referring to the examples of water, carbon dioxide and glucose as written on the white-board. In doing this, he unpacked new concepts, using prior knowledge and the same everyday examples throughout the discussion.

4.6.2 Teacher 2 (O-T2)

Lesson 1

The lesson started with a short elicitation of prior knowledge on matter (Section 2.5.1.3). The learners were then directly introduced to the definitions of atoms, molecules and elements, mainly via teacher talk. At the very beginning of the lesson, Teacher 2 defined atoms and molecules as: *Okay, I said Matter is basically made up of small little tiny building blocks called atoms and then the atoms are formed to form molecules. When we take for example two atoms or one or three atoms, and we join them together, they form a molecule.* (Appendix G2; O-T2:16). However, towards the end of the lesson, learners were not able to answer the question asked by the teacher (ibid. line 141): *Who can tell me what is a molecule?*

LLL: What? Huh?

T: What is a molecule? [No response from any learner]. When I started, I explained what an atom is and I also explained what a molecule is. [Now two learners slowly put up their hands].

However, she tried to consolidate definitions by asking learners to give relevant examples of molecules (Appendix G2; O-T2:18-24).

T: *For example, this chalk is made up of small little tiniest particles. Can somebody give me an example of a molecule, please?*

L: *Chalk!*

T: *Okay, like chalk yes. But the common one?*

L: *The 'sent'.*

T: *Yes, the sent, yeah. But I want an example that you could not live without.*

LL: *Water!*

T: *Very good! Water is a molecule.*

During the course of the lesson, Teacher 2 effectively made use of the chalkboard as a learning and teaching support material (LTSM), by writing down all the terminology, symbols and formulas for learners to see, as shown in the example below.

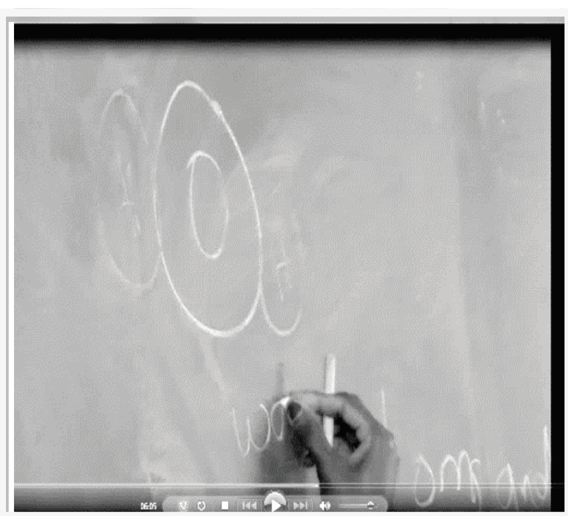


Figure 4.6.2.1 Utilisation of the chalkboard by Teacher 2

Teacher 2 thought of trying other teaching strategies as she made use of self-prepared posters (to explain the structure of the atom), the periodic table and analogies (Section 2.5.1.4) that might enable the learners to make more sense of abstract concepts such as the structure of the atom. Although the syllabus only requires the definition of an atom, Teacher 2 spent some time on the structure of the atom, atomic mass and atomic number as well. It can thus be concluded that it was the teacher's intention to scaffold learners in preparation for further chemistry topics.

As the learners are all second language users of English (Section 2.5.1.3), Teacher 2 often assisted learners with the pronunciation of terminology. Learners pronounced some elements incorrectly such as *Alminum* (Appendix G2; O-T2:195) for Aluminium; *Lid* (ibid. line 208) for lead and *Chlora, or whatever!* (ibid. line 214) for chlorine. Learners were also asked to read the names of the symbols aloud to assist in developing their pronunciation of terminology (Appendix G2; O-T2:92-97).

T: *Okay, very good! What does K stands for? I said the elements have names and the name has a symbol. So what does K stand for?*

L: *Potassium*

T: *Say "Po-tas-sium"*

LLL: *Po – tas – sium*

T: *Very good! [Teacher writes word on the chalkboard]. It is represented by a capital K.*

Interaction between the learners and Teacher 2 mainly took place in the form of the question-answer method; however, the questions were more in the form of incomplete sentences to be completed by the learners (Appendix G2; O-T2:28-35).

T: *Okay, that is the formula for water. So we have* H_2O *[Teacher writes formula on the chalkboard]. What does the H stands for?*

L: *Hydrogen*

T: *Okay, that is the Hydrogen gas and ………?*

LLL: *Oxygen*

T: *So basically water is made up of two atoms of hydrogen and one atom of oxygen. So we can say water is a .....?*

LLL: *Molecule [Answer as teacher is indicating to the word on the chalkboard]*

No learner asked any questions during the lesson. However, interactive participation took place when individual learners were asked to find elements on the periodic table. Although the learners initially struggled with the task, with the assistance of the teacher, it became clearer as they progressed. Teacher 2 also used an activity to repeat important concepts and in this way tried to improve the conceptual understanding of concepts - both good strategies for the teacher to test the learners' understanding of the concept.

Lesson 2

The lesson was a continuation of the previous lesson, and focused on elements and compounds. Teacher 2 started the lesson with establishing what the learners already knew about atoms, molecules and elements. Although there was teacher-learner interaction, Teacher 2 gave the answers to questions herself. As an example, she said: "*So, all matter is made up of atoms. So now when we combine atoms, what do we call it? We call it molecules. Okay"?*

The learners were then introduced to how to illustrate the relationship between concepts of elements and compounds. Teacher 2 tried to explain what each concept entails by making use of everyday examples such as water and carbon dioxide.

To explain the structure of water, the teacher illustrated a model of a water molecule on the chalkboard as H O H (Section 2.5.1.4). It was clear that the teacher only made use of concepts and examples as explained in the textbook. For instance, she said:

> "*I would just like to show you the pictures I have here. [Teacher finds pictures in textbook]. An element can be solid form, or a liquid or a gas. In this picture it is just in a solid form – many atoms that are formed together to form the element of iron. In the next picture you can see what a compound is. In this case – the compound of water – is hydrogen and oxygen. You can see the oxygen and then the hydrogen attached. Okay"?*

Teacher 2 continued to engage in dialogue with the learners in order to build up their knowledge and understanding. Questions asked by the teacher were not of high cognitive demand and learners were able to answer in a chorus. While it was clear that some learners were still confused about the terminology of certain concepts, other learners showed some form of insight by asking questions such as: *Miss, where do the oxygen come from?* In response to the teacher's answer by referring to prior knowledge they have about photosynthesis, another learner responded with: *Where does the 'hydro' then come from?*

The lesson concluded with a written class activity. As shown in Figure 4.6.2.2 below, Teacher 2 utilised the chalkboard effectively although learners had to share textbooks in order to obtain answers to the questions.

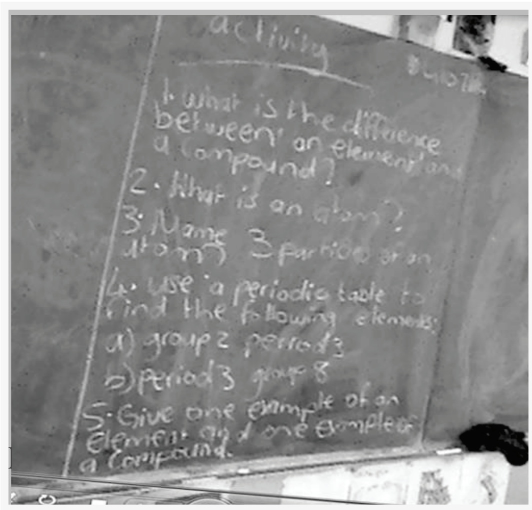


Figure 4.6.2.2 Utilisation of the chalkboard during class activities by Teacher 2.

In discussion with the two participating teachers it was clear that effective activities should be planned in order to develop an exemplar unit of work on atoms and molecules. On the one hand it would improve the learners' cognitive understanding of these abstract concepts, but on the other hand, it should make teaching and learning of these concepts fun. Therefore, activities were planned in the form of a word search that focused more specifically on the establishment of what the learners already know (Appendix H2) and games that could be used to consolidate the concepts (Appendices H3 – H5). A practical activity and project for the learners were planned for active participation of the learners and to add to the 'fun' in learning about this abstract topic. (Appendix H). The use of analogies played an integral role in the development of the unit of work, yet Teacher 2 reported that she does not make use of analogies as there "*is not much to compare to"*. (See Appendix H1 for examples of possible analogies to be used during the lesson).

As both teachers felt that the syllabus and the two textbooks oversimplified the content, as described in sections 4.4.1 - 4.4.3, more content was discussed in the lesson plans of the completed module. For instance, Teacher 1 was of the opinion that *"This topic is a huge challenge. Because it is such an abstract topic, quite often it is oversimplified to such an extent that the learners totally miss the bus and develop wrong perceptions!"* (Appendix F2; I-T1:

226), *whereas* Teacher 2 felt that: "*If I look at the syllabus there are the competencies, but in the textbook everything is just summarised. There also is not a lot of activities in the textbook. There is only one and that's it!"* and "*Maybe they should give a little bit more detail on the topic – maybe that will be better!"* (Appendix F3; I-T2:138; 148).

Teacher 1 completed a developed unit of work on power point slides, but as not all schools have access to smart boards and IT equipment, lessons were developed in a word document, to enable access by all teachers. During the interview with Teacher 2, she was asked about IT availability in her school, and this was her response: "*And here we have a computer for teachers and Wi-Fi at school, but sometimes the computer is like those 'oooold' computers and sometimes it is not even working!"* And she continued: "*We have a school laptop with an overhead projector, but you need a lot of information to show learners. But I will not use it every day as you have to borrow it etcetera. It is a schlep!"*(See I-T2:174; 205). As it was our main goal that the module should be accessible to all, websites and YouTube video clips were added (See lesson plan, Appendix H1). Content from the slides prepared by Teacher 1 was used in preparation for the lesson plans.

The unit of work concluded with a glossary of terms (Appendix H1) and we are considering writing a glossary translating the English concepts into Afrikaans/Herero as well.

4.7 CONCLUDING REMARKS

In Phase 1 of this chapter I presented and analysed data generated at the two research sites as they were described in Chapter 3. The data revealed the quality of mediation of learning in the topic under consideration at the two schools. The picture that emerged from the data generated through conducting interviews, lesson observations and documented analysis enabled me to suggest possible suggestions for future implementation.

In Phase 2 of this chapter I gave an outline of the complete unit of work planned in cooperation with the two participant teachers.

In the next chapter I discuss the findings by interpreting and explaining them based on the set of themes that emerged from my data and this is informed by the indicators from my literature review chapter in relation to my research questions.

CHAPTER FIVE: INTERPRETATION AND DISCUSSION OF FINDINGS

> *Interpretation is about giving meaning to data. It's about making sense of social situations by generating explanations for what's going on within them. Interpretation is rightly seen as the artistic, creative side of qualitative work (Hatch, 2002, p. 180).*

5.1 INTRODUCTION

In this chapter I interpret the data as analysed in Section 4 and discuss my findings on how primary school teachers mediate learning of abstract concepts in science teaching and learning, using different mediational tools. Literature and personal viewpoints add value to this discussion. The discussion is further supported by categories captured in Section 4, using interviews, observations and document analysis as data gathering techniques. In discussing the findings, seven analytical statements were drafted, reflecting on the data gathered, in anticipation that they would provide answers to my research questions.

As a reminder to the reader, the following research questions are the main goal of my study:

(1) How do Grade 7 Natural Science teachers scaffold learners to make sense of the concepts of atoms and molecules?

(2) (a) What challenges do Grade 7 Natural Science teachers experience in mediating the topic on atoms and molecules?

(b) In what ways do Grade 7 Natural Science teachers deal with the challenges that learners face in making sense of the concepts on the topic of atoms and molecules?

(3) In what ways can Grade 7 Natural Science teachers be supported with mediation of learning of the topic of atoms and molecules?

Seven analytical statements were drafted and developed to respond to each of my research questions, and I discuss these in detail below.

5.2 ANALYTICAL STATEMENTS RESPONDING TO MY RESEARCH QUESTIONS

Table 5.2 below summarises the analytical statements that emerged from the data analysed in Chapter 4 and indicates which research question they address:

Table 5.2 Analytical statements that emerged from data analysis, responding to each research question

THEMES THAT EMERGED FROM DATA ANALYSIS	ANALYTICAL STATEMENTS	DATA SOURCES	RESEARCH QUESTIONS ADDRESSED
Application of prior knowledge	1. Teachers draw on prior knowledge as a scaffolding technique	Observations and Interviews	1
Use of models/analogies in scaffolding	2. The use of models and/or analogies make abstract concepts relevant for learners to make sense of it	Observations and Interviews	1 & 3
Other LTSMs used	3. The use of learning and teaching support materials play an indispensable role in the mediation of learning	Interviews, Observations, Document analysis	1, 2 & 3
Teacher-learner interaction	4. The use of language as a mediational tool	Observations	1 & 2
Teacher-learner interaction	5. Scaffolding within the ZPD of the learners improve conceptualisation of concepts	Observations	1 & 2

Challenges faced during mediation of learning	6. PCK helps teachers mediate the learning of abstract concepts	Interviews, Observations, Document analysis	2(a) & (b)
Development of a complete unit of work	7. Development of a complete unit of work in collaboration with research participants	Interviews, Observations, Document analysis Collaboration between researcher and research participants	3

I emphasised the importance of scaffolding in the mediation of learning in Chapter 2, supporting the viewpoints of Wu (2003), Verenikina (2003) and Goos (2004). By using various teaching strategies as scaffolding techniques, teachers can create opportunities for learners to improve understanding of abstract science concepts. However, the core of scaffolding lies in the zone of proximal development (ZPD) of individual learners and helps learners to learn ahead of their development (See Section 2.5.2.3). Based on this premise, several teaching strategies applied by the research participants were observed and interpreted. This was in line with Shulman (1986) who argues that a teacher should possess pedagogical content knowledge to apply different strategies such as appropriate examples, illustrations, analogies and explanations to make the subject content accessible and comprehensible to the learners (Shulman, 1986).

As the main focus of my study was to investigate scaffolding strategies of teachers in the mediation of learning, I prefer to discuss different scaffolding strategies as separate analytical statements. Hence, I discuss each statement in detail below. Although I have presented my data in Chapter 4, a few examples may be repeated to strengthen the findings of the study.

5.3 ANALYTICAL STATEMENT 1:

Teachers draw on prior knowledge as a scaffolding technique

"*Curiosity, caring and exploration begin with what you know now*". With this statement, Rochelle (1995, p. 19) affirmed the importance of elicitation of prior everyday knowledge as the starting point for constructing new knowledge in our science classrooms. This echoes well with Sulaiman, Suan, Abdullah, Politeknik and Tinggi's (2007) views on the teacher's role to stimulate learners' interest in science learning. They suggest that this could be done by linking learners' everyday experiences to science concepts studied in the classroom. Especially at primary school level, they further argue, it is the role of the teacher primarily to 'fascinate' learners to learn science. As Teacher 1 emphasised during the interview: "*you need to trigger the child's perception of 'I want to know more' and 'how does this work'. In other words, rather* ***how*** *you think than* ***what*** *you know"* (Appendix F2; I-T1; 7).

Drawing from the lesson observations, it was noted that both teachers are aware of the importance of the elicitation of prior knowledge as a strategy in the mediation of learning. However, they implemented this strategy totally different from one another, probably as a result of experience and creativity of the different teachers (See Section 4.3).

As highlighted in Chapter 2.5.1.3, a number of researchers emphasised the importance of the elicitation of prior knowledge in the classroom. Stears, et al. (2003), for example, reason that learners are more involved in classroom discussions if they have experiences to share; Kasanda, et al. (2005) argue that integrating learners' prior knowledge increases their conceptual abilities and empowers them to take control of their own learning. I stated in this Chapter that Skamp (2009) asserts that, especially in subjects demanding higher cognitive understanding, the teacher should identify relevant prior knowledge for teaching this specific topic. In the same vein, Rennie (2011) raises a concern that teachers will have to shape up their content knowledge in order for them to bring real-life experiences into the science classroom for effective mediation of learning. It is against this background that, although the elicitation of prior knowledge may be very useful in the mediation of learning, the teacher should be creative in its implementation.

Teacher 1 succeeded in this as he started the lesson with a diagram of the Levels of Organisation in the biosphere. This was a very good starting point to emphasise the place of atoms in the Universe on the one hand and in the everyday life experiences of the learners on the other. Although this topic is not covered in the Grade 5-7 Natural Science and Health Education syllabus, Teacher 1 advocates an approach to teaching where the teacher starts at a point where the learner can apply his or her own everyday knowledge, regardless of what concepts were previously covered in the syllabus. This supports Skamp's (2009) assertion that the teacher should first identify relevant prior knowledge and from there take the learner to the next level of understanding. As Teacher 1 explained during the interview (Appendix F2; I-T1; 17):

> *"And then a kid should understand that whether I work with a human, plant, animal – everything is made up of elements. There is carbon, there is oxygen, hydrogen. Organic compounds as you find in the body today consist of 98% carbon, hydrogen and oxygen, potassium, calcium, magnesium. And as soon as a child understands* ***this****, I can take him to the next level where we can say: 'Right, if we look at carbon for example, how does carbon look like?' Then we get to the smallest identity, the atom."*

What was said in the interview was reflected in the lesson observation as well. With this approach, Teacher 1 is in line with Stears, et al. (2003) when they experienced that learners are actively more involved in classes where they can relate to the content and share their experiences more freely. This approach also coheres with Rennie's (2011) opinion that teachers should bring real-life experiences into the science classroom for effective mediation of learning.

As I indicated in Section 4.6.1, Teacher 1 explained new concepts while continuously referring to the examples of water, carbon dioxide and glucose as written on the white-board. This was a good strategy to unpack new concepts, using prior knowledge and everyday examples throughout the discussion (Stears, et al., 2003; Rennie, 2011).

During the lesson observations, Teacher 1 spent a considerable amount of time on elicitation of prior knowledge. In contrast, Teacher 2 did not really focus on the proper elicitation of prior knowledge at the beginning of the lesson, as she only focused on the definition of matter. It was clear that Teacher 2 was guided only by the syllabus and prescribed textbooks. This might be the reason why Teacher 2 feels that the learners do not really enjoy this topic, as they are still only confronted with school science, totally disconnected from their everyday experiences (Rochelle, 1995; Rennie, 2011).

Throughout the lesson, Teacher 1 continuously drew on prior knowledge as he reflected back on the fact that matter has mass and occupies space during the presentation. On the contrary, Teacher 2 never reflected back on prior knowledge during mediation of learning of the topic. Teacher 1 made use of real life examples when asking the following (Appendix F2; I-T1; 42; 64):

T: Who can tell me, how do we know that gas has mass?

L: Because you can buy it in a bottle

T: Yes, you can buy 9 kg of gas. You can go to Pupkewitz and ask for 9 kg of gas because you are going for a braai somewhere on a dune.

T: Het 'n mens se asem massa? (Freely transcribed: Do your breath have mass?)

T: Yes! Why? (Teacher breathes out against his hand). What is in your breath?

L: Water vapour

T: Yes! And carbon dioxide molecules.

Using these questions throughout the lesson, Teacher 1 adheres to the viewpoint of Stears, et al. (2003), suggesting that prior knowledge may be used effectively in different phases of the teaching and learning process. This may be the reason why the learners engaged freely with the teacher and in this way took control of their own learning.

Everyday examples, such as bread, sweets, water and carbon dioxide were also used by Teacher 1 to assist learners to be able to 'border cross' between everyday experiences and science learned in the classroom. This correlates with the viewpoint of Kasanda, et al. (2005) when they postulate that teachers should be able to make links between learners' own experiences and concepts studied in the science classroom. It could therefore be concluded that for prior knowledge to be applied successfully as a scaffolding technique during mediation of learning, the teacher needs to plan carefully and dig deeper than only reflecting back on what was done recently in class.

5.4 ANALYTICAL STATEMENT 2:

The use of models and/or analogies makes abstract concepts relevant for learners to make sense of it.

> *To introduce non-observable entities like atoms and molecules to students, teachers and textbook writers are constrained to introduce analogies, analogical models, and representational models like chemical formulas and chemical equations* (Harrison & Treagust, 1996, p. 513).

As highlighted in Chapter 2, the teaching of chemistry, which is full of abstract concepts, relies on three levels – macroscopic, microscopic and symbolic levels (see Section 2.1). Wu, et al. (2001) claim that the use of models is one of the most effective ways for teaching and learning abstract science concepts, whilst Harrison and Treagust (1996) justify chemical formulae and analogical models as most appropriate examples of models to teach the topic of atoms and molecules.

Although there is evidence from the lesson observations that both teachers incorporated models in their explanation of the structure of a molecule, it was clearly not their intention to focus on different models illustrating abstract relations between atoms. Both teachers made use of chemical formulae to illustrate the relationship between atoms to form molecules. They wrote examples such as H_2O, CO_2 and $C_6H_{12}O_6$ on the chalk board. However, none of the participant teachers clarified the meaning of the formula to the learners. From analysing the workbooks as shown in the example below, it was clear that some learners did not develop a proper understanding of the meaning of a formula, as some of them wrote H2O or CO2.

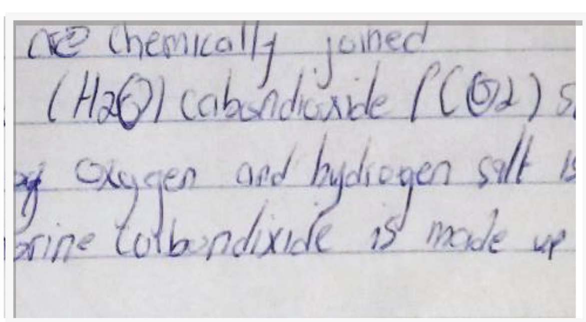


Figure 5.4.1.1: Example of a wrong mental model of the formulas for water and carbon dioxide.

In the same vein, the ball-and-stick model was used to explain the structure of a water molecule, yet no explanation of the model was given. The example below indicates that it was clear that models were only copied from the chalkboard without learners having a proper conceptual understanding of the model. According to Harrison and Treagust (1996), this may be challenging and confusing to those learners who still struggle to reason in an abstract way.

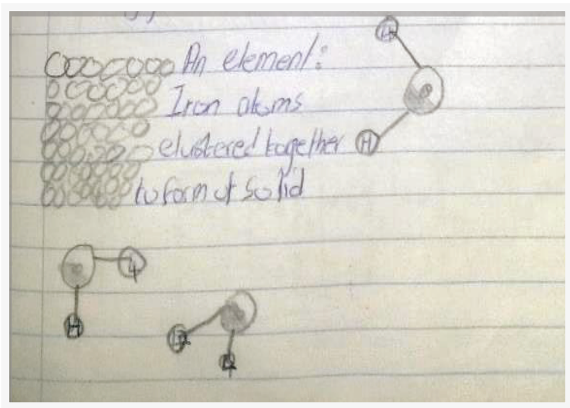


Figure 5.4.1.2: Example drawn by a learner of a ball-and-stick model of water molecules

The presentation of models to illustrate abstract concepts without proper explanation of the model, could add to the misinterpretation of the concepts and I have found that in this study it did not contribute to the effective mediation of learning of those abstract concepts. It is unfortunate that I could not ask the learners for their opinions about the mental models they have on the structure of the atom and this was a lost opportunity. In hindsight, however, this could potentially be an area for future research. More successfully, it was observed that both teachers made use of analogies as another teaching strategy to explain abstract concepts.

For instance, Cokelez (2012) draws our attention to the difference between models and analogies. As explained, models are ways to demonstrate science in a concrete way (ibid.), whereas analogies are parallels drawn to guide the students to understand a concept (Treagust, 1993). According to Harrison and Treagust (1996), for successful use of analogies to explain abstract concepts, teachers should ensure that learners are familiar with the analogy. As discussed in Section 2.5.2.3 in this thesis, the most common analogies used to explain the building blocks of matter at primary school level, is to make use of LEGO-blocks, letters in a word, or even players in a sports team, running around.

During the lesson observations, Teacher 1 came up with another interesting analogy, comparing the structure of an atom with an athletic track surrounding a field. Although learners could immediately relate to that, Teacher 1 took some time to explain the comparison between an athletic track and field and the structure of an atom. During the lesson presentation it was observed that the teacher from time to time reflected back to this analogy. This is an excellent analogy to explain the basic structure of an atom. In addition to the fact that it was relevant to his leaners' everyday experiences, there were many resemblances to be drawn.

