An investigation into how Grade 11 Physical Science teachers mediate learning of the topic stoichiometry: A case study

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by

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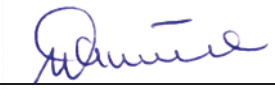
DECLARATION OF ORIGINALITY

I, MWENE KASHIIWANDAPO KANIME hereby 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:  Date: 16 JANUARY 2015

ABSTRACT

Stoichiometry is proven to be one of the difficult topics for learners in the NSSC Physical Science syllabus due to its abstract nature. Over the years the Examiner's reports reveal that learners' performance is very poor in this topic. In addition, learners fear the topic and have developed a negative attitude toward it.

It is against this background that I decided to carry out a qualitative case study; investigating how teachers mediate the learning of stoichiometry. The study was conducted at two schools in the Oshikoto Region, Namibia and it involved two grade 11 Physical Science teachers.

The study is located within the interpretive paradigm and made use of interviews, document analysis and lesson observations (which were video-taped and transcribed) followed by stimulated recall interviews to generate data. The generated data were analyzed using the inductive approach whereby themes were identified. The themes were later used to develop analytical statements in relation to my research questions and these were used to interpret the data. Moreover, the study adopted the notion of pedagogical content knowledge (PCK) proposed by Shulman (1986, 1987) as well as Vygotsky's (1978) mediation of learning and social constructivism as the theoretical frameworks.

The data were validated by triangulation, member checking as well as using the stimulated recall interviews while watching the videos with each participant.

The findings of the study show that teachers use several tools to mediate the learning process and this includes the use of language, learners' prior knowledge and analogies. In addition, it emerged in this study that teachers are faced with a number of challenges when mediating learning of this topic. Hence, the study recommends that teachers should develop their pedagogical content knowledge for them to effectively eliminate the challenges faced as well as to come up with the best teaching strategies which they can use to mediate learning and help learners make sense of the topic stoichiometry.

DEDICATION

This thesis is dedicated to my late aunt Kaarina Ingo (GwaKanime) for teaching me the value of education and for the love she gave me.

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LIST OF ABBREVIATIONS AND ACRONYMS

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
MBEC:	Ministry of Basic Education and Culture
MoE:	Ministry of Education
NIED:	National Institute for Educational Development
NSSC:	Namibia Senior Secondary Certificate
O-T1:	Lesson observation with Teacher 1
O-T2:	Lesson observation with Teacher 2
PCK:	Pedagogical content knowledge
TIMSS:	Trends in International Mathematics and Science Study
T1:	Teacher 1
T2:	Teacher 2
ZPD:	Zone of proximal development

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CHAPTER 1

INTRODUCTION TO THE STUDY

1.1. Introduction

This chapter introduces my study which is aimed at investigating how two grade 11 Physical Science teachers in two selected rural secondary schools in Northern Namibia mediate learning of the stoichiometry topic during their lessons.

I begin by sketching the context or background of the study. This is followed by the research goal, research questions as well as the possible significance of this study. I also provide definitions of the main terms or concepts that are used in this thesis followed by an outline of the thesis and some concluding remarks.

1.2. Context of the study

Science education plays an important role in the development of any country and is regarded as of the main drivers of the transformed society worldwide (Namibia. Ministry of Education [MoE], 2009). Science education is described as dealing with "understanding scientific processes, the nature of scientific knowledge and the ability to apply scientific knowledge and skill" (ibid, p. 12).

Despite the importance of science globally, science education is still faced with a number of challenges one of which is poor performance and lack of interest by the learners. For instance, the Trends in International Mathematics and Science Study (TIMSS) 2011 report revealed that the performance in science is not encouraging especially for the African countries which participated (Martin, Mullis, Foy & Stanco, 2012). Out of 42 countries which participated in the TIMSS study, only 14 reached an average score above the TIMSS centre-point of 500 points. The TIMSS report attributes the poor performance in science, especially in chemistry, to the negative attitudes toward the subject on the side of the learners as well as to the fact that learners do not see the value of chemistry in their lives (Martin et al., 2012).

Furthermore, chemistry is viewed by many learners as a difficult subject (Johnstone, 2006; Chiu, 2005). According to Johnstone (2006), the difficulty may lie in the ability of human

learning as well as the intrinsic nature of the subject. Among the chemistry concepts that the learners find particularly difficult is stoichiometry. Chiu (2005) attributes the difficulty of stoichiometry to its complexity. He also postulates that learners experience challenges in learning the topic because of the various misconceptions they bring to the classroom during the learning process (ibid).

This situation is similar to that found in Namibia with regard to science education. The Physical Science curriculum for Namibian Senior Secondary Certificate (NSSC) is divided into two sections, namely, physics and chemistry. One of the topics under the chemistry section is stoichiometry. In this topic learners are expected to know the terminology and calculations used in stoichiometric calculations (Namibia. MoE, 2009). Under the specific objective in the Physical Science syllabus it is stipulated that learners should be able to:

- *define relative atomic mass, A_r, of an atom as the ratio of the average mass of one atom of the naturally-occurring atom to 1/12 of the mass of a carbon-12 atom;*
- *define relative formula mass M_r, of a molecule or chemical compound as the ratio of the average mass of one molecule or compound in the simplest form, of the naturally-occurring atom to 1/12 of the mass of a carbon-12 atom (Note: The term relative molecular mass, M_r, may be used for molecules);*
- *state the relative formula mass of the molecule or compound in the simplest form, is the sum of the relative atomic masses of all atoms present in that molecule;*
- *calculate it as the sum of the relative atomic masses /relative formula mass;*
- *deduce the balanced equation of a chemical reaction, given relevant information;*
- *define concentration in g/dm3 and mol/ dm^3 (Note: The word molarity expresses the concentration of a solution only in mol/ dm^3 and is no longer in use);*
- *calculate stoichiometric reacting masses and volume of gases (taking the molar gas volume as 24dm^3 at room temperature and pressure rtp);and*
- *calculate stoichiometric reacting masses and volume of solutions, solution concentrations being expressed in g/dm^3 or mol/dm^3, (calculations based on limiting reactants may be set (questions on the gas laws and the conversion of gaseous volumes to different temperatures and pressures will not be set)* (MoE, 2009, p. 26).

As I have been teaching this topic for nine years, I have come to realise that most learners have different perceptions and attitudes towards it especially when it comes to the moles as well as the stoichiometric calculations. This is exacerbated in part by the fact that although

this topic is only introduced in grade 11, many learners fear the topic and believe that it is difficult before they encounter it. As a result, learners perform very poorly in the topic of stoichiometry during the tests and examinations.

Furthermore, in order to determine whether the syllabus's objectives are attained, the learners are assessed via a national examination at the end of grade 12. Their results indicate that the learners lack understanding in the stoichiometry topic. Evidence is provided in the Physical Science Examiners' reports which revealed that learners perform poorly in the stoichiometry topic and other topics where they need to apply the stoichiometry concepts compared to other topics in Physical Science (Namibia. MoE, 2007-2013).

For example, many learners could not use the correct mole ratio and correct formulas when solving the stoichiometric problems. Examples of the Examiners' comments in the Examiner's reports on questions related to stoichiometry were:

- 'this question was poorly answered';
- 'Stoichiometry was not well managed and still remains a headache for learners';
- 'molar calculations were done well by only by a few candidates'; and
- 'candidates could not use the ratio from the balanced chemical equation to determine the required quantity'.

In many cases, the Examiners' reports relate this poor performance to lack of conceptual understanding of the topic and to the way the learners were taught. Thus, the Examiners in most of the reports encourage the teachers to emphasise the meaning of, for example, the concepts as well as the symbols used in the formulas (Namibia. MoE, 2012-2013).

Being involved in the marking of national examinations (National Senior Secondary Certificate [NSSC]), I too noticed that learners perform poorly in the questions involving stoichiometry reactions as well as mole concepts. In discussion with fellow markers, they pointed out that many learners across the country in Namibia have problems in this topic although they could not suggest possible reasons which might have led to this problem.

Chiu (2005, p. 1) points out that "Chemistry is a world filled with interesting phenomena, appealing experimental activities, and fruitful knowledge for understanding the natural and manufactured world. However, it is so complex". As a result of the difficult and complex

nature of chemistry and also the fact that it is one of the most conceptually difficult subjects, it is of major importance that anyone teaching it is aware of the potential areas of difficulty. In turn, this would help teachers to make sense of these concepts.