Teacher 2 preferred to use the better known analogy of the solar system with which to compare the structure of the atom. This was also effective, as the topic of the solar system had been covered in the syllabus previously and should therefore be part of prior knowledge of the learners. Consequently, learners could conceptualise the abstract concepts of the atom and its structure, applying what is known to them. It could be argued that, to show the links, some integration within science was implemented.

5.5 ANALYTICAL STATEMENT 3:

The use of learning and teaching support material (LTSM) plays an indispensable role in the mediation of learning

> *To enable access, learning support materials should be well-structured, well-prepared and appropriate* (Czerniewicz, Murray & Probyn, 2000, p. 3).

As I have noted in Section 2.5.1.1, Vygotsky (1978) upholds material tools, such as posters, models, chalkboard, to name but a few, as one of three mediators in the mediation of learning, having an indirect effect on the other tools. Czerniewicz, et al. (2000, p. 20) describe LTSMs as "prepared materials which structure and support learning and teaching. They can be prepared by teachers in schools as well as by other educationalists in NGOs, publishers and other institutions". This may be in the form of worksheets, posters, kits, or any form of material used by the teacher to support mediation of learning. It also includes textbooks and computer software. Although models and analogies were discussed under a separate analytical statement

(Section 5.4), the reader should be reminded that models and analogies also fall under the umbrella of LTSMs.

As explained in Section 4.3, Teacher 1 is at a well-equipped school with many resources available in each classroom. Teacher 1 therefore used the smart-board with power point slides as primary source of LTSM. Czerniewicz, et al. (2000) elaborate the importance of the suitability of whatever LTSM is applied. Based on what was observed, the power point slides were relevant to the context, the learners' ability as well as the teacher's competencies. He used the slides only to emphasise main points and to stimulate teacher-learner interaction. Complementary to the smart-board, Teacher 1 used the white-board for writing down new terminology and for learners to engage in activities. This is an effective way of using LTSMs, as it can be prepared beforehand in detail and "provide scaffolds for learning; and support the teacher in terms of methodology," as advocated by Czerniewicz, et al. (2000, p. 37).

Furthermore, Teacher 1 involved learners in a practical activity, using scissors and a piece of paper, giving learners the opportunity to learn in different, interesting ways. This is in line with the requirements of the new curriculum promoting creative, problem-solving and learner-centred LTSMs, with the teacher facilitating the learning process (Czerniewicz, et al., 2000).

In contrast with Teacher 1, Teacher 2 is at a school with not even an overhead projector in the class; resources are very limited. As Czerniewicz, et al. (2000, p. 52) point out: "making learning happen in an under-resourced classroom is a huge challenge for even the best and most experienced of teachers". Despite this challenge, Teacher 2 tried to make the best of it by using the chalkboard effectively for writing down new terminology and summaries. Furthermore, she developed her lesson across the chalkboard, and prepared her own posters. A short class activity in the form of a worksheet was given to learners to consolidate concepts discussed in the lesson. These activities were also to be copied from the chalkboard first, taking up a lot of time.

In addition, drawn from the interview (I-T1) and observation (O-T1), Teacher 1 did not make use of the prescribed textbooks; alternatively, learners worked from a study guide with complete notes, diagrams and activities, prepared by him. It was observed that learners were referred to the study guide from time to time to find information. In this way, learners could be actively involved in the mediation process (Hodson & Hodson, 1998), engaging in group discussion without wasting time by copying anything from the chalkboard first. Although learners could learn more how to construct diagrams when copying the diagrams from the board, they at least had the correct diagrams in their study guides to learn from.

In contrast, Teacher 2's learners do not have their own textbooks, as she explained during the interview (I-T2; 104): *"they used to have textbooks but then they lost them. So there is now only a few".* Based on my observation of lessons and documents, this could have a negative effect on the mediation of learning in the classroom. A lot of time was spent on writing down summaries and then, as described in Section 4.6.5, summaries were often copied incorrectly from the chalkboard by the learners. It has been noted with concern that this might directly or indirectly have a negative effect of the achievement of learners.

In brief, it has been noticed with enthusiasm that both teachers acknowledge the importance of effective use LTSMs in the mediation of learning, especially abstract concepts. This is in line with what Czerniewicz, et al. (2000) point out that learning materials will always play an important role, in either a learner-centred approach or a traditional teacher-centred approach.

5.6 ANALYTICAL STATEMENT 4:

Language plays an important role as a mediational tool

The medium of instruction in Namibian schools is English. However, for the majority of teachers and learners this is not their home language. As I have mentioned in Section 2.5.1.5 this may be one of the major reasons for poor academic achievement of learners. Teachers and learners might not be able to express themselves in English or learners might not understand what the teacher is trying to say in English. Therefore, the presentation of this section will be divided into two sub-sections: interaction between teacher and learner and code-switching.

5.6.1 Interaction between teacher and learner

In Section 2.5.2 I described the theory of social constructivism which underpins my study. Drawing from the work of Vygotsky, Hodson and Hodson (1998) stress the importance of social interactions between the teacher and learners, and this notion forms the basis of social constructivism. However, many learners cannot express themselves in English, which leads to them feeling embarrassed and avoiding taking part in discussions in the classroom. A lack of comprehension may then lead to learners being unable to pronounce and spell words correctly, for example, pronouncing some molecules and elements incorrectly as "*Hydro- hydrolic oxygen", "alminum", "lid", "Chlo-ra, or whatever"* (Appendix G2; O-T2; 150; 195; 208; 214). Both teachers made an effort to assist learners in the correct pronunciation of terminology.

During interaction with learners, Lemke (1990) urges teachers to formulate questions in such a way that encourages learners to engage in conversation instead of only responding to the question. In brief, the cognitive levels of questions asked by the teacher should stimulate social interaction between teacher and learners. In this vein, what emerged from the lesson observations was that, although Teacher 1 often posed questions of higher cognitive demand, it was mainly short-answer questions and did not really guide the learners to take part in the conversation. Teacher 2, on the other hand, mainly asked questions in the form of incomplete sentences resulting in learners answering in a chorus. In this regard, both teachers failed to create a platform where learners could actively practise and develop the language skills crucial for their own cognitive development.

The effective use of the chalkboard and white board by both teachers in writing down new terminology such as 'molecule, atomic structure, compound', *etcetera*, assisted in improving learners' conceptual understanding of concepts. Notwithstanding, the limitation of English proficiency of many learners meant that both teachers still endeavoured to encourage social interaction between teacher and learner in posing questions throughout the lesson. Nevertheless, creating their own glossary of concepts at the end of the topic and interaction between peers in for example, small group discussions, could have created even better opportunities for learners to talk (Lemke, 1990) and write about their experiences in science for improved cognitive understanding (McRobbie & Tobin, 1997). Unfortunately this did not happen.

5.6.2 Code-switching

In the Namibian context, code-switching is not allowed in the classroom, as the medium of instruction is English. Nevertheless, Probyn (2009) advocates for the use of code-switching in the mediation of learning to second language learners. Code-switching from English to the vernacular, according to Probyn (2009), may assist in better cognitive reasoning, as learners will be able to relate to their own experiences. Learners will also feel more comfortable in asking questions and taking part in group discussions.

To be able to use code-switching as a teaching strategy in the mediation of learning, the teacher and learners should ideally be of the same cultural group, using the same vernacular. This was not possible in the classroom of Teacher 2, as she is Oshivambo-speaking while the majority of her learners speak Oshiherero as their mother tongue. Code-switching could thus not take place at all. Teacher 2 experienced a lot of frustration due to this situation, as she realised that although code-switching is not really allowed in the Namibian context, it would stimulate learners to take part in discussions and in this way contribute to better conceptual understanding, especially of abstract concepts.

Teacher 1, on the other hand, often code-switched from English to Afrikaans in what Probyn (2009) refers to as 'smuggling the vernacular' into the classroom. That is, conversation between teacher and learners often took place in Afrikaans, as this was the home language of the teacher and all the learners. Abstract concepts could more easily be explained, using the vernacular and learners felt more comfortable taking part in group discussions, as explained in Section 4.6.1. In my opinion it was a good strategy (See Section 2.5.1.3). What came out during such conversations, were more insights coupled with enthusiasm, especially from the learners; situations not observed in the lessons of Teacher 2 at all.

Useful insights could be gained from the following example, during the presentation of lesson 1, when the structure of the atom was discussed. One of the learners asked: "*Meneer, as die elektron beweeg, gaan hy net so en so (indicating two dimensional movements with his hands) of gaan hy so en so (indicating movement in all directions). (Freely translated: Sir, if the electron is moving, does it only go like this, or is it also going like this?).* Although the question was asked in Afrikaans, Teacher 1 responded to the question in English, stating: "*In actual fact, an atom is a ball with another ball around it, with another ball around it. So it's a three dimensional picture. And sometimes it is moving in circles. It differs from element to element. So no, it is not a flat structure, it is actually a sphere with a sphere around it and another sphere around it again, in which the electrons can move."* (See Appendix G1; O-T1; L1).

When using code-switching as a teaching strategy in the mediation of learning process, it is important that learners should be able to transform concepts explained in the vernacular into English again without losing the scientific meaning of concepts. As I observed, Teacher 1 often attempted to translate concepts explained in the vernacular, back into English to ensure the necessary consolidation.

Teaching and learning in schools is moving towards a view of learning whereby learners are viewed as having the responsibility to be actively involved in the learning process (Hodson & Hodson, 1998). As observed with Teacher 1, code-switching is a powerful tool to be used in the mediation of learning to allow effective dialogue for learners to create their own understanding of concepts and become competent participants of a sociocultural environment. However, using code-switching effectively in the classroom, depends largely on profound pedagogical content knowledge of the teacher.

5.7 ANALYTICAL STATEMENT 5:

Scaffolding within the ZPD of the learners can improve conceptualisation of concepts

Different scaffolding techniques used by the teacher, viz., prior knowledge, use of models and analogies, other learning support materials and language, are discussed in detail under Sections 5.3 – 5.6. This section will focus on how, if at all, scaffolding took place within the ZPD of the individual learners.

I clarified in Sections 2.5.2.2 and 2.5.2.3 scaffolding as various forms of guidance given by the teacher to learners as a way of mediating concepts, to increase their ability to develop their own inquiries. Subscribing to this, Verenikina (2003), amongst others, claims that the zone of proximal development (ZPD) of a learner makes up the core of scaffolding of learning, as the ZPD is defined by Vygotsky (1978) as the difference between what a child can achieve in solving problems individually and the potential development of the learner when guided by a teacher or other knowledgeable peers (Verenikina, 2003). Likewise, Goos (2004) reasons that, together with scaffolding, the ZPD of a learner is linked to collaboration where learners have the opportunity to construct and experience new knowledge when working in collaborative peer groups.

Primarily, scaffolding of learning will take place during interactions between teachers and learners. By doing this, the teacher can determine the ZPD of each individual learner and scaffold accordingly. Teacher 1 succeeded in this in the way he posed questions to his learners. At the beginning of the lesson, he would pose questions as incomplete sentences for learners only to complete. As the conceptual understanding of learners increased, he removed the scaffolds with questions of a higher cognitive demand. In addition to this, follow-up questions were asked for clarity.

During the lesson observations of Teacher 1, it was clear that leaners were capable of asking questions at a high cognitive level and were able to complete given tasks on their own; for example:" Sir, *I've got a question. If you know the building blocks of water, will it be possible to make your own water?*" (O-T1L1) and "*Sir, will it become more unstable if it has more neutrons?"* (O-T1L3).

In guiding the learners along the way, during the practical activity as well, Teacher 1 managed to create and maintain the ZPD of the learners. I found that Teacher 1 posed questions of different cognitive demand on purpose to specific learners. When learners were answering questions, he guided each learner according to his or her cognitive development. It made learners feel comfortable in this environment and they were able to communicate in order to develop a better conceptual understanding of concepts. This echoes with Levykh's (2008) argument of maintaining a ZPD of each learner on a long term basis, as discussed in Section 2.5.2.2 of this study.

Despite effective scaffolding from Teacher 1, one learner at the end of the lesson asked: "*Meneer, is 'n atoom 'n organisme*?" (Freely translated: "*Sir, is an atom an organism"?).* To me this was quite alarming to notice that not all learners were on the same level of ZPD. Teacher 1 thus runs the risk that, by not taking into consideration each learner's level of ZPD, he may remove the scaffolds too fast and in this way some learners may stay behind.

During the interview with Teacher 2, when asking her about scaffolding techniques she uses during the mediation of learning of abstract concepts, she replied that she was not aware of any.

Thus, it is not surprisingly that Teacher 2, in contrast with Teacher 1, mainly posed questions as incomplete sentences and thus did not pose questions of a high cognitive demand to be able to create a ZPD of the learners. In my opinion, learners should be engaged with quality questions for them to develop critical thinking. As she often answered questions by herself, no scaffolding of learning then took place. Verenikina (2003) asserts that the ZPD of a learner can only count as scaffolding when the learner is allowed to eventually complete the task on his or her on. Yet, if she was sensitised to establish a ZPD within each learner, it could have been more effective to probe specific questions of higher cognitive demand to identified learners.

Teacher 2 managed to guide learners through activities done on the chalkboard, slowly removing scaffolds, so that at the end the majority of learners were able to complete the task without assistance. Repetition of new terms to assist in pronunciation and memorisation was also an effective way of scaffolding learners. Questions asked during classroom activities as well as in the test were at different conceptual level and in this way it was possible for her to determine the ZPD of each learner.

Although the concepts of atoms and molecules are of a high cognitive demand, both teachers supported these abstract concepts with everyday examples, such as water and carbon dioxide. This echoes well with Skamp's (2009) view of scaffolding of learning. He argues that effective mediation of learning of abstract concepts (atoms and molecules as the focus of this study), should start with relevant prior knowledge. Teacher 1 even went further and, within the ZPD of his learners, used examples such as glucose ($C_6H_{12}O_6$) as the building block of a slice of bread. It was clear that he considered the specific examples carefully, as all three examples contain the same types of elements and thus he could easily compare them with one another.

In conclusion, I applaud the argument of Akerson, et al. (1999) that language and communication play an indispensable role in creating a ZPD for effective scaffolding of individual learners.

5.8 ANALYTICAL STATEMENT 6:

PCK helps teachers mediate the learning of abstract concepts

In Section 2.5.3 of this study, I explained in detail what PCK entails. In short, based on Shulman's (1986) theory, PCK is about applying the best strategies in the mediation of learning of specific topics to make it comprehensible to the learners and to clear up certain misconceptions learners may have about a topic. Mark (1990) subscribes to this theory and asserts that PCK cannot be isolated from subject knowledge and general pedagogical knowledge, as described in Section 2.5.3.2.

To be able to find answers to my second research question, underpinned by the above analytical statement, this section will be divided into two sub-sections: a summary of the challenges faced by teachers in the mediation of learning of abstract concepts of atoms and molecules and the interpretation of how teachers deal with those challenges, applying PCK.

5.8.1 Challenges faced by teachers in mediation of learning of abstract concepts

The main problems experienced by the two teachers as presented in Section 4.4 in this study will be categorised as follows: abstractness of the topic, oversimplification of concepts and lack of resources.

Abstractness of the topic: During the interviews, teachers complained that due to the abstractness of the topic, learners fail to conceptualise concepts, leading to poor examination achievement. Furthermore, poor language proficiency, lack of prior knowledge, practical activities and analogies as well as poor quality of LTSMs to explain concepts, contribute to learners feeling disconnected from this topic.

Oversimplification of concepts: Basic competencies from the syllabus and content from the textbook are oversimplified and not linked to the Namibian context. Learners therefore fail to make connections and this may lead to confusion and misconceptions in the minds of teachers and learners.

Lack of resources: Teacher 2 especially experienced a lack of learning support material in the form of posters, practical activities, supporting reading material and technology such as an overhead projector, access to the internet and YouTube video clips to support her in reducing the 'alienation' of this topic to the learners.

5.8.2 Ways in which teachers could apply PCK to deal with challenges

In view of these challenges, evidence showed that teachers, who purposefully use PCK in the mediation of learning, are more able to deal with these challenges. To address the problem of the topic on atoms and molecules rife with abstract concepts and not relevant to the everyday experiences of the learners, both teachers made use of relevant examples and prior knowledge of the learners. However, it was observed during the lessons that Teacher 2 did not have the same confidence in the mediation of learning of the topic. During the interview, she admitted that: "*to be honest, last year I did not understand this topic myself so well (laughing). But so far I did not give my learners enough"* (Appendix F3; I-T2:182). In some cases during her lesson presentation, no mediation of learning took place as she asked questions, but then gave the answer herself. This hindered effective mediation of learning, as in the process possible misconceptions (Section 2.4) as well as wrong mental models (Section 2.5.1.4) in the mind of the learners could not be clarified. According to the learners' responses to questions, it was evident to me that some learners were confused about the definitions of some concepts. It was worrying that no learner asked any questions during the lesson. The lack of experience of Teacher 2 could account for this, as she had not developed a strong enough PCK to have the best strategies in place to mediate learning of this specific topic. However, Teacher 2 used some everyday examples such as water and carbon dioxide to explain what different concepts entail. This was a good strategy to unpack new concepts; however, it could have been conceptualised more effectively by using more examples, diagrams and analogies.

Being the more experienced teacher, it was clear that Teacher 1 applied prior knowledge and the use of analogies in a much more effective way to deal with the abstractness of the concepts on atoms and molecules. As explained in Section 2.5.2.3, Teacher 1 gave a variety of questions of a high cognitive demand to the learners and it was often expected from learners that they apply their new knowledge to everyday experiences.

Another challenge that both teachers acknowledged was the use of English as medium of instruction, although it is neither the mother tongue of the teachers, nor the learners. For Teacher

2 this remains a problem, while Teacher 1 prefers to code-switch. It was clearly observed that the learners in School 1 had more confidence to actively take part in discussions and had a higher cognitive understanding of the concepts after abstract concepts were explained in the vernacular.

Dealing with the challenge of concepts being oversimplified, both teachers feel that this may cause confusion and misconceptions in the minds of the learners. The Grade 7 Natural Science and Health Education syllabus requires only very basic definitions, without explanations of any concepts (See Section 4.6.1). To deal with this, Teacher 1 combines the basic competencies of the syllabus for Grade 7 with those for Grade 8. He believes that with proper scaffolding, learners tend to have better conceptual understanding of abstract concepts if they can know the 'how' and 'why' as part of the 'what' (Duschl, 2008).

The other hurdle is the lack of resources at the school. Teacher 2 referred to learning support materials not being available, two or three learners often needing to share a textbook. Both teachers dealt with this challenge effectively by making summaries on the chalkboard, or preparing their own study guides and posters. The limitations of this strategy, however, is that it may be costly to prepare material and posters and teachers run the risk that learners do not write the summaries correctly from the chalkboard, as explained in Section 4. 5.6 of this study.

In conclusion, it was clear that the content explained by Teacher 1 was of a higher cognitive demand as required from the syllabus. It was clear that Teacher 1 has proper pedagogical content knowledge of the best strategies on how to mediate learning of the specific topic to make it comprehensible to the learners and to clear up certain misconceptions learners may have about the topic, as described in Section 2.5.4.3. However, it may become a challenge for the teacher to complete the basic competencies in the syllabus on time, as much time is spent on elicitation of prior knowledge to capture learners' conceptual understanding, as well as expanding the basic competencies in the syllabus.

5.9 ANALYTICAL STATEMENT 7:

Development of a complete unit of work in collaboration with research participants

Phase 2 of my study aimed at answering my third research question. Specifically, what can teachers do to improve learners' sense making of the concepts on the topic of atoms and molecules? In Chapter 4 of my study I explained what was done in Phase 2 and I explain the reasons for planning the unit of work.

The main aim while planning this unit of work, was to integrate as many practical activities as possible - to promote learner involvement and to develop the cognitive understanding of abstract concepts. (see Section 2.4). Practical activities, word search and games were included to stimulate learners to take equal responsibility for their own learning. Games were planned in such a way that group work could be promoted. With group work, teachers can encourage learners to talk science (Lemke, 1990), which is a crucial part of the social constructivist approach, as noted by Hodson and Hodson (1998). In the same vein, teachers can deviate from the traditional way of rote learning by learners and learners do not see science as boring and difficult.

The learning support material added in this unit adhered to the argument of Czerniewicz, et al. (2000) in the sense that it was not only prepared to strengthen the learners' existing knowledge, but to give guidance to the teachers as to how they could engage in the activities. An option for project work was added as an extension to the topic. The reason behind this was to subscribe to Mc Robbie and Tobin's (1997) argument that learners need to communicate in writing as well as speaking to stimulate cognitive growth. However, teachers should be sensitive to the ZPD of learners in order to determine the level of scaffolding or guidance given in this task.

Incorporating all these teaching strategies is in line with the argument of Sulaiman, et al. (2007), that, by including games, analogies, *etcetera*, learners can become 'fascinated' to learn science. Similarly, this coheres with Probyn's (2004) suggestion of the use of different teaching strategies to give linguistic support, especially to English second language users.

Extensive input was given on the elicitation of prior knowledge. Except for the fact that the use of prior knowledge is prescribed in the Namibian Government policy documents as I explained in Section 2.5.1.3, Stears, et al. (2003) posit that learners are inclined to engage more freely in group discussions when they have experiences to share. Therefore, it was important to ensure that examples were relevant to the learners' everyday experiences or learned via the science classroom (Rennie, 2011; Oloruntegbe & Ikpe, 2011). The use of analogies to explain abstract concepts, were carefully planned to ensure that the majority of learners would be familiar with the concept. More than one analogy was added to the unit of work to give teachers the opportunity to choose the one his or her learners would be most comfortable with.

The content included in this unit of work was of a higher cognitive demand as prescribed in the basic competencies of the syllabus and covered in the textbooks. This was done, firstly, to give teachers a better understanding of concepts and, secondly, to clear out misconceptions that may occur in the minds of teachers as well as learners. Again teachers should be sensitive to the ZPD of learners in order to ensure maximum conceptual understanding.

As both teachers in this study expressed the wish to have more links to You-tube video clips, this was added for teachers who may have internet access in their classrooms. With these video clips, a more visible way of abstract concepts can be illustrated to make learning more enjoyable and rewarding. It is important that teachers should clear up with learners that this is only a representation of the real concept, as urged by Adbo and Taber (2009).

The unit of work can be used by the teachers in helping learners to learn, as it consists of strategies on how to introduce, present and discover the topic of atoms and molecules at primary school level. The unit of work also facilitated discussions and reflections on how to enhance mediation of learning of this topic.

5.10 CONCLUDING REMARKS

This chapter provided an interpretation and discussion of the data presented in Chapter 4. From the analysed data sets I came up with seven analytical statements. The themes that emerged from data generated from interviews, lesson observations and document analysis, were discussed in relation to the analytical statements that were informed by my research questions. Through these statements, data were clear on how the two participant teachers scaffold learners in making sense of abstract concepts, and challenges faced by the teachers in the mediation of learning.

Effective elicitation of prior knowledge, code-switching, use of analogies and the use of other effective learning support material within the ZPD of each learner came out as effective scaffolding techniques in the mediation of learning of abstract topics. Limited development of Pedagogical Content Knowledge (PCK), development of wrong mental models and poor development of English language skills emerged as major hurdles in implementing effective support mechanisms for primary school learners to master abstract concepts such as atoms and molecules.

Surprisingly enough, although the topic on atoms and molecules is full of abstract concepts and requires a high cognitive demand, it emerged from the interviews and documents analysed that this topic is oversimplified in the Grade 7 syllabus, leading to unnecessary misconceptions and misinterpretations in the minds of the learners. For example, the majority of learners had limited insight into proper definitions of molecules, elements and compounds.

In the next chapter, I provide a summary of the findings of my study, make recommendations, suggest areas for future research, and discuss the limitations of my research study. I further reflect critically on my research journey and conclude by formulating some conclusions.

CHAPTER SIX: SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1 INTRODUCTION

The main goal of this study was to investigate how primary school teachers guide learners to make sense of abstract concepts, demanding a higher conceptual understanding. The study was triggered by the fact that my student teachers as well as more experienced teachers complained that they struggle to teach these topics in a creative and clear way in order for maximum mediation of learning to take place.