The findings above as well as my own experience triggered my interest to do this study. As a Physical Science teacher of long standing, I discovered that many learners have negative perceptions of the stoichiometry topic and most of them lack interest in it even before it is formally introduced to them. For instance, learners fail to understand the concept of moles at the start as well as the necessity of making links between prerequisite topics such as writing formulas and balancing chemical equations.

In addition, I realised that there are no studies done on the teaching and learning of stoichiometry in Namibia specifically even though this topic has been identified by a number of researchers globally as one of the problematic topics in chemistry. Thus, I decided to conduct a study looking at how teachers teach this topic of stoichiometry to their learners. To this end, the significance of this study is discussed below.

1.3. Significance of the study

Knowledge of stoichiometry is necessary in understanding complex chemistry equations especially for learners who want to pursue careers in industrial production and science. Thus, this study might help in supporting the teaching of the stoichiometry topic. In addition, this research is meant to benefit all the Physical Science teachers so that they can learn how they can help their learners to become interested in different topics that they teach. The study will also help me as a teacher in improving my own practice in the classroom.

Although the study is limited to the teachers only, the result of this study can also be useful to other stakeholders in education. As the study also looked at the challenges faced by the teachers during the mediation of stoichiometry, it can inform curriculum developers when revising the curriculum documents.

Furthermore, the study could be useful to those who want to do research in the same area as this topic is under-researched, particularly, in the Namibian context.

1.4 Research goal and questions

The main goal of this study was to investigate how grade 11 Physical Science teachers mediate learning of the stoichiometry topic during their lessons.

To achieve this goal, the following main question was asked:

Main Question:
How do grade 11 Physical Science teachers mediate learning of the stoichiometry topic during their lessons?

To answer this main question, the following sub-questions were asked:

1. What are grade 11 Physical Science teachers' views and experiences of the learners' problems in stoichiometry?
2. How do the grade 11 Physical Science teachers scaffold learners to make sense of the concepts associated with stoichiometric reactions?
3. In what ways do grade 11 Physical Science teachers deal with the challenges faced by learners in making sense of the concepts in stoichiometry?

1.5 Theoretical frameworks

This study is underpinned by the Vygotsky's (1978) constructivist theory, particularly social constructivism and mediation of learning in conjunction with the pedagogical content knowledge (PCK) (Shulman, 1986, 1987). I found these theoretical frameworks appropriate in this study as social constructivism helped me in understanding teacher-learner interactions during the mediation process. On the other hand, the PCK aimed at assisting in understanding the way the teachers presented their lessons and how they dealt with the learners' learning difficulties so that stoichiometry became meaningful to them.

1.6 Research design

This research study is a qualitative case study situated within the interpretive paradigm that aimed at understanding and gaining more insight into the way teachers mediate learning of the stoichiometry topic.

Data gathering techniques

Different data gathering techniques were used to gather data for this study, as it strengthened the study by providing triangulation and helped to ensure validity. The techniques used were:

- Document analysis;
- Lesson observations (and these were videotaped);
- Semi-structured interviews; and
- Stimulated recall interviews (while watching the videos with the teachers).

1.7 Definition of concepts

The following are the key concepts used in this study and how I employed them:

Learner Centred Education (LCE): the teaching approach which regards learners as the centre of their own learning through active participation.

Mediation: a specialized way or method of interaction between the teacher and the learners in helping the learners to learn meaningfully.

Pedagogical Content Knowledge (PCK): a concept which describes the best strategy used by the teacher in presenting the subject content on a certain topic in order for the learners to make sense of the topic and eliminate any misconception associated with the topic.

Prior knowledge: the type of knowledge that learners acquire from previous experiences, be it from home, from previous lessons or their surroundings.

Scaffolding: a temporary support mechanism. The various forms of assistance or support given to learners during teaching and learning, as a way of mediating the content supplied by the teacher.

Sense-making: making meaning out of the concepts being taught.

Social constructivism: a socio-cultural theory which advocates that learners construct their own knowledge through social interaction with others.

Teaching strategies: the teaching methods that the teacher uses during the teaching and learning process to help the learners understand the concepts being taught in the classroom.

Zone of Proximal Development (ZPD): The distance between a child's problem solving ability when working alone and with the assistance of a more knowledgeable partner (Vygotsky, 1978)

1.8 Overview of the thesis chapters

This thesis consists of six chapters.