In this chapter, I provide a reflective summary of the main findings that emerged from this study. In my conclusions and recommendations, I considered the challenges teachers face and how they could deal with them. Thereafter, suggestions for further research are discussed and limitations of the study are presented. Finally, this chapter concludes the study with a brief account of my research journey.

6.2 SUMMARY OF MY FINDINGS

The study reported on how the selected Natural Science teachers in the Namibian context mediate learning of the topic on atoms and molecules as one of the first abstract topics in the NHSE syllabus. The findings of the study provided me with answers to my research questions, focusing on best strategies teachers use to scaffold learners in making sense of this topic, as well as how teachers deal with the challenges faced in the mediation of learning of this topic.

The study was done in the form of a case study and focused on two Grade 7 NHSE teachers at different schools in the Khomas region.

Qualitative methods, specifically interviews, lesson observations and document analysis, were used to generate data. Although my research participants each were functioning within a different ZPD (Vygotsky, 1978, cited in Goos, 2004), due to availability of resources, experience and years of teaching, the intention was not to compare the two teachers, but rather to get different insights from their teaching approaches. A unit of work was developed to support Grade 7 Natural Science teachers in mediation of learning of the topic on atoms and molecules (see Appendix H). The study focused on the positive aspects that emerged from the data generated, yet identified areas for improvement as well.

I found that teachers were trying their best in the mediation of learning of abstract concepts in order for learners to make sense of these concepts although the limited pedagogical content knowledge (PCK) (Shulman, 1986) of teachers prevented the ideal scaffolding of learners from taking place.

The study further revealed that proper elicitation of prior everyday knowledge throughout all phases of the lesson plays a crucial role in the way learners conceptualise abstract concepts of high cognitive demand. This resonates with the view of Stears, et al. (2003), who emphasise that each one of the phases of the lesson allows space for critical thinking of the learners to effectively integrate their prior experiences to improve learning.

The study found that a lack of resources at the school and limited familiarity with the subject content prevented teachers from making use of a variety of teaching strategies. Enough evidence was found that the research participants faced several challenges regarding effective scaffolding of learners, in the form of the abstractness of the topic, oversimplification of the concepts and a lack of resources. To overcome these obstacles, teachers should develop a strong SCK as well as PCK to have the best strategies in place to mediate learning of this topic. This is in line with Shulman (1986) who asserts that strong PCK would empower teachers to make a subject comprehensible to their learners in the way they present the content.

Furthermore, the study has established that concepts of high cognitive demand should not be oversimplified when introduced to learners. Oversimplification of concepts would be likely to have an adverse effect on the achievement levels of learners, as learners may find it difficult to define and conceptualise concepts as they do not have proper insight into the concepts. In the same vein, more time should be allocated to the topic of atoms and molecules to ensure that teachers have ample time to introduce the topic with a variety of learning and teaching support materials. As has been noted in Section 5.5, this is in line with Czerniewicz, et al. (2000) who emphasise the importance of learning materials in the mediation of learning.

The study concludes, with Phase 2, that the exposure of and cooperation between teachers plays an indispensable role in the professional development of teachers, as well as strengthening teachers SMK and PCK as proposed by Shulman (1986). On reflection, the participant teachers agreed that a support network between science teachers would help to develop their self-confidence. By sharing ideas, teaching strategies and support materials teachers' ability to scaffold learners in making sense of science concepts should improve. This in turn, via peer interaction and argumentation, with the teacher controlling these interactions, may challenge learners to use their own experiences in understanding more abstract concepts (Goos, 2004).

6.3 RECOMMENDATIONS AND IMPLICATIONS FOR PRACTICE

Drawing on the findings of this study some issues emerged that need to be addressed.
These are as follows:

- Classrooms need to be equipped with suitable learning support materials (Czerniewicz, et al., 2000) and other necessary physical resources, to allow active participation of learners in science teaching and learning.

- Schools need to be equipped with technology and teachers should be given extensive guidance on the use of it.

- Textbooks need to be reviewed to ensure that adequate examples in the Namibian context as well as activities are included.

- The Natural Science and Health Education syllabus should be reviewed to be more complete and specific in the basic competencies, as well as to prevent oversimplification and confusion by teachers and learners.

- Schools should establish Science clubs where learners could be encouraged to take part in discussions and interactions to improve their language proficiency as well as higher cognitive development as proposed by Vygotsky.

- Teachers need to engage in on-going professional development opportunities in the form of a community of practice as proposed by Lave and Wenger (1991) for their own professional growth, way of motivation and to be in a position to deal with all the many challenges they have to face during the mediation of learning.

6.4 AREAS FOR FUTURE RESEARCH

This case study forms a useful platform for future research in the following areas:

- A similar study could be conducted, but with inclusion of learners as research participants.
- Research could be conducted on the effectiveness and elicitation of learners' prior knowledge on the topic on atoms and molecules.
- Research could be conducted to test the effectiveness of the unit of work developed during this research and to improve on this.
- In addition, further research could be conducted on the same topic, but on secondary school learners, as this topic is covered in more detail at this level.
- Finally, there is a need for further research on the use of models and analogies on the topic on atoms and molecules.

6.5 LIMITATIONS OF MY STUDY

Being a case study of only two Natural Science teachers in the Khomas Region, the findings of this study cannot be generalised; however, it provided some insights into how teachers mediate learning of the topic on atoms and molecules.

Five lessons were recorded, together with the interviews, so analysing the data was time consuming and this might have led to my overlooking valid information. As one of my participant teachers often used Afrikaans as a medium of instruction, I had to translate into English first. Member checking was then to be done to validate my data before I could proceed, something I found to be quite time consuming.

The findings and interpretations might reflect a partial view of the real events as I was interpreting the observations coloured with my own world view. To avoid subjectivity in the findings, I tried to interrogate my own interpretations critically and honestly at each stage of the research. In a reflexive process I continually examined my own biases and perspectives to make sense of how my perceptions could have influenced my conclusions and findings (DePoy & Gitlin, 2011).

I also understand that my position as a lecturer at the university could serve as a threat to the participants, mainly as I was a former lecturer of one of my research participants. May informal discussions between the researcher and the research participant however, established a good working relationship.

The fact that I am not directly involved in the school set-up, made it difficult to get hold of the teachers. Teachers who were originally chosen as research participants in the meantime shifted to other grades or were transferred to another school.

6.6 REFLECTING ON MY RESEARCH JOURNEY

On reflection of this research journey, I realised that the biggest challenge was to find a topic which was researchable and relevant, but captivating enough to occupy my 'mind, body and soul' for at least one year. Spending ample time in reading up about concepts of mediation of learning, abstract concepts, scaffolding, ZPD, *etcetera*, (concepts that I have never heard of before!) and in discussions with colleagues and teachers in the field, I could shape my research approach and topic until such time that I was able to draw up a research proposal.

However, after my research proposal was accepted, the practical implementation and implications became a reality. I had to deal with some predicaments early on in my journey already, such as a research participant who was promoted to acting principal and due an extremely busy schedule had to withdraw from my study. This obliged me to slightly change my approach, from gaining insights from two so-called 'successful' teachers to getting insights from one so-called successful teacher, and another teacher struggling with a lot of challenges but keen to improve. Due to many public holidays and long weekends, participant teachers were more than a month behind teaching schedule, putting a lot of pressure on me to gather my data on time.

Conducting pilot interviews and observations guided me in formulating and re-formulating my interview questions. As concepts that I overlooked or did not acknowledge as important, arose during interviews and lesson observations with my research participants, I had to adapt and add to my literature review accordingly. At times it seemed that nothing really made sense and then it was amazing to find how concepts and data unfolded and came together as the process continued.

Through this process, I have developed a number of key skills. I have learnt that it is of utmost importance to establish a good rapport with each research participant, particularly when the study is of a qualitative nature and cooperation between researcher and research participants is necessary to compile a unit of work together as we did in Phase 2 of this study. Furthermore, I realised that the questions as well as follow-up questions asked in an interview can be crucial in gathering data and that this requires certain skills and experience for the interview to be fruitful. I have learnt that the researcher has to develop extremely fine observation skills during interviews, lesson observations and document analysis to be able to analyse the data critically and make appropriate interpretations. Then, I have learnt how to logically put ideas together to form patterns that make sense to the reader. Lastly, I have developed new insights about teaching and learning; skills that I can now pass on to my student teachers for them to become competent teachers in science education.

If I had to conduct such a study again, I would research more before finalising my research topic, taking into consideration the research participants willing to work with me and the time slot in the school calendar for this topic to be covered. In doing this, I believe that I would be able to reduce my frustrations and maybe limitations of the study as well. During the analysis of my data, I found that the visual images taken from the chalkboard during lesson observations were not very clear; therefore I would consider using two cameras to capture maximum data during lesson observations; one to focus on the teacher and the other one to focus more on the visual material.

I would also consider taking study leave for the year while conducting my thesis, to have ample time to focus only on my studies.

Being a MEd student has enabled me to develop new insights about my own teaching and my view of education in particular. Doing the course work, magnified my view of life in general and appreciation for other cultures. Lastly, by doing this MEd course I came to learn in the words of Nelson Mandela: "*It always seems impossible, until it is done".*

6.7 CONCLUSION

This chapter provided a summary of the findings from this study; made some recommendations for practice and suggested areas for future research. Furthermore, this chapter discussed the limitations of the study and concluded with some reflections on my research journey.

This case study has provided me with valuable insights into the extent to which scaffolding of learners affects the teaching and learning of abstract science concepts that demand a higher cognitive understanding. Research has also shown that for meaningful learning to take place, teachers should develop a strong PCK in order to have the best strategies in place to mediate learning of this topic effectively. It also suggests that teachers need to be knowledgeable in their subject content knowledge and be mindful of the incorporation of learners' prior knowledge and experiences into their teaching and learning practices. The study further revealed that oversimplification of abstract concepts may confuse learners more and prevent development of proper understanding of the concepts.

This study finally suggests a need for the development of a support network between teachers in order to expand on their subject content knowledge as well as pedagogical content knowledge to be able to make use of different teaching styles as they scaffold learners in the process of making sense of, in particular, abstract science concepts.

The study ends by concluding that teachers need to engage in on-going professional development opportunities in the form of a community of practice for their own professional growth and to be in a position to deal with all the many challenges they have to face during the mediation of learning.

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APPENDIX A1 - REQUEST FOR RESEARCH

P. O. Box 9816
WINDHOEK
11 April 2014

To: Regional Director

REQUEST FOR RESEARCH AUTHORITY

As an assistant lecturer at UNAM, Faculty of Education, I am a registered student in the Faculty of Education at Rhodes University. I have successfully completed the course work of the Master's Programme for Science Education in 2013. As part of my study I am now required to carry out a research project on a topic that I have identified where I can assist teachers to improve their teaching. Therefore, the aim of my research is to investigate how Grade 7 science teachers mediate learning of abstract science topics with emphasis on the topic atoms and molecules.

In phase 2 of my research project I then plan to, with the assistance of participating teachers, prepare a teaching module on the topic atoms and molecules for Grade 7. This module will be available to all grade 7 teachers in the Khomas Region who can benefit from this.

I therefore kindly request your office to allow me to use two schools in the Khomas Region as the research sites for my research project. I intend to observe lessons on atoms and molecules in a Grade 7 class, observe learners' workbooks and interview one Grade 7 Science teacher at each selected school. The schools will finally be identified as soon as permission has been granted from your office. At this moment I consider [redacted] Primary School as well as [redacted] Private School. Consent of principals and teachers involved will also be asked. I am expected to complete this activity not later than end of June 2014.

The schools and research participants will be assured of anonymity and confidentiality in the final research report. They will also receive drafts of the report and will be invited to provide corrections as need be to ensure that the information is accurately recorded and reported. The final teaching module on the topic atoms and molecules will be available to research participants who will then be free to use the teaching material as they wish.

Attached please find a copy of my approved research proposal.

I will be grateful if my request receives your highest consideration.

Yours sincerely

Hoepfner

Ms Narenda Hoepfner
Assistant Lecturer – Science education
Faculty of Education
UNAM Khomasdal Campus

Supervisor: Dr Ken Ncgoza
University of Rhodes
email: K.Ncgoza@ru.ac.za

Contact details: 206 7254 (work)
081 243 3000 (cell)
email: nhoepfner@unam.na

APPENDIX A2 - CONFIRMATION LETTER

REPUBLIC OF NAMIBIA

KHOMAS REGIONAL COUNCIL

DIRECTORATE OF EDUCATION

Tel: [09 264 61] 293 4410
Fax: [09 264 61] 231 367/248 251
Enquiries: Ms H. Imene

Private Bag 13236
WINDHOEK

20 February 2014

Dear Ms Narenda Hoepfner

REQUEST FOR PERMISSION TO VISIT AND ADMINISTER RESEARCH AT LOWER PRIMARY SCHOOLS

Your letter dated 17 February 2014 is hereby acknowledged.

Your request to conduct a research at [redacted] Primary School and [redacted] Private School with regard to "observe lessons on atoms and molecules in a Grade 7 class, observe learners' workbooks and interview one Grade 7 Science teacher at each selected school" is approved with the following condition:

- The Principal of different schools to be visited must be contacted before the visit and agreement should be reached between you and the principal.
- The school programme should not be interrupted
- School should not be forced to take part in the programme.
- Teachers and learners who will take part in this exercise will do so voluntarily.

Wish you all the best.

Yours sincerely

MINISTRY OF EDUCATION
PRIVATE BAG 13236, WINDHOEK
2014 -02- 20

MS A.A. STEENKAMP
DEPUTY DIRECTOR OF EDUCATION

DEPUTY DIRECTOR
KHOMAS REGION

APPENDIX B – LETTER TO PRINCIPALS

P. O. Box 9816
WINDHOEK
11 April 2014

The Principal
[redacted]
WINDHOEK

Dear Principal

REQUEST FOR RESEARCH AUTHORITY

Topic: *An investigation into how two Natural Science teachers in the Khomas Region mediate learning of the topic atoms and molecules in Grade 7*

As an assistant lecturer at UNAM, Faculty of Education, I am a registered student in the Faculty of Education at Rhodes University. I am conducting an important research on the above topic, as it is identified as one of the major problems in science teaching and learning, especially on primary level. In phase 2 of my research project I then plan to, with the assistance of participating teachers, prepare a teaching module on the topic atoms and molecules for Grade 7. The final teaching module on the topic atoms and molecules will be available to research participants who will then be free to use the teaching material as they wish.

I therefore kindly request your permission to allow me to conduct research at your school.

The findings will be used for research purposes only. The confidentiality of participants will be highly kept.

Yours sincerely

Ms Narenda Hoepfner

Assistant Lecturer – Science Education
Faculty of Education
UNAM Khomasdal Campus

Contact details: 206 7254 (work)
081 243 3000 (cell)
email: nhoepfner@unam.na

APPENDIX C – CONSENT LETTER FROM TEACHERS

CONSENT LETTER

An investigation into how two Natural Science teachers in the Khomas Region mediate learning of the topic atoms and molecules in Grade 7

Researcher: Narenda Hoepfner
Assistant Lecturer - Faculty of Education
UNAM

- The purpose of the research study has been explained to me. I understand and agree to take part.
- I understand that while information gained during the study may be **audio/video taped and published**, I will not be identified and my personal responses will remain confidential.
- I understand that I can withdraw from the study at any stage and this will not affect my status now or in the future.
- I have had an opportunity to discuss taking part in this study with the researcher.

Signature of Participant: ________________________________

Date: ____

I certify that I have explained the study to the participant and consider that he/she understands what is involved.

Signed: Hoepfner________________________________

APPENDIX D1 – DIAGNOSTIC TEST TO FIRST YEAR STUDENTS

STRUCTURE OF ATOMS AND MOLECULES

NAME: ______________________________

1. ANSWER THE FOLLOWING QUESTIONS ABOUT THE INTRODUCTION TO ATOMS AND MOLECULES.
2. PLEASE READ THE INSTRUCTIONS OF EACH QUESTION CAREFULLY AND ANSWER EACH QUESTION ON THE QUESTION PAPER.

1. Which of the following indicate the charged parts of an atom?

   a. Only electrons b. Only protons c. Neutrons only

   d. Electrons and neutrons e. Electrons and protons f. Protons and neutrons

2. An object that is positively charged contains all protons and no electrons. TRUE or FALSE

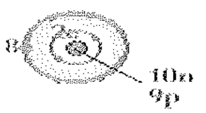
3. An object that is negatively charged could contain only electrons with no accompanying protons. TRUE or FALSE

4. An object that is electrically neutral contains only neutrons. TRUE or FALSE

5. Make a simple drawing to illustrate the arrangement of different parts of an atom.

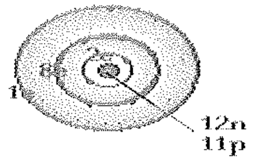
6. Identify the following particles as being charged or uncharged. If charged, indicate whether they are charged positively or negatively. (n = neutron, p = proton, e = electron)

Particle A



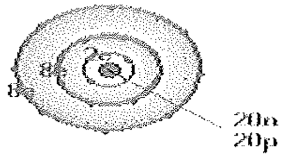
____

Particle B



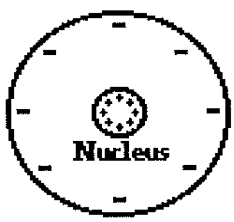
____

Particle C



____

7. Consider the graphic at the right of a neutral oxygen atom.



a. Explain what must happen in order for the oxygen atom to become negatively charged. ____

____

b. Explain your answer.

____

DIAGNOSTIC TEST TO FIRST YEAR STUDENTS CONTINUES...

8. Respond to the following student statement:

   "A positively charged object is an object that has an excess of positive electrons."

   ____

   ____

9. How do you determine the atomic number of an atom? ____________________

   ____

10. The bold, whole number found on the periodic table is called the________________.
    Is unique for each element? ______________

11. The total number of protons and neutrons in an atom is called the ____________________

12. An atom with the same number of protons but different number of neutrons is called a
________________.

13. What are the main subatomic particles of an atom?

____

14. The subatomic particle that has no charge is called a ____________________.

15. Fill in the following chart

Atomic Number	Mass Number	Number of Protons	Number of Neutrons	Number of Electrons	Symbol of Element
6	13				
	25	12			

16. What is matter? ____

    ____

17. What are:

    ATOMS: ____

    MOLECULES: ____

    IONS: ____

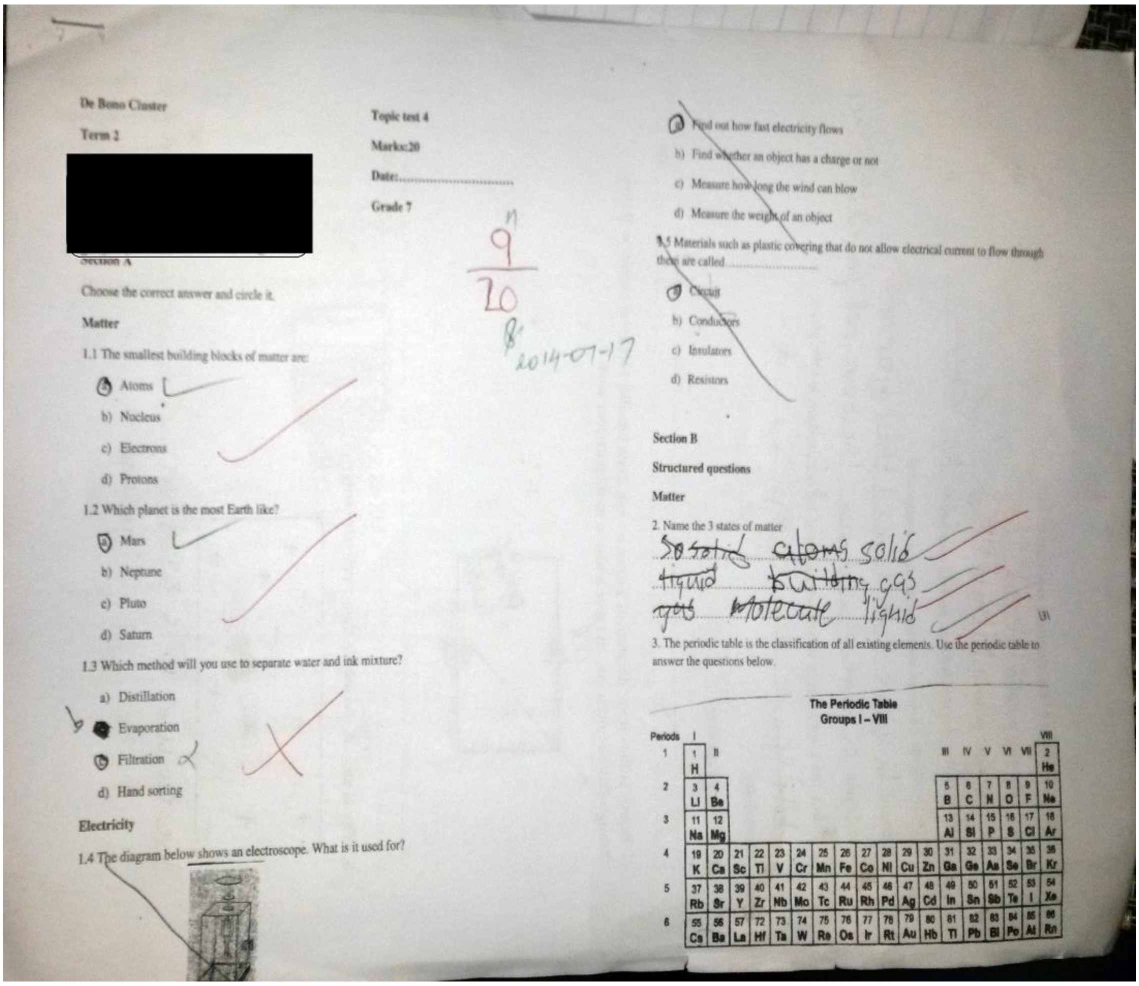
    ELEMENTS: ____

18. How does the state of matter change with the change in temperature?

    ____

19. How does the kinetic theory of matter explain the inter-conversion of the state of matter?

    ____



De Bono Cluster

Term 2

[redacted]

Section A

Topic test 4

Marks:20

Date:..............................

Grade 7

9/20

2014-07-17

Choose the correct answer and circle it.

Matter

1.1 The smallest building blocks of matter are:

a) Atoms
b) Nucleus
c) Electrons
d) Protons

1.2 Which planet is the most Earth like?

a) Mars
b) Neptune
c) Pluto
d) Saturn

1.3 Which method will you use to separate water and ink mixture?

a) Distillation
b) Evaporation
c) Filtration
d) Hand sorting

Electricity

1.4 The diagram below shows an electroscope. What is it used for?

a) Find out how fast electricity flows
b) Find whether an object has a charge or not
c) Measure how long the wind can blow
d) Measure the weight of an object

1.5 Materials such as plastic covering that do not allow electrical current to flow through them are called.......................

a) Circuit
b) Conductors
c) Insulators
d) Resistors

Section B

Structured questions

Matter

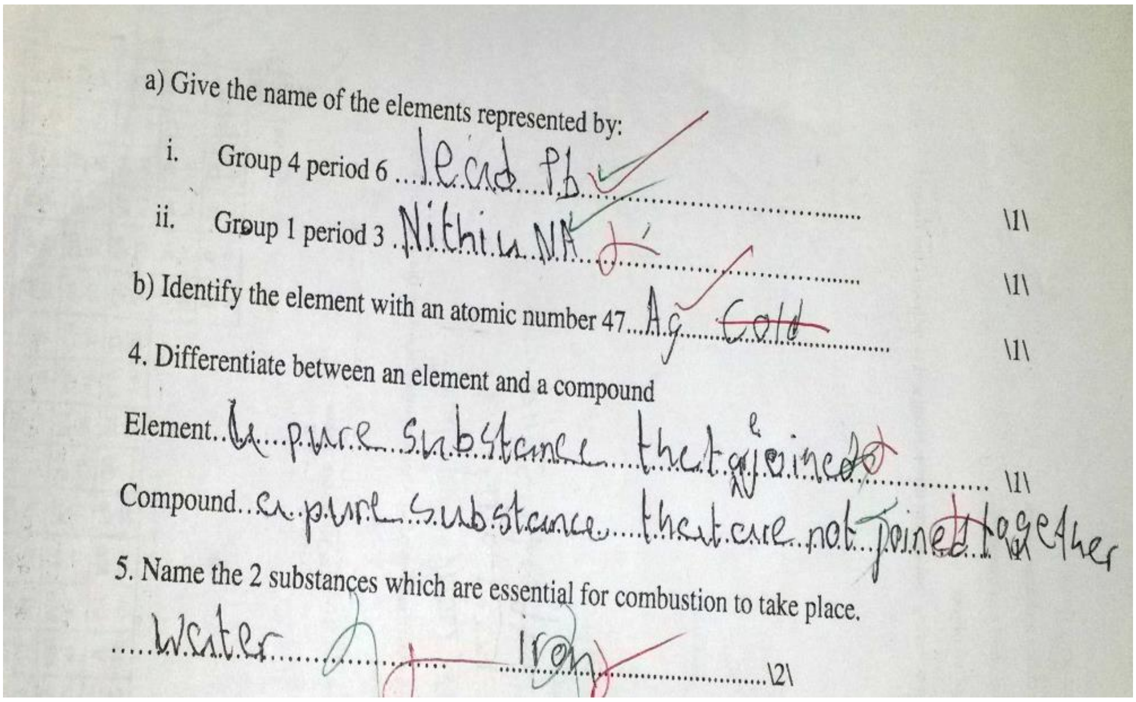
2. Name the 3 states of matter

~~So solid~~ ~~atoms~~ solid
~~liquid~~ ~~building~~ gas
~~gas~~ ~~Molecule~~ liquid \3\

3. The periodic table is the classification of all existing elements. Use the periodic table to answer the questions below.

The Periodic Table
Groups I – VIII

Periods	I	II											III	IV	V	VI	VII	VIII
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Rt	79 Au	80 Hb	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn



a) Give the name of the elements represented by:

i. Group 4 period 6 ...lead Pb.......................................

ii. Group 1 period 3 ..Nithiu NA....................................... \1\

b) Identify the element with an atomic number 47...Ag ~~Gold~~.......................... \1\

4. Differentiate between an element and a compound

Element...a pure substance that joined...................... \1\

Compound...a pure substance that are not joined together

5. Name the 2 substances which are essential for combustion to take place.

.....water.................. iron...........................\2\

APPENDIX E – SAT RESULTS FOR GRADE 7 NATURAL SCIENCE GR 7 (2010)

Republic of Namibia

MINISTRY OF EDUCATION

DIRECTORATE OF NATIONAL EXAMINATIONS AND ASSESSMENTS

Report on the National Standardized Achievement Test (NSAT), 2010

Grade 7 Science

School Demographic Information:

School Code:	E032	School Name:	WINDHOEK GYMNASIUM CS
Rural/Urban:	Urban	Region:	Khomas
No. of Learners Taking the Test:	77		

	Cognitive Level	National	Regional	School
Describe the mixing of substances to make solutions as a physical process	Knowledge	56	60	77
Explain that the components of mixtures can be separated by methods	Application	46	58	64
Topic: Building blocks of matter: air around us		51	57	84
State the composition of air in the atmosphere	Knowledge	64	70	88
State that one fifth of the air around us consist of oxygen and the four fifths consists of nitrogen	Knowledge	49	54	86
Name two substances which are essential for combustion	Knowledge	37	50	64
Topic: Nature and effects of forces		66	70	90
Describe pushing and pulling (repulsion and attraction)	Knowledge	71	77	94
Classify forces in contact and non-contact forces	Application	63	68	85
State that forces are measured in newtons	Knowledge	67	66	73
Topic: Weight and mass		61	60	58
Explain the difference between weight and mass	Application	61	60	58
Topic: Energy in everyday examples		65	58	87
Describe energy as the ability to do work	Knowledge	65	58	87
Topic: Sources of energy		39	47	75
List the most important energy sources for Namibia	Knowledge	37	41	62

APPENDIX F1 – INTERVIEW SCHEDULE

PRE-INTERVIEW QUESTIONS

Mediating the topic Atoms and Molecules

1. How do you experience teaching the topic Atoms and Molecules to grade 7 learners?

2. (a) What do you think about taking into consideration learners' background knowledge in assisting them to make sense of the topic atoms and molecules?

   (b) How do you make use of learners' background knowledge when teaching this topic?

   (c) Are there any topics done in grades 5-7 already that can link up with this topic?

3. (a) What teaching strategies and learner support material do you use in teaching this topic? (group work, projects, only presentations, use of models, worksheets? any other strategies?) If models are used, what type of models are used and why (eg. demonstration, only physically, or do they make drawings as well?)

   (b) Do you make use of any analogies to explain the topic? Any reason why this specific analogy is used?

   (c) How will learners be actively involved when teaching and learning the topic of atoms and molecules?

   (d) In terms of teaching material, do you make use of the textbook or do you prefer to prepare own notes? Do you feel that the textbook gives enough content for learners as well as teachers to make sense of the topic?

   (e) Do you feel that the syllabus is clear enough on the objectives for this topic? Please explain.

4. (a) How do you assess learners' understanding of this topic?

   (b) In what form are questions asked? Orally or written?

   (c) What is the learner's overall performance when tested on this topic?

5. (a) What challenges do you experience in teaching the topic of atoms and molecules?

   (b) How do you deal with these challenges?

APPENDIX F2 – INTERVIEW TRANSCRIPT: TEACHER 1 (I-T1)

[R= RESEARCHER COMMENTS; T1 = TEACHER 1 COMMENTS] 15 APRIL2014

R: Thank you for being willing to assist me in my research and for your time to share some ideas with me. You have the questions of this interview in front of you, so we can start immediately.

T: Yes, I see some of the questions refer to the starting point or prior knowledge that I use, in other words, what associations do I make use of to assist the learners to understand the concepts. So what I usually do, and that is also why the syllabus is written like that, is to always start with the Scientific Method – what is inside the scientific method as a whole and how do you approach a problem or question inside the sciences. And what I actually mean with that is that you need to trigger the child's perception of "*I want to know more*" and "*how does this work*". In other words, rather **HOW** you think than **WHAT** you know.

Then after the Scientific Method we do Living Organisms. The basic things of Bacteria, Algae, Plants and Animals. The reason for this is to make things tangible for the kids. He knows a plant – he understands the body. We only focus on organ level, not cellular level yet. Very basic – looking at organs inside living organisms. But we do not go beyond the tangible, cause the moment you go beyond; you now need technology to explain - microscopes, physical tools to go deeper. That is what they call the reductionist approach – you start big and then go smaller and smaller. So you start at a point where the kid still understand – he can smell, taste, feel.

And then a kid should understand that whether I work with the Universe or an ecosystem or whether I work with a human, plant, animal – EVERYTHING is made up of elements. There is carbon, there is oxygen, hydrogen. Organic compounds as you find in the body today consist of 98% carbon, hydrogen and oxygen, potassium, calcium, magnesium. And then all the rest such as vitamins and other elements in minute amounts. And as soon as a child understands THIS, I can take him to the next level where we can say: "Right, if we look at carbon for example, how does carbon look like? Then we get to the smallest identity, the atom.

Then I take them further and we can play the game "Musical chairs" to illustrate the structure of an atom. There are then kids physically sitting on chairs in the middle. I put a red hat on half the number of kids in the middle and they will then represent the protons that is positively charged and they will give weight to the atom. Because regarding Matter, everything in this world has to do with weight. The earth has an attractive force and we stick to the earth because we have weight. And that basic weight lies in the atom because the atom has weight and because it has weight, the molecule can have weight. And then I will quickly bring them back to the Levels of Organisation. Then for the other half I will give yellow hats to put on. Or rather green ones, you will now see why green and not yellow. My concept of something that is moving is a yellow Volla (Volkswagen)! So a yellow Volla for me indicates something that is moving!

R: Okay, interesting!

Yes, so you have red protons and green neutrons in the middle, sitting on chairs, giving weight to the atom. And they don't move. And the same amount of protons you have the same amount of neutrons you have. And now we don't talk about isotopes, we only focus on the basic atom. And then the same amount of electrons with yellow hats on, run around this bunch like yellow Vollas!

And then I will also let them understand that for the atom to be stable, it needs partners. Now what does that mean? You have the nucleus of the atom where protons and neutrons hold hands, they move nowhere. And then you have the electrons moving around this nucleus – it is like one of the laws of nature! And then I will show them – and this is also one of your questions – What learning materials do I make use of? – So now I will use the smart board and I will show them physically a video of exactly how the protons are fixed and the electrons are running around it! Because around this nucleus there are orbits and you will often see the picture – the nucleus in the middle and the electrons running in these orbits around the nucleus.

And then one of the laws of nature is for this atom to be stable, there should be a specific amount of electrons in each orbit. In the first orbit there should be only two electrons, so to be stable I have two kids running, two Vollas, two electrons. And there should always be an equal number of electrons – partners. In the next orbit I will have 8 kids running, also 2-2 together. And this is one thing the child must learn – there are many scientists like Rutherford and Bohr who did lots of experiments and received Nobel prizes for this to determine the amount of electrons. So the child must know, if the atom has 2 electrons in its first orbit and 8 in the second orbit, it makes up ten electrons and now the atom is stable. The moment if this atom only has 6 electrons in its outer orbit, it is short of 2. What I then normally do is to put two yellow hats on the floor to indicate it needs two places to be taken up. What I then usually do is to take oxygen as a classic model. Oxygen works perfectly as an unstable gas. Hydrogen has the simplest structure with only one proton and one electron. Because it has only one electron, it is also unstable. So there is one hat available to combine with the oxygen. But oxygen has two open hats; therefore another hydrogen can combine with it. And so we build up a water molecule there in the classroom. This idea I will usually do with a class that does not perform up to standard. I have one such class that, doesn't matter whether I give them a glossary test, spelling test or class test, they will always underperform. With them I will do Musical chairs with the Volla concept. If I have a class that performs better, I will only use the Smart board. I will for example show them models on the Internet that indicates how atoms combine physically.

And then of course I use many different examples. I will use water as basic form of all life. Then I will take Sodium hydroxide – Sodium, oxygen, hydrogen. And everything I will refer back to the Periodic Table. So there you see the Periodic Table. And the Periodic Table is set up exactly in just a way that all the elements are on a specific place due to their atomic mass. And according to this I will show them the concept behind the Periodic Table. What does the Periodic Table look like? Then we will take a specific element, for example Argon or Helium. We will look at the amount of protons of Helium – it has 2. What is its atomic mass? Then we will take different combinations. If it has two protons and is not an isotope, it will also have two electrons. And because it has two electrons, it will be in the first orbit. And with some classes we will build the basic form of the atom without the hats and dances! Of course this concept works perfectly for grade 6 where the concept of atoms is still very abstract.

Something that also works well is to use different magnets. You can take a blue-red magnet to illustrate the proton/neutron. Then you can let the learners sit around the table en we can say to one another: “Remember the law of nature says two electrons in orbit one, then eight electrons in the rest. So if you have an atomic number of 14, then you know it is 2 electrons, then 8, gives you 10, so the third orbit then has 4 electrons. So you have space for another 4. What can we combine with this atom? The child should only remember that if you put different things together, you will not get a new element. This is where the concept of compounds then comes in.

Quite often people will ask me how I learn this to a child. There are just some things and concepts a child should know. As he knows this is a hand or a foot, he should know that you get atoms and atoms have certain characteristics making it an element. When two of these atoms come together, it forms a molecule. And then he should know that it builds up to form organelles, cells, organs and different organs make up an organism.

R: So you take the child from big to small and then again from small to big.

T: Exactly. But the starting point should always be what the child knows now. I even bring in gravitational force. What the child learn about mass and height is even applicable to the atom, cause that is what gives the atom its characteristics. Electrons and neutrons and all these things cannot exist on their own, they only exist in context with the atom. And because the nucleus of the atom has weight, everything on earth will have weight in terms of the gravitational force of the earth. And then in grade 7 they also do only covalent bonds where two atoms will share electrons.

And then I also have the Smart board as learning material together with this physical sitting on chairs concept. I also sometimes make use of magnets as mentioned before as well as where you make use of the ball and stick model. But these I will only use after I did the structure of the atom and let’s say you combine oxygen with two hydrogen atoms. But I will always emphasise the three particles of the atom – proton, neutron nucleus with the electrons moving around the nucleus.

R: Do you cover the normal Namibian syllabus?

T: Yes, we cover the Namibian syllabus and then we will only add different examples. What we do however, is to take the workbooks of next year and integrate the competencies and requirements as part of our textbook. The problem with the syllabus for me is often the supporting readings. You can simplify something to such an extent that you may confuse the learner totally. For me it is more important for the kid to be able to do many examples to capture a concept than to oversimplify it.

One of the publishers contacted me in the week to look at the Science textbook for Namibia, as it is now time for the new syllabus as well. So I proposed that they should rather not ask one person to write the whole textbook for a certain grade, but rather to take a theme through from grade 4 to 7. The reason for this is that themes often tend to be loose hanging from the continuity to build up from simple to more complex. And quite often, if one person can do the building up of complexity, you can search for more examples and then just add one level of complexity each year.

R: Do you at this school make use of the grade 7 Natural Science and Health textbook? Or what textbook do you make use of?

T: We do not use the prescribed textbooks at all. I'll show you what we do. I am now busy working through next semester's book cause last year we did not add the competencies as well. Now we are doing it. So our Science textbook for this year will look like this: [*Teacher shows a binded, copied A4 book with notes of each module, photos, illustrations, basic competencies at the beginning of each topic as well as questions and worksheets at the end of each topic.]*

R: So you do not actually know what the prescribed books look like?

T: No. I only take the requirements and then I will add extra stuff such as practical worksheets. It is not a separate thing. But what we are going to do next, because the worksheets can get quite a lot and on different levels – from level 1 testing only knowledge and definitions to level 3 that is application, is to set up a separate worksheet booklet. Then I can decide which ones I want to use each year. So yes, we take the requirements of the syllabus and put in in the separate book. And then of course I will ensure that the minimum basic requirements are met as well as more, especially for Namibia.

Another thing I often experience from the textbooks is that it generises concepts. A learner must understand concepts and know what are only examples of the concept. This is my argument – we tend so often to oversimplify concepts that the learners starts to confuse concepts with examples.

R: And then the child gets even more confused the moment when he needs to do things in more detail.

T: Definitely! Another strategy that I also make use of sometimes is interactive sessions. For example I will present something, and then the kids must go home and revise the topic. The next morning it will be like a fire alarm. I will for example say: "Pieter, come to the front and explain to us this or that. So I will literally repeat the concepts three times.

R: And I assume this will be the same for the topic Atoms and molecules?

T: I will do this in exactly the same way. For the two classes I have this year, I will do it in this way: I will present the concepts for the first time, starting with revision of the Levels of Organisation. Then I will say: "Right, let's take water for example today. We will discuss the structure and all and then we will take another molecule, for example

Sodium chloride. So I will say: “right, there you go! Go and find out more about sodium chloride. What does it look like? You know the Periodic Table, etc, etc. The next morning I will put Sodium chloride on the board and ask kids to come to the front. I will ask them to draw the atom of sodium. We know now the atomic number, and remember our rule about so many protons, so many electrons, so many neutrons. Where should the protons and neutrons be? In the middle – on the chairs. And the “Volla”-electrons are running around. Then I repeat the concept again. And then I will give them some other examples and a worksheet. And a third time consolidation! But the secret is, and I am doing this quite often – let’s take particles for example – things that move. Okay, there is an atomic bomb. Russia is threatening to nuclear the Ukraine. So I will always bring it back to what is happening **now**. And often that is my problem with the textbook examples. It is the responsibility of the teacher to keep it alive by keeping it recent. Okay, we have the advantage of the smart board and then I can go on Youtube and show the kids – today North Korea shut down a nuclear thing. And I will show them that this technology used, refer to the Uranium in Namibia. And that depend on the teacher. Some teachers will highlight that textbook from front to back. I always try to keep the subject alive by keeping it relevant and actual. I must also tell you that for me it is very important to start every lesson with the conclusion of the previous one. For example, I will always summarise yesterday’s lesson in two minutes.

Last year I had to discuss the Science Fair with the Grade 7’s. And at that time the Uranium mines in Namibia was under discussion. And there is the Hiroshima thing in Japan. And the tsunami – so that day I could discuss with them the whole concept of stability and energy around nuclear power that should be controlled. It is one of the reasons why the Uranium mines in Namibia are threatened. And the Uranium the kid reads about on the front page of Die Republikein (*a Namibian newspaper)* is the same he sees on the Periodic Table and could bring it back to protons, electrons and neutrons. But this depends a lot on the teacher. For me it is of utmost importance that the kid should bring everything back to his environment. Again – they know Uranium, they know the Rossing mine. They know it, but how can we bring it into connection with what we are doing? We have power stations in Japan; we have Koeberg in South Africa. This is how you keep science relevant!

R: If I can bring you back to the syllabus – do you feel that the basic competencies is enough regarding clarity especially for the novice teacher? How do you interpret the syllabus?

T: What I will do, is to revise our textbook for the second semester that also covers the topic atoms and molecules. I also have the syllabus with me to work through during the holidays. So can we discuss this question in detail again at the beginning of next semester? As I used to train Biology teachers at the PUK in South Africa, I think I have quite an idea what the level of knowledge is when a teacher walks into a classroom for the first time. And then we should also consider the amount of learning aids available in some schools of course!

R: I will appreciate this, as I have slightly a problem with the syllabus. According to me, the theme is Atoms and molecules, but the basic competencies only require the definition of an atom and an element and then the kids should now the first ten elements of the Periodic Table together with a few extras.

T: So the jump directly from the atom to the Periodic Table.

R: Yes and then only a few topics later they do Electrostatics where the learner is exposed to protons and electrons that are moving. That is why I would like to hear from teachers covering this in the classroom how they experience this.

T: Okay, I will check on the syllabus in more detail and then get back to you. But as I have said, I believe that everything is working in building blocks. When you do Electrostatics, for example, that basic concept of protons and electrons should have been captured already. The biggest mistake we can make is this thing of oversimplifying things to such an extent that it becomes so complicated to the learners in later years. We always think that we will confuse the kids so we often only give the skeleton of concepts and by doing this we start to develop wrong images in the mind of the child.

R: Do you feel that this can be one of the shortcomings in the syllabus that may lead to problems teaching and understanding the subject?

T: Let me quickly refer back to the Levels of Organisation. My learners already did plants and animals. So they know a little bit about organs and structures. They know about the flower and a leaf and a lung and a heart. Now here – **everything** starts here! The moment you leave out this and jump to the next level, it gets confusing. Therefor I am a big advocate for the reductionist approach. What the child knows and then we go smaller and smaller. And when you are small, you again go wider and wider. It is then when your learners understand that the power station in Japan that generates electricity for the community – that community is me and you and at the end it comes from the Uranium atom with its electrons and protons. So the first day in grade 7 I will tell the learners that the whole world is put together with tiny little things. And the big question for them always is HOW? Then I will tell them that is why there is a Creator. Cause if you put all these things in a little test tube and shake, you will still not have anything. There is what they call a driving force that puts the whole universe in an order, and all that our scientists have to do is to try to understand this order. I am not here to question this order; I only try to understand how everything fits into one another. So in my first lecture I will show them the video “Planet Earth with Living things”. So I show them the cells and the birds and the Universe. Do you know why? Because when you talk about atoms on day 1 and you talk about atoms again six months later, the child has heard about it somewhere already. But as I have said before, the syllabus tends to compartmentalise things such a lot that they lose track with one another. So the Levels of Organisations for me is more or less the most important prior knowledge and then of course Form and Function. Everything in Biology is based on form. Something looks like this because of its specific function and it has a specific function, therefore it looks like this. And the kids’ biggest fear for the physics and chemistry is because these concepts are not taught to them in understandable ways. And so often in the secondary school when the learners study charges and these things, the teacher does not bring them back first to the atom and reminds them again about what they have done previously. They assume that the learners do have that prior knowledge. It is then also important that teachers should be able to make associations, something I realise not all teachers are able to do. And it then that your learners start to loose connections!

R: Do you feel that the textbook should give slightly more guidance and detail especially for the novice teacher?

T: Absolutely! That is the reason why we do not make use of these textbooks at all. But I must say that the teacher should also be adaptable where he or she is. Arguably – if I am for example at Rossing, I had amazing examples. These kids know and understand these concepts. But if I am teaching at Karasburg, it is sheep world, so I will have to focus more on proteins and tissues. What is a protein? What does it look like? How is meat put together? So then I will focus more on carbon, oxygen and hydrogen as elements. So I think it is important to have different examples without losing the framework. Examples should support concepts, not replace it! That is often the problem with textbooks. The textbook often does not subscribe the concept. And it is important to consolidate the concept! Especially atoms and molecules. This topic is a huge challenge. Because it is such an abstract topic, quite often it is oversimplified to such an extent that the learners totally miss the bus and develop wrong perceptions!

R: Do you find that learners start to form mental models of a concept that is wrongly interpreted?

T: Definitively! I am a huge advocate that the basic structures should be done, but then expatiated with examples, examples, examples. Don't show them for example only water. Show them table salt, glucose, etcetera. Why does glucose have that structure? And when you drink Energade it contains glucose. Why? But the examples should be flexible. And unfortunately the textbook can be very static. And then of course many a time teachers oversimplify content because they themselves do not have the knowledge to go deeper!

Another thing that I often experience is of course the fact that learners do not know how to interpret questions in the exam. They are drilled with questions and answers. If you see this question, you should write this as answer. So they never learn how to interpret their work. And then of course very important in science is terminology. Kids must know the origin of words and the meaning of it as a lot of information is contained in a word!

The scientific method is another difficult concept for learners. But if they **understand** it, they can interpret a lot! Now for example you can take a Mc Donald's burger. If you eat too much of this you will get fat. Why? And then we can take that burger and break it down till we get to the building blocks of atoms. What is inside a burger? Meat, flour and sugar. What does all these things consist of? Then you end up again with carbon, oxygen, hydrogen – different elements, atoms.

R: Do you feel it is important to first cover elements and only then atoms or vice versa?

T: Definitely first elements, then atoms. Because what does this learner know? He eats for example an apple. What is inside this apple? Cells. Okay, what is inside these cells? Sugar – sucrose, fructose. What does this look like? Carbon, oxygen, hydrogen. So always from what the learner knows. It opens the mind to explore. A child will not easily work from the unknown to the known, this is confusing.

An atom is a very abstract concept for the learner. A molecule, an element! So another example that I also use sometimes is the school building – made up of bricks. That is also quite a nice analogy to make use of. The child sees the bricks. So here you have the building block component together with the atoms and molecules. I also often use this concept – a house with bricks, cement and forces keeping all together.

This is now quite a lot! But you are welcome to visit my class when we cover this topic.

R: Thank you so much and I will really appreciate it if you can let me know in advance when you are teaching this topic. With your permission I would like to videorise two of the lessons as well.

T: You're welcome and I will let you know. And then we can also discuss the detail of the syllabus and textbook as well.

APPENDIX F3 – INTERVIEW TRANSCRIPT: TEACHER 2 (I-T2)

[R= RESEARCHER COMMENTS; T2 = TEACHER 2 COMMENTS] 16 MAY 2014

R: Thank you for taking part in my research and being will to assist me in this. I really appreciate this.

T2: You're welcome.

R: So shall be start immediately? Please tell me how you experience teaching the topic atoms and molecules.

T2: I can say that the topic is type of challenging. Should I give a reason?

R: Yes, please. Why do you say that it is challenging?

T2: I think the reason because it is the first time that the learners are doing a topic like this. It is never done in Grade 5 or 6. Yes, so for them, they are really trying to: "Okay, what are molecules?" Even, somehow they have prior knowledge on molecules, for water is a molecule. But then the fact that I have to talk about atoms and the electrons, and the positive and negative structures. They look at you so strange!

R: But do you thing that at the end of the topic they enjoy learning about all these?

T2: No, I don't think so at all. They don't. Especially when it comes to electrons and the elements like in the Periodic Table. They give me this look like: "Wow, what is going on here? Is this Physical science, or what?" They not really enjoy it. Yeah, maybe the smart ones who are really into learning and stuff. But others, it's just…. I don't know.