Chapter one introduces the study and provides the context of the study, the motivation for carrying out the study as well as its significance. In this chapter I also present the research goal and research questions. The key concepts used in this study are also defined in this chapter followed with some concluding remarks.

In **Chapter two**, I review the literature relevant to the study in an effort to gain insight into what previous researchers have said or discovered on the teaching and learning of the stoichiometry topic. The literature reviewed also includes literature on strategies used in the mediation of learning. The theoretical frameworks that underpin this study are also explored in detail, namely social constructivism, mediation of learning and pedagogical content knowledge (PCK).

Chapter three elaborates on the methodology employed in carrying out this research study. In this chapter I present the research design for the study and the research paradigm which is the interpretive paradigm. The strategies used to generate data including how the data generated was validated are also discussed in this chapter.

In **Chapter four** which comprises two sections, I present and analyse the data generated using the various strategies discussed in Chapter 3. The presentation includes some direct quotations from the participants with some comments from the researcher.

Chapter five consists of the interpretation and discussion of the data gathered as presented in Chapter 4. This is done in terms of analytical statements developed from emerging data presented in Chapter 4. The data is discussed in this chapter with reference to the theoretical frameworks and literature outlined in Chapter 2.

Chapter six concludes the study. In this chapter I provide a summary of the findings and provide some recommendations for further research. The chapter also outlines the limitations

of the study. It concludes with a critical reflection on the whole research journey which includes the lesson learned from the study.

1.9 Concluding remarks

In this chapter I present the background of the study. The chapter also outlines the research goal and questions, the research design and the overview of the thesis chapters. The next chapter discusses the literature on mediation as well as the teaching and learning of stoichiometry. In addition, I discuss the theoretical framework underpinning this study.

In the next chapter, I present a review of the literatures relevant to this study.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

The main goal of my study is to investigate how the grade 11 Physical Science teachers mediate learning of the topic on stoichiometry. In this chapter, I discuss the literature that informed my study. I begin by looking at the Namibian Physical Science Curriculum documents, particularly how the topic on stoichiometry is presented in the curriculum documents. Secondly, the concept of mediation of learning is discussed, looking at its importance and the strategies used in mediation of learning in general. Thirdly, I discuss the literature on stoichiometry focussing on the learning and teaching of the topic, including the challenges involved.

In the last section of this chapter, I provide a discussion of the theoretical framework that underpins this study. The theoretical aspects explored here are constructivism, in particular, social constructivism, mediation of learning as well as pedagogical content knowledge as they are found to be relevant in this study.

2.2. Namibian Physical Science curriculum

The Physical Science curriculum for Namibian Senior Secondary Certificate (NSSC) is divided into two sections, namely, physics and chemistry. The Physical Science subject policy (Namibia. MoE, 2008) outlines some of the aims of Physical Science as a subject which aims to enable learners to:

- acquire understanding and knowledge in Physical Science through a learner-centred approach;
- acquire sufficient understanding and knowledge to become confident citizens in a technological world;
- take or develop an informed interest in matters of scientific importance; and
- develop an awareness that the study of science is subject to social, economic, technological, ethical and cultural influences and limitations, and that the application

of science may be both beneficial and detrimental to the individual, the community and the environment (pp. 1-2).

However, the policy does not elaborate on how these aims can be achieved. One of the chemistry concepts which learners are required to understand is '*Stoichiometry*'.

Although some of the objectives to be covered under stoichiometry like writing formulas and balancing equations are covered in previous grades, the concept of moles and stoichiometric calculations are only introduced in the NSSC curriculum, that is, grades 11-12.

2.3. Stoichiometry

Stoichiometry stems from a Greek term *'Stoikheion*' meaning *element* and an English suffix – *metry* meaning *to measure*. It is a branch of chemistry involved with measuring the quantity of a substance, that is, evaluating quantitative measurements connected to chemical compounds and reactions (Schmidt & Jigneus, 2003). It is founded on the basic laws such as the law of conservation of mass. That is, total mass of reactant(s) equals to the total mass of the products and the law of definite proportions.