R: You have said that they don't do any of this topic already in grade 5 or 6. But do you feel that there is any other prior knowledge that they already have before doing this topic? Are there any topics done already that can assist you in teaching this topic?

T2: Only water. When I give an example of a molecule or a compound, then I can say that okay, water is a molecule because it is made up of oxygen and hydrogen. That they are familiar with, otherwise, ….. atoms? What I am trying to do when I teach this topic, I always give examples like a book, a table, your desk, you, even us humans all have atoms in our bodies. Okay, they are also familiar with the topic Matter. So when it comes to atoms, atoms are the tiniest particles of matter.

R: So what have they already learned about matter in grade 5 and 6?

T2: Atoms are under the topic Matter. So the main topic is Matter and atoms and molecules are a sub-topic.

So what have they done on Matter in grade 5 and 6?

T2: In grade 7 we did not really touch on the topic, but in grade 6 there is Matter. But then they are just talking about Materials and then they are also talking about the three states of Matter.

R: How do you make use of this prior knowledge that they already have when introducing this topic to your learners?

T2: I just, what I do, I will for example use a desk as example, as I said earlier. Then I will say: "Okay, since we are talking about Matter, and Matter they know is anything that can occupy space and has mass. So in that matter are t-i-n-y little particles that form up that object, and those particles are atoms. So somehow they can relate.

R: Okay. What teaching strategies do you use in teaching this topic?

T2: There isn't really much. Cause it is a small topic, so there isn't really a lot in there. But I use to explain to them what I prepared beforehand. And then I ask them to draw the atom so that they know what I am talking about. What makes up the atom? So they are not really involved in this.

R: Do you make use of any analogies – or comparisons when teaching this topic?

T2: No, not really.

R: So you will not compare the atom with, for example the solar system with a centre and the planets revolving around it?

T2: No, I do not link it with anything. It's challenging. There is not much to compare to. Oh okay, maybe the solar system – this is another topic under Matter as well. And when they come to the solar system, they are much more interested, because we are talking about the closest planets to the sun; there isn't life on Mars because there isn't oxygen and those things. So then they are more interested. I can compare that to real life things, but atoms… (*laughing*), not really!

R: Yes, in that case it makes it definitely more challenging. So you also do not make use of any models?

T2: No, not any models. I just make use of a poster with the Periodic Table on where the elements are, because elements also fall under atoms and molecules.

R: Okay, and is there any way how you can involve your learners actively in this topic? As this is also a bit challenging!

T2: No, I cannot really say it is a practical lesson. Apart from them drawing the atom. Okay, how I involve them – what I do - I am having a Periodic Table poster with the elements in my class. I put this on the chalkboard and then I will ask any learner who like to point on the poster where can we find for example oxygen, because there are only symbols on. Then they will point on the poster the different elements.

R: So you make actively use of the Periodic Table. And then, do you feel that the textbook gives enough information of the content as well as how learners can actively take part?

T2: Yes, it does, because the textbook is based on the syllabus. So everything that the learners need to know is there.

R: If I can quickly take you back to the syllabus. Do you feel that the syllabus is clear enough on exactly what you need to teach?

T2: Yes, I can say that it is clear because it is telling you what you should do – explain to the learners that atoms are the tiniest building blocks of matter. So for me it is clear. For me, I just have to look at the basic competencies to see, okay, this is what I need to teach. So yeah, I think it is clear.

R: But I had a look at the syllabus and have seen that the main theme is Atoms and Molecules. But in the basic competencies thsy never use the word molecules. So, according to the basic competencies learners never need to explain or define a molecule. And then I also noticed that the learners do not need to know anything about electrons and protons already. Do you teach that part to your learners?

T2: About molecules?

R: Yes, as well as the structure of the atom with protons, neutrons and electrons.

T2: Yes, I teach that

R: Although it is not directly stated in the basic competencies of the syllabus? Because according to the syllabus they only need to know that the atom is the smallest building block of matter.

T2: Yes, it's true! Yeah. So somehow what I do, the information is in the textbook, although not in the syllabus. Cause what I think, the syllabus is straight forward, yeah…. the book …. so maybe it is not so clear! (*laughing)*

R: It's fine! I only noticed it in the syllabus and was wondering if you do more than what was prescribed in the syllabus?

T2: Yeah, I do, I usually do. They have to know what a molecule is as well and then the atoms – atomic structure.

R: What about the atomic weight and atomic number from the Periodic Table? Do you also cover that?

T2: Yes, I also do that although it is not expected from the syllabus. Just that they know. Cause they require these things to know in grade 8 or so. Just that they can have the basics and relate more to it.

R: What textbook do you use?

T2: The Natural Science in Context. This one is the one that I can say its having enough information. Okay, not really enough to when it comes to this topic. Cause this topic is only about 2 pages.

R: But do they explain the structure of atoms in more detail, although it is not stated as such in the syllabus?

T2: Yes, so I feel the textbook is fine.

R: Do you only use the textbook, or do you give additional notes as well?

T2: I give them notes as well because the textbook – learners don't have textbooks!

R: What? Why?

T2: Yes, they used to have textbooks but then they lost them. So there is now only a few. So what I do – I take the textbook and then summarise from the textbook. Or sometimes get my own notes from the internet or some other textbooks as well, like Natural Science and Health Education or something like that by Pollination. So I just combine different kinds of notes and give them the notes on the chalkboard. And then when they draw, they draw a Periodic Table. But then the Periodic Table in the textbook is not so clear, so I prefer them to copy the Periodic Table from the poster and then the atomic structure form the textbook.

R: So you prefer to put all together in your own notes?

T2: Yeah, yeah!

R: Okay, that's good! How do you assess the learners at the end of the topic?

T2: Okay, at the end of the lesson, since it is only one or 2 lessons, I only ask them to recap like some questions what I have told the learners like ask them where maybe oxygen or aluminium is on the Periodic Table and then for example what the symbol for aluminium is. But sometimes I also, maybe at the end of the topic, now Matter, I give them the questions in the textbook – there are assessment questions in the textbook that they need to copy and then they go answer them at home and then we mark them. I also give them tests like at the end of the topic. Tests and topic tasks.

R: And how is the overall performance in this specific topic?

T2: Not so good comparing to others – comparing to the human body and the environment that I did in the first term. Cause for me these are things that they… they… okay, they might see gold everyday as an example of matter. But these are not things they relate to in everyday life for example the human body. You know the kind of food we eat, to them they are more interested in the human body – the sex, sexual intercourse, the relationship between boys and girls, that things! So for them this is not so good!

R: *(Laughing)* Okay, apart from the fact that they do not find this topic interesting, is there any other challenges that you experience in teaching this topic?

T2: Just the fact that you have to explain something that I also find a challenge myself. I understand it, but I don’t understand it **so** fully – you know like any other topic. Yeah, I do research. \but then it is quite challenging trying to explain something, trying to make it FUN, you know, but they don’t really see it in!

R: Do you think if the textbook gave a little bit more information, that it maybe could be a little bit easier for the learners to study and understand the topic better?

T2: Yeah, maybe… *(Not sure)*

R: Do you think that they maybe oversimplify this topic and with that confuse the learners more?

T2: Yes, I definitely think so. Maybe they should give a little bit more detail on the topic – maybe that will be better!

R: Do you think that the learners in grade 7 are mentally on a level already that they will be able to understand a little bit more detail? Or do you feel that cognitively they are only developed still to understand only the basics?

T2: Yeah, they should know the basics, but the thing is they also sometimes wonder for example: “Why does this thing happens?” Cause the thing is “Okay, this is how water is formed”, then they say “Okay, so what?” I think the learners want more. Not necessarily a lot of information, they just want to link things to “Why does these things happen?”

So do you feel that they oversimplify the topic too much?

Yes, I think so because if I look at the syllabus there are the competencies, but in the textbook everything is just summarised. There also is not a lot of activities in the textbook. There is only one and that’s it!

R: Okay! If I can bring you back to the textbook, do you feel that they give enough examples in the Namibian context, for example on the elements? If I think of Uranium – Rössing and the other mine that is opening now – all these things?

T2: No, they do not go into a lot of detail. They don’t really talk about different elements and focus on a specific element. For example, that Uranium is mined in Namibia, because it is not required in the syllabus, the textbook does not focus on it at all.

R: They need to know the first ten elements of the Periodic Table, am I right? But you say that they do not relate to any element in the Namibian context?

T2: I think they only refer to the first ten elements on the Periodic Table. Yeah, that’s it.

R: Do you think that it could be more relevant to learners if it was rather prescribed to know the first ten elements, but add some other elements that are relevant, for example gold, silver, tin, uranium – that is relevant to the learners’ everyday experience?

T2: Yes, that is mined in Namibia. That can also work!

R: Do you have access to enough other resources to be able to find out more about the topic? Or is this also quite challenging?

T2: It’s not really challenging – I can go on the Internet and then use my two textbooks.

R: Do you have access to the Internet at school, or do you need to do it on your own?

T2: At school, sometimes the computers are not working. So I only use my Tablet or use the internet at home. Sometimes when I do not have enough information on a topic, or do not understand it myself, I will ask some of the senior teachers to help me with information.

R: But it can be a challenge to get information from the internet or YouTube at school?

T2: Yes, it can. Exactly! Because the internet also don’t give you always what you want. They give you certain things and then you must work out your own way again. Or sometimes you don’t have credit or date – then what? And here we have a computer for teachers and WiFi at school, but sometimes the computer is like those oooold computers and sometimes it is not even working!

R: As you are in primary school, do you have access to senior phase textbooks?

T2: Not really, but I have some friends teaching in secondary school. But they do not really help me a lot!

R: I don’t know if you will be able to answer this, but do you feel that you give your learners enough information on this topic to take this information through to grade 8 or 9 when they do that topic in secondary school?

T2: I don’t think so, cause to be honest, last year I did not understand this topic myself so well *(laughing).* But so far I did not give my learners enough.

But do you feel that, if you look at the syllabus, with the knowledge gained from the textbook and the syllabus it will be enough to take to secondary school for this specific topic?

T2: No, I don’t think so. Cause like I said, some things are not in the syllabus like the molecules. I think it is always better to visit other sites on the internet as well as ask other teachers to help. I also thought of is to Google for a practical lesson to see how other teachers also teach this. Something like this.

R: Do you know what is taught in this topic in grade 8 to 10?

T2: I have no idea.

R: So I believe this is also quite a challenge because you do not really know what the learners need for prior knowledge in secondary school?

T2: Yes. Maybe it is time that I consult a grade 8 to 10 syllabus to take a little basics from grade 8 and apply it in my lessons.

R: Okay Linda, is there anything else you think we need to know about this topic? What do you think we can do more to assist learners in enjoying this topic?

T2: One thing is to have an OHP to show learners the atomic structure – a live one! I remember at College we had slide shows where there were atoms. And where electrons are free moving, they are moving. That's how matter conducts electricity, cause electrons are free moving. I want to show the learners how those electrons are moving in the atomic structure. With the protons and neutrons in the centre. I want to show them that, okay!

R: To come back to the learning support material and teaching strategies. Do you have any access to any form of IT?

T2: We have a school laptop with an overhead projector, but you need a lot of information to show learners. But I will not use it every day as you have to borrow it etcetera. It is a schlep!

R: But will it be possible to show learners for example a video clip from YouTube?

T2: Yes I think so, but I don't have a video to show them. Because most things on the internet are more. how can I say.. it's not that simple, it's more complex. And it's more based on the United States.

R: So it is not really relevant to our context?

T2: Yeah, I might try, cause I thought of it already. To show the learners as I explain I can show them. For example atomic numbers – learners must know where it comes from, so then we have IT access.

R: Say for example, if the textbook gives possible websites of where you can access video clips or information, do you think this will help to teach topics better?

T2: Yes, definitely it will. This will make it more fun and interesting for them.

R: So if you have assistance on how to use IT to teach the topic it will help?

T2: Yes! And another challenge I have on these IT things, it is just that uhm.. you need some … uhm… to be honest, I do not really know how to use it. I try to use it once last term, but then I had to ask my colleagues to help. But sometimes they are also busy with their own lessons. And then it is only you and then you are stuck, trying to connect things and learners are looking at you waiting for you to …. yeah…

R: So you never had a workshop or illustration on how to make use of the IT at your school?

T2: No, especially the new projectors I have to figure it out myself, maybe.

R: So a short workshop on how to use the technology, maybe effective and make things easier for you?

T2: Oh yes, I definitely think so!

R: Okay, I think that is about it. Thank you so much, you really gave me a lot of information to work on now. Thank you so much for the interview.

241 T2: You are welcome, Miss.

APPENDIX G1 – LESSON OBSERVATION TRANSCRIPT: TEACHER 1

(O-T1L1&2) (Double period) 30 JULY 2014

T: Good morning Grade 7's. We are going to look at Basic Chemistry and we are going to do the section in your books on ATOMS – the structure of atoms, a bit of the functions of atoms in relation to what you guys have done up to now . And we are going to start off with this picture. (*Teacher puts on Smartboard and show the picture of the Levels of Organisation to the learners).* Who knows th*is picture?* I think yo*u* all know this picture by now.

What we have done up to now (*Teachers indicates on diagram each level).* We have done organisms when we did animals – vertebrates and invertebrates, ne? Onthou julle dit? We did body systems – digestive system, urinary system, nervous system up until last week. We've done organs themselves because organs are part of systems, ne? So we did organs up to last week up until the brain that you guys could touch on Monday! So we did organs. Then we did a bit of tissue when we start looking at nerve tissue and neurons – remember that? And when we did the digestive system – the capillaries in the small intestine! So ons het so bietjie aan tissues geraak, ne? And then, we did not really do cells already, maybe mentioned one or two cells like the epidermis and when we did photosynthesis remember last term and looked at the chloroplast I showed you what the plantcell look like - lyk soos klein baksteentjies so langs mekaar, ne! But we did not spend too much time on cells. And then there is one extra that I asked you guys to add to your diagram, which is….?

LL: Cell organelles!

T: Yes, which is cell organelles. So between molecules and cells we have cell organelles, okay? And now, very important, is that we are going to focus on this (*teachers encircles molecules and atoms on the diagram).* So the topic this morning relates to eventually what you guys have done so far for the term as well as we did Matter last term as well. Onthou julle dat ons Matter en gravitational force and weight and Newton en al daai goed gedoen het? Remember that?

And at the end atoms do not only have a function in terms of the biological concept, but it has a physical-chemical relationship as well. So if we look at the whole Universe, it all relates back to atoms. Atoms basically allow for the whole Universe to stay together. This is because the atom is structured in a specific way which I am going to show you this morning. It's because the atom is the atom that the whole world can stick together and stays together. And it is continuously … what? *(teacher makes vibration movements with his hands*)

LLL: Vibrating!

T: Yes, the whole Universe is continuously vibrating and I am going to show you this as well.

And when we start touching on molecules I just give you the example when we did the digestive system about three weeks ago what happens to the building blocks of carbohydrates for example. So I'm gonna show you also where an atoms fits into a loaf of bread which we eat every day. Okay, is it fine?

LL: Yes, Sir

T: (*Opens power point on smart board, with heading "MATTER*") So everything on earth , everything you can see, smell or touch, is Matter. But there's lots of matter around us that we cannot see or smell. Can you smell nitrogen?

L: No

T: Can you smell oxygen in the air, or carbon dioxide?

L: No

T: Nee, ons kan dit nie ruik nie. Dis hier in die lug. Who can tell me, how do we know that gas has mass?

L: Because you can buy it in a bottle

T: Yes, you can buy 9 kg of gas. You can go to Pupkewitz and ask for 9 kg of gas because you are going for a braai somewhere on a dune. If you open the tap, the gas will fill this room but it will still have mass. So everything in the whole Universe has mass. If anything is composed of particles, it will have mass. Even a dust particle, even the lightest gas in the world! Who knows what the lightest gas in the world is? Can you guess?

L: Hydrogen

T: Yes! And we will go to why hydrogen is the lightest gas. So now we know that a brick has mass and a pencil have mass and takes up space. And the very important one that many of you did not know before a week ago, is that even air has mass!

Right, now, uhm….. can you think of anything that is not considered as matter? Kan julle aan een ding dink wat ons elke dag eintlik ervaar en ons sien dit met ons oë, maar dit word nie as Matter beskou nie?

L: *(No response)*

T: Hierdie masjien (*indicating to the projector light in the roof)* doen dit ook.

L: Lig!

Lig! So there are physicists in the world who actually think that if you look at light and the Universe – for light to exist, there must be some form of matter involved. So the normal answer that people will give you is that light is not matter. Can you capture light and cool it and condense it so that it can have mass?

LL: No!

T: So that is one thing! Het "n mens se asem massa?

T: Yes! Why? (Teacher breathes out against his hand). What is in your breath?

L: Water vapour

T: Yes! And carbon dioxide molecules, ne! So actually there is very little that we know that does not have mass. Okay? So now in the previous picture we said that ATOMS are the smallest building blocks in the biological sphere. In die biologiese wereld – ons het mos nou met diere en organe en die goed gewerk. And we heard this morning its building block is the atom. And the most universal definition of the atom is the smallest possible unit that Matter can be divided, while still maintaining chemical properties. (*Teacher shows definition on smart board.)* And that is very important because an atom can be broken down again into smaller parts – and you know what the three parts are?

L: Protons

T: Yes, and a proton can even be broken down into smaller parts: sub-particles. But the atom is the smallest part that has …..? (*indicating on smart board)*

LL: Chemical properties!

T: And that is very important to understand. Cause that relates to chemical reactions, to biological structures, to Universal structures. In die Heelal soos ons dit sien, ne! Because ……. Atoms have chemical properties that allow for reactions and bonding etcetera to take place. Okay! Now – there are over 100, actually 118 types of atoms. Now if we talk about atoms it actually relates to elements. And when we get to the Periodic Table we will touch on that. Then you guys will understand why we say that if everything – **all** Matter made up the Universe, how can there only be 118? But they don't exist on their own, they exist in combination and millions and millions different types of combinations and chemical bonds. So more or less 90 to 94 kom natuurlik voor in die natuur en die ander word vervaardig – are made in labs. Even some of the existing atoms, if they are involved in chemical reactions, they actually split into two types of elements, but because the reaction needs them to split, they are not regarded as separate elements. Verstaan julle dit? Hy kan nie in 'n normale toestand as 'n element bestaan nie, eers as hy interaksie maak, skei hy in twee elemente. En daarom beskou hulle dit nie as twee verskillende elemente nie.

T: Next, can we see atoms?

LLL: NO!

T: No, but they devised – hulle het al hier in die laat 1930's – they devised an atom model. So the physicists thought of what the atom looks like, so they devised a model, and then they developed a series of experiments. So we cannot see the atom but we can see the result of the atom's function.

I am now going to talk in Afrikaans so that everybody understands – Baie keer kan ouens nie altyd 'n ding sien nie, maar hulle maak 'n teorie van hoe hulle dink dit moet lyk. Nou as ons 'n reaksie met daai ding maak en die resultaat is wat ons verwag het dit moet wees, dan is die model reg. Verstaan julle?

So millions of experiments have been done since 1930 in every single lab across the world up until this day and they still prove the model of the atom is the right one! So the atomic bomb that you see is the result of the function of the atomic structure. So even though we cannot see the atom we know that the atom model fits into the function of the atom. Okay? Dis belangrik om te verstaan – dis nie alles wat ons kan sien wat ons altyd weet dit is so nie – omdat hy werk op 'n sekere manier, daarom wee tons die atom se model werk! Okay? Now, a very important thing about Matter – remember when I told you guys there are about 118 elements? It is on your Periodic Table somewhere on page 125, but we'll get to that. Atoms, in order to make, or to see atoms work in the Universe, the need to combine, they need to bond, they need to separate to create different types of matter. And remember when we did digestion about ten days ago – who of you can tell me what this type of gas is? (*Teacher writes CO_2 on white board).*

LL: Carbon dioxide

T: Yes! Koolsuurgas. Now can anyone guess what … (*encircles the C in the formula*)

L: Calcium!

T: No, what element is related to this atom?

L: Carbon!

T: Yes! And that one? (*encircles O_2)*

LLL: Oxygen!

T: Yes, oxygen*! (teacher writes words 'carbon' and 'oxygen' underneath symbols on the white board)*

T: Okay, now I'm gonna show you carbon and oxygen in another way. Who of you knows what this is: (*Teacher draws slice of bread on white board).*

LL: Bread!

T: A slice of bread, yes! Okay, we eat the slice of bread and it goes through the digestive system. And what type of nutrient is this slice of bread?

L: Carbohydrate

T: Okay, so let's say this is a carb. Neh? So once it's gone through the digestive system, and what do we get? What is the basic unit of a carbohydrate? Simple sugar, ne? Give me an example of a simple sugar.

L: Sucrose

T: Okay, Sucrose (teacher writes words of the white board). Wie het gesê glucose?

L: I did, Sir!

T: Mooi! Nog?

LLL: Maltose! Fructose!

T: Okay, fructose comes from fruit, but let's write fructose as well. Now you all know glucose because you have it when you drink Energade or Powerade. En daai lekkertjies wat mens so suig – is glucose! If we take glucose and look at its composition – right at the end, in terms of its chemical structure – hoe sal ons glucosr chemise skryf? We wrote carbon dioxide's chemical formula. If we write glucose's chemical formula, it looks like this (teacher writes $C_6H_{12}O_6$ on the white board). $C_6 – H_{12}$ - O_6. Can you recognise there two elements the same as carbon dioxide?

LLL: Yes! Carbon and oxygen

T: Ja, ja, ja, daar sit hulle, maar dit is nie carbon dioxide nie! Totaal ‘n ander molekuul – en dit word glucose genoem! So can you understand when we say that atoms can combine to form additional types of matter? Is a slice of bread mater?

LL: Yes!

T: Yes, is carbon dioxide matter?

LLL: Yes!

T: Yes, but they are totally different! Een is ‘n gas en een is ‘n sny brood! En op die ou end is dit nogsteeds net carbon en oxygen! Wat is hierdie? (*Teacher writes* H_2O *on white board*).

LL: Water

T: Yes, water! Can you recognise those two (*indicating to H and O in water*) with those two there: (*indicating to* $C_6H_{12}O_6$ *)*

LL: Yes!

T: And is glucose the same as water?

LL: No!

T: Definitely not, but the basic unit, the building block to construct water and glucose still involve the same atoms, in different ratio and different types of bonds. Het julle dit?

LLL: Yes!

T: Right! (*Proceeds to smart board*) When I told you guys that the whole Universe is vibrating, can you understand it when you see these “thingetjies” wat so in die rondte hol? (*Teacher indicates to the diagram of the structure of the atom on smart board)* So when you see the atom as a vibrating unit, the whole Universe is put together in basic units that vibrate like this. Of course they are absolute on a very tiny level – wat ons nie kan sien nie, but it’s all vibrating – moving like this1

And now – all of you take your scissors. Do you all have a piece of paper to use? So all of you take your paper and I’m going to show you now how small an atom is. Okay? No, I’m going to try and demonstrate to you how small an atom actually is! So I want you all – you never done this before, ne?

LL: No!

T: Okay, take this piece of paper like this (*demonstrating how to fold paper*) and fold it in half. And cut it now on the fold – eerste een is die maklikste! Okay? (*Learners follow instructions from teacher – actively involved each one in cutting his/her paper*). Okay, hou nou vir my die een stukkie so vas *(demonstrating while learners are doing the same*)

Okay, remember now this one was first – I'm going to indicate it on the white board so that we can count. Ek gaan julle nou wys hoeveel keer mens moet sny om by die atoom uit te kom! Ons het nou al een keer gesny! Goed, sny hom nou weer, dis nommer twee. Nou lyk hy so. Vou hom nou weer vir my in die lengte en…

L: Moet dit netjies wees, Meneer?

T: Nee, dit hoef nie netjies te wees nie, sny dit net in die middel deur (indicate to learners). Nou lyk dit so! Nou vou jy hom weer – that's right! Nou's dit nommer drie!

L: Moet hy nou so lyk? (showing paper to teacher).

T: Yes, hy moet nou so lyk.

T: Nou's dit nommer 4 – deel hom weer en sny hom weer.

T: Yes, en vou hom weer – nou is dit nommer 5! So I need you to fold and cut it again! Raak al moeiliker, ne?

L: Yes, Sir

T: So you need to keep going – tot jy hom 31 keer gevou het!

L: Dis onmoontlik!

T: Hahaha, it dit onmoontlik? Dit is onmoontlik! So kan julle sien ons het nou by 6 gestop – ons moet nog tot by 31 gaan! Met ander woorde, kan julle verstaan hoe klein 'n atoom is?

L: Yeah, I give up!

Is dit fisies moontlik om dit te doen met hierdie stukkie papier?

LL: Nee!

T: Maar kan julle verstaan as ons dit souk on doen – if we could have done this, we would have come to one atom particle that is part of matter that is this piece of paper. And we keep going, keep going!

L: Meneer, ek is al by 8!

T: Aah, kom ons wys gou hoe lyk 8! Okay, Heinrich went up to 8 – and he still has to go up to 31 to get to an atom! Okay, guys, do you get the idea – extremely small!

L: Ek is al by 11!

T: Impossible, then you need a microscope already! Okay, guys, do you get the concept now? So what would you need to make more than 9 cuts?

L: Microscope

T: Yes, a normal light microscope. And with the light microscope, then you need a knife of very thin blade. And eventually you will use a microtome that is a special machine that can cut 1000th of a millimetre and thereafter you go to an electron microscope and then you will only stop at about 16 times. And you still need to go up to 31 times! So you get the idea – it is infinitely small!.

T: Good, let's look at other examples.

L: Sir, I've got a question. If you know the building blocks of water, will it be possible to make your own water?

T: Yes, of course! You can – it is possible to make water, absolutely! If you can have hydrogen and oxygen isolated, you vcan make water. Hoever, one thing we need to understand whdn we make something universal as water, and you use an atom like hydroge4n that is extremely unstavble, is to have a controlled environment where you manufacture water. It's extremely complicated, but it can be done.

L: Is it expensive?

T: Oh, you can imagine! But that's why around 1950 – 1960 they tried to spilt water to get hydrogen to produce energy – om karre te laat ry! So if you can have hydrogen (which is one of the most unstable elements), a controlled environment, you can imagine how much energy can be involved! But it is extremely expensive and extremely dangerous because of the amount of energy involved.

T: Right, let's go back to the atom. *(Teacher continues with notes on the smart board).* To demonstrate the size of the atom – you know aluminium foil that we use in the kitchen? The thickness of the aluminium foil is about 50000 atoms on top of each other! ; One human cell contains about a trillion atoms. ; It would take you 500 years to count all the atoms in a grain of salt! So infinitely, infinitely small! Okay, so ATOMS: (*Teacher shows 3-dimentional, moving diagram of atom with protons and electrons running around, on smart board).* Let's get back to the three main components of an atom. We have the **protons**. Positively charged – there you can see them (indicating on diagram). Situated in the centre of the atom – we have a name for that but will come to that in a moment.

L: Nucleus!

T: Yes, the nucleus. Protons, situated in the centre of the atom, positively charged. Neutrons, not always the same number as the protons, in the nucleus, and they have NO charge. And when we get to each of these three components, we will deal with each separately because some of them may have very unique features that make matter what matter is. So materie is materie as gevolg vna die eienskap van atome. Omdat atome dié eienskap het, is materie wat materie is. That's why Matter is Matter!

L: Sir, what is the biggest atom?

T: The biggest atom? It depends on if we look at the periodic table, the one with the most protons, the heaviest one. Okay? *(Learners start looking in the textbooks in front of them for the periodic table).* What is element 119? Daar is hy! Ununennium. Hoe groot is hy? Dit gaan oor sy massa wat hy het!

T: (*Focus back on notes on smart board)* so there we have the three components of the atom. The neutron has NO charge, in the centre of the atom, associated with the protons. Right? Electrons, negatively charged and they move in bands around the centre of the atom, the nucleus. Now guys, you know what a track and field is?

(*Teacher shows diagram of track and field on the smart board*). Now this is a very good analogy we can draw between an atom and an athletic field. So hier het ons in die middel waar al die veld items is, ne? Most people at the field items are kind of more sessile, sitting under the umbrella, the shot put, verspring, bietjie en dan sit ons weer. So they are more the guys not doing much physically, and are often a bit heavier than the rest! The athletes – they are in tracks around the field. Hulle spring almal weg en dan hol hulle – after the first two minutes we have the first one there, the second guy there and here's the third guy! But that is kind of how the atom looks like. We have heavier objects in the centre – the protons and neutrons and we have the electrons like the fast running athletes, running in lanes around the field. Maak dit vir julle sin?

LLL: Yes, Sir!

T: Right, so let's look at what the protons look like. Cause if we say that atoms determine what matter looks like, what does the atom then look like? First of all, positively charged particles, they make up the nucleus of the atom, in this case the centre point. And they are equal to the atomic number of the atom. Remember this, because when we get to the periodic table, this is an important feature that you should know about the element. And they contribute to the atomic **mass.** So very important, protons are the heaviest particle in the atom, in the nucleus. So because protons have mass, therefor matter has mass. Understand this?

LL:" Yes!

T: Okay, and there are always equal numbers of protons and electrons. So the negatively charged particles are always in number the same as the positively charged protons. (*Proceed to next slide*). Right, the neutrons are neutral particles; **no** charge! They are also in the nucleus of the atom together with the protons (die outjies in die middle van die veld – hulle rus daarso onder die sambreel!) They contribute also together with the proton to the atomic mass! So just a reminder to you guys again – Protons determine the **atomic number** but protons AND neutrons together determine the **atomic mass.** Die gewig van die atom, ag die massa vnan die atom!

L: Meneer, in an atom – is the protons and neutrons equal amount?

T: No. No, not in all elements. Electrons and protons are equal in number, but not the neutrons and protons. And that is why you will see every time you have one proton, it is equal to what they call one atomic mass unit (teacher writes words on the white board). And if for example and atom has say a mass number of seven, it is an equal number. So if a proton is 1 amu and a nueutron is also 1 amu, then the mass should be an equal number, but is is not!

L: But the mass of a neutron and an atom is the same?

T: No, not exactly, maar hulle is albei baie swaarder as die elektrone in die atom. Die elektrone is 'n atom is so om en by 1850 keer ligter as protone en neutrone, daarom beskou hulle nie die elektrone as deel van die components wat gewig het nie. That is a general law of physics. So the mass of the atom, if you relate it to the protons and the neutrons that is situated in the nucleus – here in the centre of the atom, it is the field of the athletes track.

T: So let's have a look at the electrons. (*Proceed to next slide).* They are negatively charged particles that move around the nucleus and we call it **ORBITS** or shells. Dis die verskillende bane rondom die atletiekveld. Each orbit shell can hold a maximum amount of electrons – ons gaan nou daarby kom - and they move so rapidly around the nucleus, that they form an electron cloud - dis eintlik 'n wolk rondom, so vining beweeg hulle! They move extremely fast – high levels of energy! The mass of the electrons is **so** insignificantly compared to the protons and neutrons that we do not regard their mass as part of the atomic mass of the atom. And there are always equal numbers of electrons to the number of protons. So if there are 5 protons, there will be 5 ….?

LLL: electrons!

T: If there are 4 protons, then there will be ….?

LLL: 4 electrons!

T: Right, and very important about electron, is that they make chemical bonds possible. So protons and neutrons give weight to the atom, but the electrons make bonding possible. So when carbon was used in CO_2, remember I have shown you CO_2 right now, or the oxygen in carbon dioxide of water or glucose – it was the electrons in the oxygen that made the different bondings possible! Verstaan julle dit? So that is the function of electrons. So let's have a look at just the orbits.

T: (*Proceed to next slide*). In each orbit there is a certain number of electrons. And once that orbit is full, it is stable and won't take up more electrons. So the first orbit only have 2 electrons, then it is stable and all places are taken. The second orbit can have eight and depending where the element is in the periodic table, the third orbit can have eight or eighteen electrons.

L: Is dit net agt of agtien, of is dit enige iets tussen in ook?

T: Nee, net 8 of 18, depends on where it is on the periodic table. And let's look at this – when the outer shell is full it will not react with any other atom. Okay, I'll explain this to you in a moment. So let's have a look (*continue with slide on smart board*). Atoms with full outer energy levels do not react. Elements without a full energy level do react. So what they do, they will either give an electron away, or they take an electron or two atoms will share and electron. And I'll show you guys when we come to bonds. You just need to know – orbit one has two electrons, dan is hy vol! Orbit two has eight electrons then it's full and you only need to know up to orbit 2. You don't need to know what happens there after!

L: Sir, is it the same with water and oil that if you mix it, it doesn't bond?

T: Okay, that is at solution level and not on atomic level. So it is a good question, but has nothing to do with the atomic level!

T: Very important – electrons which are furthest away from the nucleus in the outer shell – they have the most energy and will be open to bond! But don't worry about this now, I will show you this when we get to bonding! Okay?

T: So right, (*proceeding to next slide*). Let's take hydrogen atom as an example. It has only one proton and one electron. Hydrogen has NO neutron!

L: Is that what makes it so unstable?

T: Yes, but it is still one of the most common atoms in all chemical reaction of matter in the universe. So that's why hydrogen is regarded as very very crucial in chemical reactions. Even if it doesn't have a neutron! Yes? (*Reacts to learner putting up his hand*)

L: Meneer, as die elektron beweeg, gaan hy net so en so (indicating two dimensional movements with his hands) of gaan hy so en so (indicating movement in all directions).

T: In actual fact, an atom is a ball with another ball around it, with another ball around it. So it's a three dimensional picture. And sometimes it is moving in circles. It differs from element to element. So no, it is not a flat structure, it is actually a sphere with a sphere around it and another sphere around it again, in which the electrons can move. Right?

L: Yes, Sir

T: Right, so how many electrons should fit in the outer orbit of any element?

LL: Two

T: Okay and hydrogen only has …?

LL: One

T: So there's space for …?

LL: One more

L: Is di took 'n rede hoekom hy so unstable is?

T: Yes, very unstable. There's only one electron and that electron is continuously looking for a buddy. That's why hydrogen is extremely good or universal in terms of its reaction with other atoms.

T: Aah, that's important and of course a good question for the exam: "Name one element that doesn't have a neutron, but is still regarded as an element".

T: Right! Oxygen (*proceed to next slide*). So oxygen has 8 protons, it has 8 neutrons and it has 8 electrons. And how will we fill in the orbits? You always start with the orbit closest to the nucleus first, neh! So we put in two. Hoeveel bly oor?

LLL: Six!

T; Right, so now we have six electrons in the outer orbit, so we still have place for ….?

LLL: Two!

T: Yes, another two!

L: Meneer, beteken dit da thy unstable is as hy net twee plekke oop het? Ja, ja, suurstof as 'n atoom op sy eie – just the element oxygen does not exist as oxygen atoms in nature. It's always in combination with other elements, or with other oxygen atoms. It’s only the noble gases that can exist, want hulle buitenste orbits is vol. Maar moenie daaroor worry nie!

L: Soos neon!

T: Soos neon, helium, zenon, argon – those are the noble gases – their outer shell is gull, therefor they don’t react with other elements. But oxygen is NOT a noble gas, because it has still …?

L: Two places open!

T: SO oxygen has two in the first orbit and six in the second orbit. So elke keer moet jy bytel. We will do some examples later! Let’s take Sodium – Natrium in Afrikaans. Sodium has eleven protons, it has twelve neutrons and remember, it does not need to have the same amountof protons and neutrons. But the protons and electrons need to be the same, okay? So look – the first orbit we have two electrons. The second orbit we have fill up …?

L: Nine

T: No, second orbit we have to fill up 8 – so we have 2 + 8 – gives us ten. So in the third orbit we need another ….?

LL: One!

T: So depending where sodium lies on the periodic table, there is actually space for another seven electrons.

L: Meneer, maar hoeveel ringe is daar?

T: Seven! Up to seven orbits. But you guys only have to know the first two.

L: So al 118 pas perfek in die sewe in?

T: Ja,ja,ja.

L: Meneer, is ‘n atoom ‘n organisme?

T: Nee, dis nie ‘n organisme nie! Onthou jy die levels of organisation? Waar lê die organism? (*shows levels of organisation in textbook of learner)* Daar lê hy! En waar lê die atom? So nee, ‘n organism word opgebou uit atome, so stome is nie organisms op hulle eie nie.

Bell rings

T: Okay guys, we will continue tomorrow! You may pack your stuff and have a good day!

CLASSROOM OBSERVATION TEACHER 1 LESSON 3(O-T1L3) 30 JULY 2014

T: Good morning class! Have a seat and let's quickly summarise what we have done yesterday! *(teacher opens power point on smart board – summary is pointed out on slide)*

Number one: Atoms are the smallest unit of matter with chemical identity. We said yesterday that matter has mass because an atom has mass. And who remember where the atom's mass is located? (*pointing to specific learner*)

L: The proton

T: The proton and the neutrons and they are situated in the …?

L: Neuron!

T: No, what do we call that centre part?

L: Oops! Nucleus!

T: Nucleus, yes! So the mass of an atom is in the nucleus. And because an atom has weight and we know that matter has mass, that's why an atom is the smallest unit of matter. Maak dit sin vir julle? Okay! Don't forget that! And an atom still has chemical properties. So I want to show you three molecules. (*Teacher writes on white board*) CO_2 - what's this?

L: Carbon dioxide!

T: And who can remember what this is? (writes $C_6H_{12}O_6$ on white board).

L: Glucose!

T: Okay, and who knows what this is?

LLL: Hahaha! Water!

T: Can you see similar atoms but they are totally different - that's a gas, that's a simple sugar ant that is water? So where are the atoms? (Teacher underlines C in CO_2 as well as in $C_6H_{12}O_6$). And here we have oxygen (underlines the O in CO_2 , H2O as well as in $C_6H_{12}O_6$). It's all the same atom, but very important, three totally different combinations – totally unrelated sources of matter! Is CO_2 matter? Yes! Ons kan dit weeg, ons kan dit in 'n bottle druk – soos gas! Can we weigh water?

LL: Yes!

T: Has water mass?

LLL: Yes!

T: Yes! Glucose – does it have mass?

LLL: Yes!

T: Yes! Why? Because in its chemical composition atoms are involved! Okay? So one thing that is very important (indicating to CO_2). What organism uses this gas?

L: Plants

T: Plants, yes! And where does the carbon come from that plants produce?

L: From CO_2

T: So CO_2 is a very important source of carbon. And carbon is the foundation of the structure of life! That is what makes living organisms different – hulle bevat koolstof. En dis wat plante vervaardig. So even plants – every single object in the universe that has mass is made up of atoms. And there are three parts of an atom we did yesterday.

L: Neutrons

L: Protons

T: Yes, protons, positively charged

L: And electrons

T: Yes and electrons …. ?

LL: Negatively charged

T: Right. So to summarise (*continue from slides*). Protons and neutrons in the nucleus and have ….?

LLL: Mass!

T: Okay. Electrons have no mass – 1850 keer ligter as 'n proton! So will have no effect on the mass of an atom. Okay? Then protons determine the atomic number. So when we get to the periodic table today you will know when we talk of the atomic number, we talk of the number of ….?

LL: Protons!

T: Right. Protons and neutrons together determine the ……? (*indicates on slide*)

L: Atomic mass

T: Remember what we said right now – the mass of an atom is in the nucleus, and what is IN the nucleus of the atom?

LLL: Protons and neutrons

T: Very good! And the function of the electrons is to allow for ….. (indicates answer on slide)

LL: Chemical bonds

T: I quickly want us to go back to molecules and … wait, let's revise this first. (*teacher shows another slide on the smart board)* Remember when we did the orbits yesterday? How many electrons in the first orbit? Tiaan?

L: Two

T: Two, yes! Romano and in the second?

L: Four!

T: Be careful!

L: Eight! (*not the same learner answers*)

T: That's it! Eight in the second. And who knows in the third?

L: Eight

T: Eight, or?

L: Eighteen!

T: Yes! Now what I want you to do is – I want you to come to the white board and we are going to draw those 5 elements on the smart board. Who wants to come first? Come Gerhard, I will help you!

(Learner comes to the front)

T: Okay, you will take sodium for us – I will help you! So sodium has 11 protons and 12 neutrons. So let's take the blue for the protons and then you can just make a plus (+). We use the green for neutrons that is a neutral colour – just make a dot (●).for the neutron. And the electrons? Red! We do it like this (e^-).

T: Okay, I will read for you to make it easier (teacher reads from smart board). En as ons hierdie goed doen, skryf ons elke keer die element se naam neer. In the case of sodium, it is Na. I will explain now where the symbol comes from. (teacher reading from smart-board) So there is Sodium and it has 11 protons. How many orbits do we need to fill in? The first one has …?

L: 2

T: Second one?

L: 8

T: That gives us 10. So we need to draw a third one as well. So fill in the 11 protons with plusses.

L: Meneer, ek verstaan nie hoekom meneer daai drie lyne rondom teken nie!

T: Okay, jy gaan nou verstaan! If you don't understand when he is done, I will explain again!

L: Okay

T: Okay Gerhard, dan vat jy vir ons die groen en hy moet 12 neutrons he. Maak net sirkeltjies. Wie wil solank volgende gaan? Sal nou 'n dogter moet vat die keer. Okay ons sal vir Kayla vat.

T: (focuses again on white board where learner is busy). (Teacher sees that learners is making Θ to indicate neutrons.) Okay, onthou hulle het nie 'n lading nie, so jy maak net 'n kolletjie. Anders as jy dit so maak lyk dit of hy 'n negatiewe lading het. (teacher corrects boy's diagram). Remember, a neutron has NO charge! The electrons have the negative charge!

L: Ja, meneer!

T: So how many neutrons does he need to draw?

LLL: Twelve

T: Right! And what do we call that centre region?

L: Nucleus

T: Now Gerhard, you need to do eleven electrons. Now look carefully, Alicia (talking to the girl who did not understand previously), he is now going to draw in the eleven electrons for us. (Boy draws in 2 electrons in orbit 1). So, the first orbit always has …?

LL: Two

T: The second orbit has …?

LL: Eight

T: So 2 + 8 gives us?

LLL: Ten!

T: So where does he put the eleventh one? (Boy is drawing last electron in orbit three) Aah, dankie Gerhard! So how many electrons?

LLL: Eleven!

T: Let's give him a hand! And there we have all the electrons! Verstaan jy nou waar kom die drie vandaan, Alicia? Jy maak eers die eerste twee vol met twee in die eerste orbit – dis 'n universal law on the atom model – the first orbit has two electrons, dan's hy vol! The second orbit has 8, dan's hy vol. And in the case of Sodium, there is only one left, so the third orbit will take that one, dan is daar nog sewe plekke oop

L: Meneer, by daai laaste orbit, daai een electron, mag hy enige plek op daai lyn lê?

T: Okay, hy beweeg, ne? Ek teken hom maar net op 'n plek. Maar hy beweeg mos eintlik, so hy kan op enige plek lê. Kom ons vat 'n element met dertien elektrone. Hoeveel het ons dan in die derde orbit gesit?

L: Three

T: Yes, three! Do you understand now, Alicia?

L: Yes, Sir

T: Right, come do carbon for us. Let's go to the periodic table. Carbon has six protons, so only draw plusses (girl continues to complete diagram on whiteboard), six neutrons – also in the nucleus, ne! Vat nou die rooi, dan moet y vir ons ses elekrone insit. Kyk mooi wat doen sy – eerste orbit has?

LL: two

T: Second orbit has space for eight, but you only draw in ….?

LL: Four

T: Yes, and together it makes six! Quickly come and show us oxygen, and then we can do helium. The rest of you – use your books and draw it in – do the examples yourself!

LL: Dis maklik!

T: Okay, let's take helium. See if you can do this one. I will tell you that helium has an atomic number of two. What do you do when you see this two? So twee van wat het hy?

L: Twee protons!

T: Ja! Onthou, die atomic number is protons, ne! Hoeveel neutrons? Hoeveel electrons?

LL: Two!

T: If it has two protons, it must have two electrons – same number! So in the outer orbit is two. It has only two electrons, so is it stable gas?

L: Yes, it's a noble gas

T: Right, so let's quickly revise the following – atomic number. (next slide on the smart board). So we said helium has an atomic number of two. What is the atomic number in this element? (Teacher shows example on smart board)

L: Three

T: That's right, so the atomic number is the same as the number of protons. Can you understand that we say the protons Give the element identity? If this had only two protons, what element would it be?

L: Helium

T; Yes, but what element is it now? Now it has three protons, so it is Beryllium – or Lithium, sorry! Lithium has three protons. If it had four protons, it would have been Beryllium. So protons give an element chemical identity – hy sê vir jou waste element is dit. Right, let's look at atomic mass. We've said which two particles of the atom has mass?

LL: Protons and neutrons

T: Protons and neutrons, yes! So let's have a look – the following is a bit technical. But you will understand the moment when I showed it to you. The total number of protons and neutrons in the atom's nucleus, give the atom its mass number. Cause it is the only two parts that have mass. So together they determine the atomic mass number of the atom. And that value will always be one atomic mass unit. So if a proton and neutron both have a value of one, what is the atomic mass number for this element?

L: One!

T: No, each one of these is **one**!

L: Oh, okay!

L: Seven!

T: Wie het gesê seven? Aah, good! Look carefully what happen (teacher shows in detail on smart board where the seven comes from). We said the amount of protons and neutrons determine the mass number. So how many protons?

LLL: Three

T: And how many neutrons?

LL: Four!

T: So the total atomic mass for this element is …?

LLL: Seven!

T; So, meneer, Sodium s'n sal dan 23 wees?

T: Yes, Sodium het 12 en 11 gehad. So wat is syne dan?

L: Twenty three

T: Mooi, Tiaan! Right, so let's just quickly have a look at when we combine atoms. This is now where it becomes tricky.

L: Sir, will it become more unstable if it has more neutrons?

T: No, the electrons determine the stability of the atom. The neutrons will only affect the mass of the atom. But that is a good question! Clear?

T: Right, let's look at a very important concept that many learners kind of loose along the way. Remember, there are only about 118 types of atoms. But here I showed you three total different molecules that all involve oxygen, carbon and hydrogen. Nothing complicated – it's all basic atoms! But they need to be in combination. What do we call this combination when the atoms combining together?

L: Compounds

T: Right, if two or more atoms are grouped together, we call it a …..

LL: Molecule! (Learners read answer from smart board)

T: So when two or more atoms are joined together, we call it a molecule. You know what oxygen look like? $O_{2.}$ Oxygen cannot exist on its own as an atom, because it has these two electrons short, remember? It only has six! So one of the most important of oxygen, is that it will always exist as an oxygen molecule. So a single unit of oxygen will be called a ….. molecule! When those atoms are different, we call it now a compound molecule. So if we look at CO_2, $C_6H_{12}O_6$, H_2O (teacher indicated it again on the white board), is it a compound molecule?

LL: Yes:

T: Why?

LL: They are different.

T: Yes, here are three different atoms combined in glucose. So if I show you Helium, it is only a gas – it's a noble gas. So is it a molecule or a compound?

LL: Molecule!

T: Molecule, cause it is only one! Strictly speaking it's still an atom, but in terms of one atom type, it would be a molecule. So all molecules – are molecules compounds?

LLL: Yes!

T: (indicating again to CO_2, $C_6H_{12}O_6$ and H_2O on white board). So this is one molecule of CO_2, this is one molecule of glucose and this is one molecule of ….?

LL: Water!

T: Okay, Now quickly turn to Levels of Organisation in your books of page 39. Can you see what the next level is after atoms? Gerhard?

L: Molecules

T: Yes, molecules. So we actually see atoms in their chemical structure, we refer to them as molecules. So when you eat bread, you eat complex starch structure which actually are made up of different atoms, but we refer to it as a starch molecule. Want hy het daai, en daai en daai atoms (Teacher shows, C, H and O on whiteboard). And it is a compound molecule. Okay, let's see (*Teacher puts another slide on smart board, indicating examples of molecules and compounds).*

Learners answer in a chorus when asked whether structure is a molecule of a compound.

T: Okay let's go to the periodic table. (Teacher shows coloured diagram of periodic table on smart board, clearly indicating metals and non-metals. He then showed a next slide indicating only oxygen as it appears on the periodic table).

I just want to show you this slide so that you can kind of like bring this information into context with the whole periodic table structure. So when we look at the periodic table, you can see there are little blocks and they are arranged in some fashion, I will tell you how, and each block has a lot of information. Let's quickly look at what information is contained inside each block, because once we do the periodic table, you guys then know what is an orbit or a shell, you kind of like know now what is the number of atoms each element has in it outer shell. (Teacher refers back to examples drawn on the white board). You know something about the atomic mass number, from the nucleus; you know something about atomic number. Right? Now what scientist did, was to group this amount of information into some form so that other people can use it. And listen guys, you don't ever have to memorise anything on the periodic table. It is there – you can just use it. But there are a few elements that if you know their atomic number and atom mass you will do chemical equations very quickly. So you will see I kind of like know some of them because we have use them already. So after a while you get to know them. Yes Gerhard?

L: Sir, Is there 118 or 117 elements?

T: 118. Some chemistry scientists will actually tell you 119. We can actually produce more as some elements can split into two with a certain chemical reaction but normally we don't count it then as two separate elements.

T: Right, look at the different blocks and see where all the information is held and then you can understand where all the information come from. The first thing is the letter we use to show the element. Like carbon, which is a capital letter? C! We use hydrogen a capital letter H, Oxygen capital letter O. If it is just one letter, it is always written in a capital letter. Of it has two, like sodium, - sodium kom van die latynse word natrium af, because it is an old ancient language that will never change, they use the word natrium – so it is Na. The first letter will be capital, but the second letter will always be a small letter. Okay? So the element is always given as a symbol. Then it has the atomic number that comes from …?

LL: Number of protons!

Right! Atomic mass number, the number there (indicates on slide) comes from ..?

L: Number of protons and neutrons

Right! So all that information is contained inside that little box about that element and now they grouped them all on the periodic table according to their number of orbits – up to seven – and the number of electrons in their outer shell.

Bell rings.

Next time we will then continue with this and have a look at the groups and periods of the periodic table.

APPENDIX G2 – LESSON OBSERVATION TRANSCRIPT: TEACHER 2 (O-T2L1)

1 JULY 2014

T: Good morning class. Please take out your workbooks – let me quickly see your books [*Teacher walks through the class, checking if work of previous day was done.]*

Right, we are busy with the building blocks of matter. Please close your books now. Remember it is now time that you start to listen as well, but I will also write it on the chalkboard for those of you who still did not hear! [*Teacher writes down "Building blocks of matter" on chalkboard*].

Okay, what is matter? What does the word Matter mean? Cause even the solar system is matter – it falls under Matter. So what is Matter?

L: Everything that takes up space and has mass.

T: Very good! Matter is basically anything that has mass and can take up ………..

LLL: Space

T: Very good! Now Matter is made up of different or it is actually made up of small building blocks - and those building blocks we call them ATOMS [*write word on the chalkboard*]. So atoms are basically the tiniest or smallest parts that make up matter. For example, this chalk is made up of small little tiniest particles and this particles we call atoms. So today I am gonna talk about Atoms and Molecule4s. [*Teacher write Atoms and Molecules on the chalkboard*.]

T: Okay, I said Matter is basically made up of small little tiny building blocks called atoms and then the atoms are formed to form molecules. When we4 take for example two atoms or one or three atoms, and we join them together, they form a molecule. Can somebody give me an example of a molecule, please?

L: Chalk!

T: Okay, like chalk yes. But the common one?

L: The sent.

T: Yes the sent, yeah. But I want an example that you could not live without. Something that is very common and you cannot live without!

LL: Water!

T: Very good! Water is a molecule. [*Teacher writes the word water on the chalkboard.*] Water is made up of two different atoms. What is water made up of? We learned it last year!

L: the H 2 O!

T: Okay, that is the formula for water. So we have H_2O [*Teacher writes formula on the chalkboard*]. What does the H stands for?

L: Hydrogen

T: Okay, that is the Hydrogen gas and ………?

LLL: Oxygen

T: So basically Water is made up of two atoms of hydrogen and one atom of oxygen. So we can say water is a …..?

LLL: Molecule! [*Answer as teacher is indicating to the word on the chalkboard!]*

T: So we can say water is a molecule but it is also a compound as it is made up of different atoms. Hydrogen and oxygen – so two different atoms. But I am not going to talk about compounds today. Compounds and elements we will talk about tomorrow. I am going to show you what an atom looks like, or the structure of an atom. [*Teacher asks learner to assist in putting up a poster of the structure of an atom on the chalkboard.]*

T: Okay, so we have the structure of an atom here. This is just how an atom look like. I want you all to look on the chalkboard, please. [*Teachers indicates on the poster*]. This is an atomic structure. Every person or everything, even the ruler in my hand, is made up of atoms. The desk is an atom, the chair you are sitting on is an atom. You, your body, your jersey, everything is made up of ……..?

LL: Atoms!

T: So she [*referring to learner who answered previously*] defined matter as anything that has mass and occupy space. So that is basically matter. Now we get different kinds of atoms. Atoms are not all the same, as they are different. Now an atom has three particles. The first particles [*teacher indicates on poster to the nucleus*] we have the nucleus. And the nucleus is made up of protons and electrons. We also have the ………….? [*Teacher is indicating to the electrons on the poster]*

LLL: Electrons!

T: So now the nucleus have no charge, basically. And I am sure you have an idea of this already from grade 6 when you were doing static electricity?

LL: Yes we did this in Design and Technology.

T: [*Showing again on poster*]. Okay, so we have the electrons, and the electrons have a negative charge and the protons have a positive charge. So basically in the centre we have the nucleus and the nucleus is made up of …….? [*Teacher indicates on poster*].

LLL: Protons and Neutrons

T: So now one thing you should also know is an atom has equal number of protons and electrons. Okay? Now I was also talking of water made up of different atoms. So atoms can also be the same, for example, you have two atoms that bind together to form an element. Right? Now we have different kinds of elements and those elements are put into a table. This table is called the Periodic Table. So we have different kinds of elements on the Periodic Table. [*Teacher asks a learner to assist in removing the poster of the atom and putting up a poster of the Periodic Table on the chalkboard.]* Okay, this is a Periodic Table and the Periodic Table has many elements, more than 100 elements. Now elements, okay, I am going to explain elements more in detail tomorrow. An element is just basically, it cannot be split up into simpler pieces. In other words, it is just the same atoms that are joined together. Do you understand? So now elements are actually separated from each other – we have metals and non-metals. So on the Periodic table we have metals on your left side and the4n on your right side you can see the non-metals. So they are separated by a zig-zag line. That is why you see I used a red Koki pen to separate metals and non-metals with the zig-zag line.

Okay and one thing you *must know, is that elements have names. Just like you have a name, they also have names. And these names, on the Periodic table, are represented by symbols. You can see the Li, the B and at the bottom we have the name of each element. One thing you also see on the Periodic Table, there is an atomic number – those are just the number of protons. And then you can see on the bottom the atomic mass. Every element has mass and this is their atomic mass. Understand?*

LLL: Yes Miss.

T: Okay, now a Periodic Table has groups and periods. Now groups are the ones from top to the bottom [teacher indicates on the poster] like for example, we have Group 1, group 2,3,4,5,6,7,8. Don't worry about the ones in the middle. We just count these ones. And if I count them from left to right, those are the Periods. So basically a Periodic Table is made up of periods and *groups. [Teacher writes the words on the chalkboard]. So which ones are the periods? [Teacher talks to a learner sitting at the back, daydreaming]. You are looking so confused as if I am speaking in a different language! So I would like to know which ones are the periods. Okay, which ones are the groups?*

L: [Not the one she was talking to]. Top to bottom.

T: And the periods? They are from left to right, for example (pointing to periods on poster], Period 1, period 2, 3,4,5,6, and then 7. Do you understand?

LLL: Yes!

T: Now I want to ask you – can you tell me an element in group 1, period 4? [Four learners immediately put up their hands]. [Teacher asks one learner to answer].

L: K

T: Okay, very good! What does K stands for? I said the elements have names and the name has a symbol. So what does K stand for?

L: Potassium

T: Say "Po-tas-sium"

LLL: Po – tas – sium

T: Okay, very good [Teacher writes word on the chalkboard]. It is represented by a capital K. And one thing you must also know, is the first ten elements from your head. The first one we have is Hydrogen, then Lithium, Beryllium, we have Boron, Carbon, Nitrogen, Oxygen and then Fluorine, Sodium and Magnesium. In your textbook there is a Periodic Table that you will draw later. You should know the first ten and what they stand for. For example, you should also know Iron, there are some elements I just picked out, for example Iron, the symbol for Iron is Fe. Now you don't write it capital F and capital E. You write it capital F and small letter e. [Teacher writes correct symbol on the chalkboard].

T: So who can give me an element in Period 3, Group 2? Come and show me so that everybody knows what we are talking about.

L: [Come to the front and indicate group 1, period 4 wrongly. Teacher ignores the answer]

T: Group 2, Period 3! [The teacher asks another learner to forward]. You should know the groups and which one is the period!

L: [Coming to the front, indicating group 2, period 4]. Group 2, period 3.

T: Which one is period 3? The numbers are even written next to the period!

L: [Now indicating correctly – tend to miss out H as period 1].

T: What is the name of this element?

L: Magnetism

T: Read it again, it is not magnetism.

L: Oh! Magnesium

T: So the name is Magnesium and the symbol is Mg, okay? Somebody else wants to try? [About half of the class immediately put up their hands].

T: [teacher picks at boy at the back]. Okay, group 6, period 2.

L: [Indicating on the poster, although very hesitantly to Oxygen].

T: Yes, it's correct! Oxygen! So the symbol for oxygen is O. So it's as easy as that! Periods from left to right and groups from top to bottom. .

T: One thing you should considering about the structure of atoms – the electrons are always moving. They are orbiting around the nucleus of the atom. Now imagine this as the solar system we have discussed earlier. [Teacher is again pointing on the poster of the structure of the atom on the chalkboard]. We have the sun in the middle, consider this to be the nucleus. Now the nucleus in the middle is basically surrounded by the electrons. So the electrons are orbiting the nucleus. Now going back to the solar system – the planets are orbiting or going around the ………?

LLL: Sun!

T: [Teacher points at the poster]. And remember the protons have a….. LLL: positive charge! And the electrons have a …….. LLL: negative charge!

T: Okay, so the Periodic Table is made up of what? [Teacher points at learner at the back whose hands is in the air]

L: Groups and Periods

T: Yes, okay, groups and periods, but what is on the Periodic Table? Maybe I should question like that. What do we find on the Periodic Table?

L: Elements

T: Yes, very good! And what kind of elements do we find here? They are separated with a zig-zag line? What do we find on the left and what do we find at the right?

L: On the left we find metals and on the right we find non-metals.

T: Very good! On the right side we find non-metals and on the left side we find metals.

T: Who can tell me what is a molecule?

LLL: What? Huh?

T: What is a molecule? [No response from any learner]. When I started, I explained what an atom is and I also explained what a molecule is. [Now two learners slowly put up their hands to answer].

L: A charge made up of atoms

T: Yes, very good. Basically when we have two or more atoms joined together, they form a molecule. Give me an example of a molecule. Something that is made up of different or the same atoms.

L: Water

T: Yes, water, very good! So what makes up water?

L: [Taking a wild guess]. Hydro-; hydrolic oxygen

T: [Teacher ignores answer and writes formula for water on the chalkboard]. What is the name of this atom? [Indicating to H]

L: [from the back]. Hydrogen

T: Very good! So we have two hydrogen and one oxygen atom. So that is basically the formula for water

T: Then, which one are the period and which ones are the groups on the Periodic Table? How will you differentiate them?

L: [Almost 90% hands in raised – teacher asks learner in front who did not raise his hand]. You can even indicate it to us on the Periodic Table!

L: [To the front, indicating on Periodic Table]. This one is periods [showing top to bottom]. [Then correcting himself – the groups are these ones [showing top to bottom].

T: Okay, which ones are the periods?

L: [Indicating top to bottom]

T: Okay, start all over again cause now we are confused.

L: [Again showing top to bottom]. These ones are the periods and the groups are these [indicating numbers 1 to 8 on Periodic Table].

T: Okay, he is close. Someone else to come and show us?

L: [Coming to the front and indicating top to bottom]. These are the groups.

T: Okay, those are the groups! From ……?

LLL: Top to bottom!

T: And the periods?

L: [Indication left to right]. LLL: Left to right!

T: Okay, any questions? No questions? Okay, one more thing! The list of elements you should know. No, no, don't write anything, I will give you the summary tomorrow. [Teacher starts to write down symbols of elements on the chalkboard; learners are making noise]. Okay, these are the elements you should know. The first one is C. What does C stand for?

L: Carbon

T: [Teacher writes names next to symbol on the chalkboard]. You should know C, you should also know O. Next one?

L: Uranium

T: Cu:

L: Copper

T: Can anyone see Cu on the Periodic Table? [One learner shows Cu on Periodic Table].

T: Very good! Okay, here it is. Then Au?

L: Miss, miss! Aluminium!

T: No, it is not Aluminium [Teacher asks another learner].

L: Gold

T: Very good. Where is Au on the Periodic Table? Yes, you are close enough to see! [talking to learner in front]. And Fe? What does Fe stand for? [Asking one learner at the back who is not giving attention]

L: No idea!

T: You are busy with business down there instead of paying attention in class! [Teacher asks another learner].

L: I think it is iron

T: Ah, very clever! Iron! And Ag?

L: Teacher, teacher! It is silver[Learners are now responding all quickly and all together].

L: [Teacher pointing to Al]. Next is Alminum.

T: Say it again

L: Alminum

T: Okay, A-lu-mi-nium. Next?

LL: Nitrogen

T: Okay, what you should know, you will have to memorise them. C for Carbon, O for Oxygen.

LLL: [Read names of elements together spontaneously].

T: Okay, please take out your books and be silent. I'm going to give you a short classwork. Oh sorry, there are still two left! Pb – what does Pb stand for?

L: [Learners do not really give attention anymore]. Platinum [Learner in the front responds].

T: No, it is not Platinum, but Platinum is also an element.

L: Palladium

T: Oh, come on Martin!

L: [Third learner tries to answer]. Lid!

T: Yes, lead, not lid! And Cl? Come find Cl on the poster and tell me what it is. [Three learners come to the front to find Cl on the poster].

LL: Chlorine!

T: [after writing the word on the chalkboard]. Trevor, please read for me this word [sitting at the back of the class, not really giving attention].

L: Chlo-ra, or whatever!

T: Come on, we are here to learn! [Teacher asks another learner].

L: Chlorine

T: Okay, very good. The name for this element is Chlorine. So take out your books. I'm going to give you a short classwork. [Teacher writes questions on the chalkboard]. Use the Periodic Table to find the elements. Which group and which period they are found.

[Bell rings]

T: See you then tomorrow

LLL: Good day Miss!

LESSON OBSERVATION TRANSCRIPT: TEACHER 2 (O-T2L2) **04 JULY 2014**

T: Good morning Class! Close your books; it's time now for Science.

LL: Yes Teacher

T: All right, referring back to our lessons on the atoms and molecules, what is an atom? What is the difference between an atom and a molecule? I have given you the summary. [Only three learners raise their hands].

L: It's a tiny piece of …….

T: Tiny building block of what?

L: [Another learner answers] Of matter

T: So all matter is made up of atoms. So now when we combine atoms, what do we call it? We call it molecules. Okay? We also talked about element. Elements are groups in a table called …..?

L: Periodic Table

T: Yes, so on the Periodic Table we find elements. So give an example of an element please. [No response]. Give me examples of elements – we've got a lot of them!

LLL: Chlorine. Carbon. Oxygen. Fe!

T: Which is iron. Very good! Yes, those are all elements. Okay, let's keep our books closed today. We have more that 100 elements on the Periodic Table. So today I want to talk about elements and compounds. Who can give me an explanation of the word element? What does the word element mean? [No response from any learner]. Okay, you don't know? An element is a pure substance that cannot be broken up into simpler substances. For example, we have oxygen, iron. Let's take iron as an example. Iron is made up of the same atoms. So those kinds of atoms, they make up an element, so they are the same. So basically an element is just a pure substance that's made up of the same type of atom.

T: And the difference between an element and a compound. A compound is made up of different types of atoms. For example, for an element I can give you aluminium. [Teacher writes down word on chalkboard]. I can have an element as a solid [make simple drawing of same atoms on chalkboard

] which is just made of atoms of the same type. Now, when it comes to compounds, who can give me an example of a compound?

[Two learners raise their hands – teacher ignores both].

A compound is a pure substance as well, but you can break it up into other simpler substances. So it's not only made up of the same atom, it's made up of different types of atoms. So which is an example of that?

L: Chalk?

T: Okay, chalk. Name common things!

L: Water!

T: Yes, water, the one that you know! What is the chemical formula for water? How do we write water?

LLL: [good response from learners]. H-2-O

T: [Teachers writes down formula on chalkboard]. H_2O*. What does it tell us? Cause now we are talking about compounds here. When it's made up of two or more different atoms.* H_2O *– what does it mean?*

L: Hydrogen

T: How many hydrogen atoms?

LLL: Two!

T: {[Teacher writes down hydrogen on chalkboard]. Hydrogen. There are two, and then …..?

LLL: Oxygen!

T: [Teacher writes oxygen on chalkboard]. So there is basically one oxygen atom. So you can draw this.
[Teacher draws simple model of water molecule on chalkboard]
Oxygen to be in the middle. Attached is two hydrogen atoms to make up a compound water.
Another compound – what gas do we breathe out?

LLL: Carbon dioxide!

T: Very good! What is the chemical formula for carbon dioxide? How do we write it? Just as H_2O for water, how do we write carbon dioxide? [Teacher writes CO2 on the chalkboard]. What does the C stand for?

LLL: Carbon!

T: Carbon, and O stands for ….?

LLL: Oxygen!

T: We get different types of compounds. You know egg shells? [No response from any learner]. Okay, you know eggs?

LLL: Yes!

T: You know the skin of the egg? Now we don't say "egg-skin", we say "egg shell". Now those shells are also made up of compounds. They are made up of calcium and carbon. It's not always easy to separate these atoms, although you can. Understand?

LL: Yes!

T: Okay, before we go on – any questions? Do you know the difference between an element and a compound?

LL: Yes!

T: Element – pure substance, same kind of atoms. Compound – made up of other kinds of ….?

L: Substances

T: Atoms, actually. Questions before I go on? You don't have questions? I would just like to show you the pictures I have here. [Teacher finds pictures in textbook]. An element can be solid form, or a liquid or a gas. In this picture it is just in a solid form – many atoms that are formed together to form the element of iron. In the next picture you can see what a compound is. In this case – the compound of water – is hydrogen and oxygen. You can see the oxygen and then the hydrogen attached. Okay?

LLL: Yes

T: You can take out your books now. I'm going to give you an activity to answer a few questions. Okay, any questions before we continue?

L: Miss, where do the oxygen come from?

T: Oxygen? Okay, the elements are not made, it is just there naturally. It is just there. Let's quickly go back to the process of photosynthesis - how the plants make food and then release oxygen?

L: Oh yes!

L: [Another learner to ask]. Where does the hydro then come from?

T: What?

LL: [Other learners correct the pronunciation]. Hydrogen!

T: These gases are naturally in the air. Just like you ask me where does gold come from? What is gold? Why did God make gold? It's just there naturally.

[Teacher writes class activity questions on the chalkboard. She distributes textbooks amongst learners – 2 learners per textbook. Learners copy the questions and continue answering questions, finding answers from the textbook].

***Bell rings**. Learners are not done yet but need to hand in textbooks before they leave the classroom.*

APPENDIX G3 – LESSON OBSERVATION SCHEDULE

OBSERVATION SCHEDULE ____________________

COMMENTS

1. **USE OF PRIOR KNOWLEDGE**
   Introduction
   Throughout
   Conclusion

2. **SCAFFOLDING**
   Examples
   Explanations
   Open ended questions
   Relating to everyday life
   Learner questions
   Redirecting questions

3. **USE OF LANGUAGE**
   Clear instructions
   Code switching
   Clarity of questions
   Explanations

4. **TEACHING STRATEGIES**
   Lecturing
   Question-answer
   Group discussion
   Use of technology
   Activities / practical; worksheet

5. **LEARNER SUPPORT MATERIAL**
   Use of models
   Analogies
6. **CONTENT KNOWLEDGE**

7. **PCK**

8. **GENERAL LESSON PRESENTATION**
   Flow of lesson
   Cater for all students
   Visual presentations with diagrams
   Reinforcing thinking
   Summarising

9. **DEALING WITH LEARNER DIFFICULTIES**
   Challenges

10. ANY OTHER COMMENTS OR OBSERVATIONS MADE

APPENDIX H1 - PHASE 2: UNIT OF WORK ON THE TOPIC ATOMS, MOLECULES AND THE PERIODIC TABLE: LESSON PLAN

GRADE 7

DURATION: 4-5 PERIODS OF 30 MINUTES EACH

SYLLABUS SECTION 3.3.1; 3.3.2

BASIC COMPETENCIES FROM NAMIBIA NATURAL SCIENCE AND HEALTH EDUCATION SYLLABUS GRADE 7:

3.3.1 ATOMS AND MOLECULES

- state that atoms are the smallest building blocks of matter
- explain that all matter consists of elements or combinations thereof
- state that the Periodic Table is a classification of all existing elements
- classify elements into metals and non-metals
- state that every element has a name and a symbol (know at least the first 10 elements, as well as C, O, U, Cu, Au, Fe, Ag, Al, N, Pb, Cl)
- state that elements combine together chemically to form compounds (e.g. water, H_2O and carbon dioxide, CO_2)
- name practical examples of most common elements, compounds and mixtures found in everyday life, the Earth's crust, the atmosphere and water

3.3.2 ELEMENTS AND COMPOUNDS

- state that elements combine together chemically to form compounds (e.g. water, H_2O and carbon dioxide, CO_2)
- name practical examples of most common elements, compounds and mixtures found in everyday life, the Earth's crust, the atmosphere and water

The basic competencies of the syllabus do not require the structure of the atom in this Section. However, the existence of electrons and protons are to be covered in Section 6.1 (Static Electricity). Therefore, for better conceptual understanding of concepts, the basic structure of an atom as well as the formation of molecules will be covered in this Module as well.

This theme will be divided into two parts:

(a) Atoms, Molecules and Compounds

(b) Elements and the Periodic Table

(A) ATOMS, MOLECULES AND COMPOUNDS

ELICITATION OF PRIOR KNOWLEDGE

1. **What is matter?**
   - Matter is anything that (a) occupies space, and (b) has volume.
   - 3 possible states: solid, liquid, gas (how do we know that gas also has mass and volume?)
   - Matter can change its state
   - Continuous movement of particles (diffusion, mixing of substances)
   - Made up of smaller particles, known as ATOMS

2. **Levels of Organisation:** Start with what is known to learners e.g. Organisms are made up of organ systems; systems are made up of organs; organs are made up of cells; cells are made up of molecules; molecules are made up of smallest parts, **atoms** and is unique for each type of matter**.**

Because matter has mass and occupies space and atoms are the smallest parts of matter, therefore atoms also have mass and occupy space (Relate back to this concept when structure of atom is discussed).

EXAMPLES OF VIDEO CLIPS AVAILABLE ON YOU TUBE

1. Introduction of the concept of an atom: Introduction to SCIENCE and the ATOM Cartoon (http://www.youtube.com/watch?v=wRYfbGPG3LA)

2. Introduction to and structure of atoms: Atoms and Molecules | Mocomi Kids http://www.youtube.com/watch?v=hc0EtPPpZUU

3. Structure of the atom: Atom song by Peter Weatherall http://www.youtube.com/watch?v=gVYTiowX3oA

PRESENTATION – OUTLINE OF CONTENT COVERED

ATOMS

What is an ATOM: The word Atom comes from the Greek word Atomos, meaning indivisible (Smallest building block of matter, with chemical identity. (From prior knowledge)

How small is an atom?

> ***Practical activity***: *Fold and cut an A4 page through the middle. Take one part, fold and cut it again in the middle. Continue taking one half, fold and cut it in the middle, until it is too small to be cut in half any more. (8 – 10 times).Can you see how small is the paper already?*
> *To get an idea of the size of an atom, the paper should be cut into halves 32*

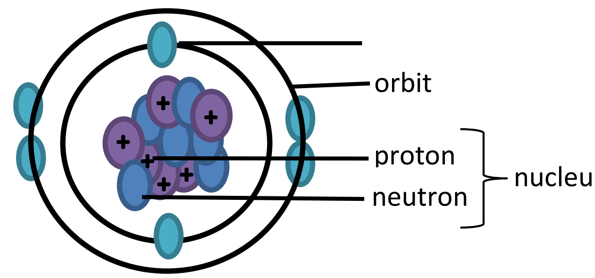
Did you know?

- The thickness of aluminium foil that we use in the kitchen is about 50 000 atoms on top of each other.
- One cell in our bodies contains about a trillion atoms!
- It would take us about 500 years to count all the atoms in a grain of salt

Matter has mass and occupies space. As atoms are the building blocks of matter, ATOMS also need to: have **mass** and occupy **space.** Therefore, an atom is made up of smaller parts known as **sub-atomic particles.**

Let's look at the structure of the atom:

> *Use of **Analogies**- 1. <u>Track and field:</u> field items don't have lots of movement (nucleus); fast track around field – different lanes in which athletes run around field (electrons).*
> *2. <u>Solar system</u>: sun in the middle, not moving (nucleus); planets in orbits around the sun (electrons)*



(1) Protons: Positively charged particles; help make up the nucleus of the atom; equal to the number of electrons; contribute to the mass of an atom.

How many protons in an atom?

Each type of matter has a definite and fixed number of protons. The atoms of any particular type of matter/element always contain the same number of protons.

For example:

- oxygen atoms always contain 8 protons
- carbon atoms always contain 6 protons

Therefore, if the number of protons changes, the atom becomes a different type of matter.

NUMBER OF PROTONS = **ATOMIC NUMBER** of an atom.

(2) Neutrons: Neutral particles; no charge; help make up the nucleus of atom together with protons.

Protons and neutrons together are the heavier parts of the atom – give **mass** to atom. Found in the middle (centre) of atom known as the **nucleus of the atom**.

PROTONS + NEUTRONS = ATOMIC MASS of the atom

(3) Electrons: are very tiny and light, so do not really add to mass of the atom. They are moving around the nucleus is orbits / shells, almost like the planets around the sun. Therefore the electrons will give **volume** to the atom. Their mass is insignificant compared to protons and neutrons.

Electrons are involved in the formation of electrical bonds (refer back to when doing molecules).

Atoms can either loose or gain electrons. If the atom loses an electron, there will now be more protons that electrons, so the atom will now be positively charged (more protons = + charge)

If it gains electrons, atom becomes negatively charged (more electrons = **-** charge)

An atom that carries an electrical charge is called an **ion**

Electrons will always move in pairs in the **orbits.** In the first orbit around the nucleus, there will only be a maximum of 2 electrons. In the other orbits, up to 8 electrons can move in each orbit.

Activity: *Make three different coloured paper hats for learners to put on their heads.*
Draw a + or a – sign on each third of the hats to explain the charges of protons, electrons and atom as a whole. The last third has no sign on.
Play the game 'musical chairs' with learners to illustrate stable protons (+) and neutrons (no sign) in the centre (learners with two different coloured hats sit on chairs close to one another), and electrons (-)
Running in orbits around nucleus (draw circles around nucleus with chalk and learners with third coloured hats are running in pairs on chalk lines around the nucleus).
Explain concept of electrons being in pairs with only 2 in the first orbit, and 8 in the other orbits.

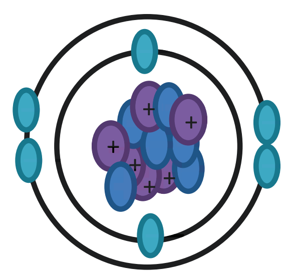
(Different types of atoms can be illustrated with the concept of musical chairs, having a different amount of chairs in the centre each time).

Atoms contain **equal numbers** of protons and electrons and have **no overall charge**

Let's try this!

Draw the structure of the following atoms on the chalkboard:

For example: Carbon: 6 protons, 6 neutrons, 6 electrons
Atomic number = 6 (amount of protons)
Atomic mass = 12 (amount of protons + neutrons)



Class Activity: *Now try the following:*
Helium: 2 protons, 2 neutrons, 2 electrons
Oxygen: 8 protons, 8 neutrons, 8 electrons
Hydrogen: 1 proton, 0 neutrons

There are 119 different types of atoms. Each type of atom has a short way to write it, known as a SYMBOL. The symbol for hydrogen is H; the symbol for oxygen is O, the symbol for carbon is C and for copper is Cu.

NB: Note that the first letter of a symbol is always with a capital letter and the second letter is a small letter! Eg. Pb (lead)

Each type of atom is referred to as an **element.** (We will discuss elements later in more in detail!)

MOLECULES

What is a MOLECULE?

Atoms often combine to one another, to form new substances, called **molecules.** The short way to write a molecule, is known as a **formula (H_2O; CO_2)**

Look at the following examples:

- Two Hydrogen (H) atoms can combine with one Oxygen (O) to form a new substance, called a water (H_2O) **molecule.**
- One carbon atom (C) can combine with two oxygen atoms (O) to form one carbon dioxide (CO_2) **molecule.** (Can you remember where carbon dioxide is formed?)

When different atoms of different elements combine, it forms a **COMPOUND**.
The elements hydrogen and oxygen are made up of only hydrogen (H) atoms and oxygen (O) atoms.
Water molecules (H_2O) are made up of more than one type of atom, therefore water is a **compound**. Can you think of other compounds as well?

Let's try the following: *The formula for one glucose molecule is $C_6H_{12}O_6$. What types of atoms are a glucose molecule made up of? (Glucose is the building blocks of all types of carbohydrates, such as bread and sweets)*

Can you see that although a molecule of carbon dioxide (CO_2) is a gas, water (H_2O) is a liquid, and glucose ($C_6H_{12}O_6$) is a solid, they are made of the same type of atoms, but are totally new substances?

Did you know?

- 66% of the mass of the human body is made up of oxygen atoms.
- A perfect diamond is a single molecule made of carbon atoms.
- A cube of sugar contains as many atoms as there are stars in the Universe.

GLOSSARY OF TERMS

Atom: smallest building block of any matter

Atomic mass: amount of protons and neutrons together in an atom

Atomic number: amount of protons in an atom

Electron: negatively charged particle of the atom, found in orbits around the nucleus

Formula: short way to indicate a specific molecule

Matter: anything that has mass and occupies space.

Molecule: when two or more atoms combine chemically

Neutron: particle of an atom with no charge, found in the nucleus.

Orbit / Shell: lanes around the nucleus of an atom in which the electrons are moving

Proton: positive particle of an atom, found in the nucleus

Symbol: short way to indicate a specific atom or element

Sub-atomic particles: different parts that an atom is made up of

CONCLUSION

1. Divide class in groups of 4. Each group gets a set of dominoes to play with and combine terminology with correct definitions. (Appendix H4)

2. Learners divide into groups and get the opportunity to build '***Magnificent Molecules'*** with jelly tots and tooth picks. (Appendix H5).

3. Learners write the glossary of terms in their workbooks.

4. Homework activity: Draw the structure of a:

   (a) Lithium atom, with 3 protons, 4 neutrons and 3 electrons.

(b) Nitrogen atom with 7 protons and an atomic mass of 14. (Remember the atomic mass = protons + neutrons and there are an equal number of protons and electrons in an atom!)

(B) ELEMENTS AND THE PERIODIC TABLE

ELICITATION OF PRIOR KNOWLEDGE

Shortly revise the following concepts done on atoms: atom, molecule, atomic number, atomic mass, symbols and formulae.

EXAMPLES OF VIDEO CLIPS AVAILABLE ON YOU TUBE

1. Elements song: BEST WAY TO LEARN THE ELEMENTS! - Periodic Table Song
   http://www.youtube.com/watch?v=uJGrwWOWt3Q

2. Elements of the Periodic Table: Memorize Periodic Table Effortlessly! [Elements 1 to 10]
   http://www.youtube.com/watch?v=u5kgvIBEjMM&spfreload=1

3. Structure of the Periodic Table: Chemistry Rap - The Periodic Table of Elements
   http://www.youtube.com/watch?v=Apr7MdbHGQo

PRESENTATION – OUTLINE OF CONTENT COVERED

WHAT IS AN ELEMENT?

- All (living and non-living) kinds of matter in the universe is made from about 119 different substances, called elements.
- A pure substance composed of a **single kind of atom**.
- Cannot be broken down into another substance by chemical or physical means.
- Examples of elements:
  - Hydrogen (H): The lightest and most commonly found element.

- Helium (He): A gas used to fill up balloons.
- Oxygen (O): A gas we need to breathe in for respiration.
- Carbon (C): The building block of carbohydrates.
- Gold (Au): A metal used to make jewelry.
- Uranium (U): A metal mined at Rössing mine near Swakopmund, used mainly for nuclear power.
- Silver (Ag): A shiny metal used to make jewelry.
- Iron (Fe): A greyish shiny metal. The core of the Earth is largely made up of iron.
- Aluminium (Al): A strong metal used to make cooldrink cans, window frames and heat resistant clothing for firefighting.
- Lead (Pb): A relatively soft metal used mainly in batteries and for plumbing.
- Chlorine (Cl): A yellow-green gas used to sterilise water and to disinfect swimming pools. It is very poisonous and was used as a chemical weapon during the First World War
- Copper (Cu): A metal usually mined near Tsumeb in Namibia, used to make wires
- Nitrogen (N): A colourless gas making up about 78% of the air you breathe. Nitrogen is in a liquid at a very low temperature (around -200 ºC!) and has many useful applications including storing items at cold temperatures and for removing warts.

- All known elements in the universe are organised by their chemical properties in a specific way known as the Periodic Table.

WHAT IS A PERIODIC TABLE?

1. The periodic table arranges all the elements in groups according to their properties.

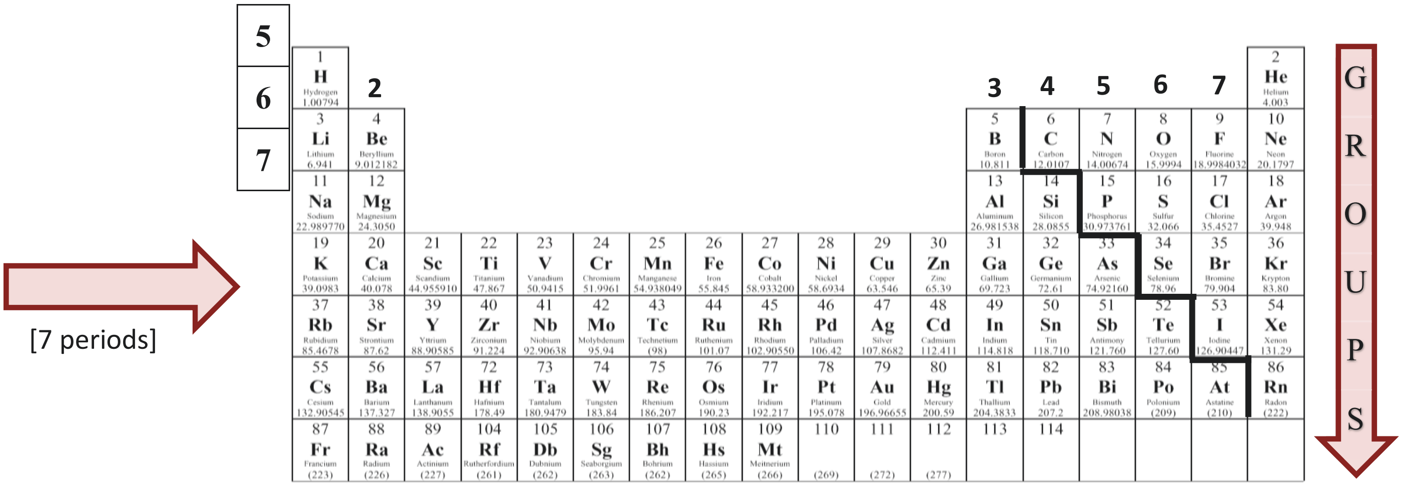
2. Elements in the same vertical ***GROUP*** have the same number of electrons in the outer shell (the amount of electrons correspond to their group number)

3. The horizontal ***PERIOD*** will indicate the amount of orbits in which the electrons move.

The Periodic Table

1 **8**

1
2
3
4



[Obtained from: http://110.164.64.200/FreeWare/program/www.wisegorilla.com_clipart.html/www.wisegorilla.com/images/chemstry/0-Periodic%20table.gif]

4. Most of the elements are metals. Metals and non-metals are separated with a zig-zag line on the periodic table.

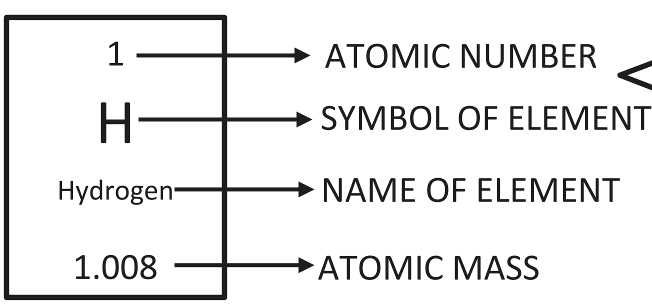
- All elements on the LEFT side of the zig-zag are all METALS
- All elements on the RIGHT side of the zig-zag are all NON-METALS

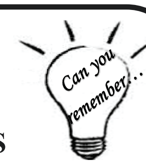
Let's try:
Enlarge a periodic table on a poster or hand out copies of a period table to group
Ask learners to identify the groups and period of certain elements.
Identify each element as a metal or non-metal.

HOW DO I READ THE PERIODIC TABLE?

The boxes that make up the periodic table contain a significant amount of information.

Let's take Hydrogen as an example to find all the information:





ATOMIC NUMBER = PROTONS

SYMBOL = ABBREVIATION OF THE NAME

ATOMIC MAS = PROTONS + NEUTRONS

GLOSSARY OF TERMS

Compound: Substance made up of more than one type of element

Element: A pure substance made up of a single kind of atom

Groups: The vertical columns of the periodic table

Metal: Elements on the left side of the zig-zag line on the periodic table

Non-metal: Elements on the right side of the zig-zag line on the periodic table

Periodic Table: A table that arranges all the elements in groups according to their properties

Periods: The horizontal rows of the periodic table

CONCLUSION:

1. Learners complete the WORD SEARCH (Appendix H2).
2. Play the game BINGO, using symbols of elements, for learners to become familiar with the symbols, atomic number, atomic weight and uses of elements. (APPENDIX H6).
3. Learners write the glossary of terms in their workbooks.

APPLICATION: PROJECT WORK - PERIODIC TABLE CUBES

Introduction

This activity will help you to explore the Periodic Table of Elements. The Periodic Table is a way of organising all of the building blocks (chemical elements) of the universe.

What is needed?

Picture of your element
A4 colourful cardboard
Scissors
Glue
Crayons
Template of a cube

What to do:

Divide the class into groups.
Each group chooses a different element to research.
Each group gets a template of a cube to complete the information about their specific element.

Use the six sides of the cube to complete the following about the chosen element (put the information of each number on a different side of the cube):

1. NAME OF THE ELEMENT
2. SYMBOL OF THIS ELEMENT
4. PLACE OF THIS ELEMENT ON THE PERIODIC TABLE (Group and Period)
3. PROPERTIES OF THIS ELEMENT
5. USES IN EVERYDAY LIFE
6. PICTURES / PHOTOS OF THIS ELEMENT

After completion, each group gets the opportunity to present their element to the rest of the class. After presentation, cubes can be fixed with string from the roof, windows or walls of the classroom.

APPENDIX H2 – WORD SEARCH: ATOMS AND MOLECULES

Atomic Structure Word Search Puzzle

B	L	G	O	N	O	T	O	R	P	Y	A	X

Introduction
This activity will help you to learn and enhance your vocabulary, as well as strengthened memory of and ability to recall terms in the topics Atomic Structure and the Periodic Table.

What to do:
Find as many words as you can in five minutes. When you find a word, encircle or colour the word. Remember, words may be written horizontally, vertically or diagonally!
Points will be allocated to different words – so try to find the difficult ones as well!
When time is up, all the points will be added up for all the words you found to see who got the most.
Give it your best shot to see how many words you can find!

C	W	A	R	A	D	I	C	F	O	J	K	O
E	N	O	B	T	L	N	E	U	T	R	O	N
P	E	R	I	O	D	I	C	T	A	B	L	E
N	M	L	T	M	E	T	A	L	S	O	P	N
E	R	S	E	S	T	M	U	I	S	L	A	C
G	A	T	O	M	I	C	W	E	I	G	H	T
O	W	U	B	C	E	Y	E	Z	U	X	V	R
R	M	U	I	S	E	N	G	A	M	O	F	E
T	A	M	E	L	E	C	T	R	O	N	S	T
I	C	E	L	G	W	R	H	S	L	N	I	T
N	O	N	M	E	T	A	L	S	J	A	K	A
D	F	A	E	B	E	L	U	C	E	L	O	M

APPENDIX H2 continues - WORD SEARCH ANSWER SHEET

Answers and points allocated to different words:

1 point each:

neutron
non metals
periodic table
metals
atomic weight
electron
orbit
atoms
potassium

3 points each

nitrogen

matter

4 points

2 points each

proton

calsium

magnesiu
m

molecule

B	L	G	O	N	O	T	O	R	P	Y	A	X
C	W	A	R	A	D	I	C	F	O	J	K	O
E	N	O	B	T	L	N	E	U	T	R	O	N
P	E	R	I	O	D	I	C	T	A	B	L	E
N	M	L	T	M	E	T	A	L	S	O	P	N
E	R	S	E	S	T	M	U	I	S	L	A	C
G	A	T	O	M	I	C	W	E	I	G	H	T
O	W	U	B	C	E	Y	E	Z	U	X	V	R
R	M	U	I	S	E	N	G	A	M	O	F	E
T	A	M	E	L	E	C	T	R	O	N	S	T
I	C	E	L	G	W	R	H	S	L	N	I	T
N	O	N	M	E	T	A	L	S	J	A	K	A
D	F	A	E	B	E	L	U	C	E	L	O	M

elements

APPENDIX H3 – DOMINOES GAME

ATOM DOMINOES

Copy a set of dominoes and the template on card board. Cut out the different dominoes.

The one side of each domino indicates a concept relating to the atomic structure. The other side of each domino has a description of one of the concepts given.

Use the template give and try now to put each definition next to the concept it relates to on another domino. If all the definitions are correctly put to the relating concept, your dominoes should form a rectangle!

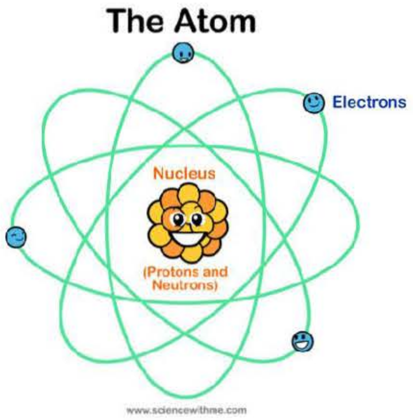
MOLECULE	**ATOM**	**FORMULA**	**NEUTRON**	**ELECTRON**	**ATOMIC NUMBER**
Forms the nucleus together with protons	Short way to indicate a molecule	Positively charged	Has mass and occupies space	Protons + neutrons	Eg. water
SYMBOL	**PROTON**	**ORBIT**	**MATTER**	**SUB-ATOMIC PARTICLE**	**ATOMIC MASS**
Electrons are moving in this	Amount of protons in an atom	Building block of matter	Same number as protons in an atom	Examples: H, O, C	Atoms are made up of this

TEMPLATE FOR DOMINOES ON THE STRUCTURE OF THE ATOM:

THE STRUCTURE

OF

AN ATOM



MAGNIFICENT MOLECULES

TRY NOT TO EAT BEFORE ACTIVITY IS DONE!

1. **In this activity you are going to build several molecules from atoms, using different colours of jellytots and toothpicks.**

2. **In your groups, decide what colour jellytot will represent each of the following atoms and write it down in the table below:**

Atom	Colour
Hydrogen	
Oxygen	
Carbon	
Sulphur	
Silicon	

3. **Now build your own molecule, using the formula given of each molecule in the blocks on the next page to guide you. Use the specific colour jelly tots (indicated in table above) as atoms and toothpicks to combine the "atoms".**

4. **Discuss the following in your groups and then *complete the given blocks (see next page):***

   (a) make a drawing to illustrate the structure of the molecule.
   (b) describe the uses of each type of atom in the molecule.
   (c) describe the use of the specific molecule in our everyday lives.

(a) (b) (c) H_2O	(a) (b) (c) H_2
(a) (b) (c)	(a) (b) (c)

CO_2 y this one! SiO_2

(a)

(b)

(c)

H_2SO_4

APPENDIX H 5 – ELEMENTS BINGO!

ELEMENTS - BINGO

1. Complete your grid below by filling in the symbol of different elements (indicated on the periodic table at the back of your Bingo grid) in each box - ONLY use the symbols of the elements shown on the Periodic Table at the back of your Bingo grid to personalise your Bingo grid (one symbol per box!) This means that nobody will have a grid with the same elements on the same places!
2. NB! Do NOT REPEAT symbols on your grid!
3. Everyone should now have a completed Bingo grid with a symbol of a different element as indicated on the Periodic Table at the back written in each of the boxes
4. Ready? A caller will now read a clue about an element. You will interpret the clue and if the clue fits an element on your grid, cross out the box on the grid with the symbol that fits the clue.
5. If no elements on your grid fit the clue, do not cross out any box on that turn.
6. If you have two correct options, you should cross out only ONE element at a turn.
7. The first player to correctly cross out all 5 boxes in a row (up-down, across or diagonally) must loud and clear shout out B I N G O! and will then be the winner.
8. Right, let's DO this!!

CLUE CARDS FOR ELEMENTS BINGO GAME

The symbol for the element "Gold" **Au**	Element with same amount of electron shells than Helium **H**	Non-metal with 4 electron shells **Br; Kr**
Element used in thermometers **Hg**	The symbol for the element "Potassium" **K**	The symbol for the element "Xenon" **Xe**
The symbol for the element "Zinc" **Zn**	The symbol for the element "Silver" **Ag**	The symbol for the element "Boron" **B**
Element with three shells and one electron in outer shell **Na**	Element with atomic number of 6 **C**	Non-metal in Group 3, Period 3 **Al**
Element with 12 electrons **Mg**	Element with atomic mass of 7 **Li**	Non-metal with 8 electrons **O**
Element with 12 protons **Si**	Element with atomic mass of 20 **Ne**	Metal in group 1 with 3 electron shells **K ; Ca**
Noble gas with 10 electrons **Ne**	Non-metal; Group 5; Period 3 **P**	Noble gas in Period 3 **Ar**

Elements used to form a carbon dioxide molecule **C ; O**	Element needed for white teeth, having 9 electrons **F**	Element used in "party" balloons **He**
Element with same amount of electrons in its outer shell than Oxygen **S**	Element with 35 neutrons in its nucleus **Cu**	Element used to make 10cent coins **Ni**
Element found on the tip of a match **P**	Element causes a rotten egg to stink **S**	Element necessary for strong and healthy bones and teeth **Ca ; Mg**
Element in Group 1 with 4 shells for electrons **K**	Element with 7 electrons in its third outer shell **Cl**	Symbol for the element "Mercury" **Hg**
The symbol for the element "Beryllium" **Be**	An element with 26 protons in nucleus **Fe**	Element used in swimming pools to keep it clean **Cl**
Element with 3 electrons in its outer shell **B ; Al**	Element with atomic mass of 127 **I**	Element making up 78% of air **N**

PERIODIC TABLE OF ELEMENTS

1 ATOMIC NUMBER (protons)

H SYMBOL OF ELEMENT

1.008 ATOMIC MASS (protons + neutrons)

	1	2												3	4	5	6	7	8
1	1 H 1.008																		2 He 4.003
2	3 Li 6.941	4 Be 9.012												5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
3	11 Na 22.989	12 Mg 24.305												13 Al 26.981	14 Si 28.085	15 P 30.973	16 S 32.066	17 Cl 35.452	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078						26 Fe 55.845		28 Ni 58.693	29 Cu 63.546	30 Zn 65.39						35 Br 79.904	36 Kr 83.80
5																		53 I 126.904	54 Xe 131.29
6											79 Au 196.966	80 Hg 200.39							

COPY ON BACK OF ELEMENTS BINGO TEMPLATE