2.3.1. Learning stoichiometry

Many researchers indicate that stoichiometry is one of the more complex and abstract topics in chemistry (Chiu, 2005; Wolf, 2007; Upahi & Olorundare, 2012; Gulacar, Overton & Bowman, 2013). The complexity of this topic arises from poor or lack of understanding of the fundamental concepts such as ratio and proportional calculations (Upahi & Olorundere, 2012). According so Chiu (2005), the difficultness of chemistry topics arise due to the fact that in addition to "understanding the symbols, terminologies and theories used in learning the concepts, learners also need to transform instructional language or material that the teachers use in the classroom into meaningful representation" (p. 1).

Furthermore, stoichiometry requires a series of skills, organized chemistry knowledge as well as mathematical ability (Gulacar et al., 2013). As a result of the number of skills required in stoichiometry, many learners view the topic as difficult (Huddle & Pillay, 2006; Furió, Azcona, & Guisasola, 2002). According to Felder (1990), some learners fear the idea and start to panic the moment they hear the term 'stoichiometry'.

2.3.1.1. Difficulties experienced by learners in learning stoichiometry

Numerous studies in science education disclose a number of difficulties learners experience when learning stoichiometry and solving stoichiometric problems (Schmidt, 1990; Furio et al., 2002; Huddle & Pillay, 1996; Fach, de Boer & Parchmann, 2007). Many of the difficulties discussed are in connection with the learners' previous conception on different stoichiometric concepts. Learners come to school from different backgrounds and with a lot of knowledge and experiences. This knowledge and experience can either help or hinder their understanding and sense making of the scientific concepts (Chiu, 2005).

There are many researchers who have investigated the misconceptions held by learners in relation to learning stoichiometry (Schmidt, 1990; Furio et al., 2002; Huddle & Pillay, 1996; Fach et al., 2007). These studies provide evidence that learners do have misconceptions about the topic in the sense that they:

- Equate the mass ratio of an atom in a molecule with the ratio of the numbers of atoms and the mass ratio with the molar mass (Schmidt, 1990; Fach et al., 2007);
- Cannot determine the limiting reagent in a given problem when a substance is given in excess (Huddle & Pillay, 1996);
- Confuse or do not know the definition of and relationship between stoichiometric entities (Furió et al., 2002); and
- Believe that the amount of substance cannot be less than one mole (Fach et al., 2007).

The studies referred to above suggest the importance of learners' prior knowledge in learning and understanding stoichiometry. Svinicki (1994) indicates that the goal of learning is to incorporate new information into existing memories. Roschelle (1995) adds that learning occurs mainly from what learners already know from previous experiences rather than from what is presented in the classroom. According to Roschelle, this helps learners to assimilate new experiences easily because they incorporate the new information into their existing understanding.

Huddle and Pillay (1996) in their study conducted in South Africa revealed that students have difficulty in solving stoichiometric problems because they lack basic concepts related to stoichiometric calculations such as ratio and proportions as well as balancing of chemical equations which they ought to have known how to do before taking on the topic. They urge

that in order for the students to successfully solve stoichiometric problems they must be able to fully show understanding of ratio and proportion calculations.

Furthermore, Huddle and Pillay's (1996) research findings reveal two major misconceptions that hinder university students' abilities to solve stoichiometric problems:

1. Students assume that 'limiting reagent' implies 'lower stoichiometry'; and
2. Limiting reagent implies the least number of moles.

For instance, from the equation: $\mathbf{2}Ca_3(PO_4)_3 + \mathbf{6}SiO_2 + \mathbf{10}C \rightarrow 6CaSiO_3 + 10CO + P_4$, many students chose $Ca_3(PO_4)_3$ as a limiting reagent simple by looking at the stoichiometric coefficient from the equation. Huddle and Pillay (1996) further claim that these misconceptions are due to the lack of in-depth conceptual understanding of the concept resulting from poor teachers' content knowledge.

Upahi and Olorundare (2012) in their study conducted in Nigeria gathered similar evidence, and reported that many learners in Nigeria are unable to write and balance chemical equations and thus end up performing poorly in stoichiometry. In addition, learners become discouraged and lose hope in their ability to solve problems when the ratio is not 1:1 (ibid).

Fensham (1983) identifies language as another factor that contributes to the complexity of stoichiometry for the learner. He refers to the fact that students tend to describe what happens to the reactants during the chemical reactions. For example, students use terms such as a metal '*disappears*' or '*dissolves*' in an acid when asked what happens during the reactions. And according to him this causes confusion as these terms might have other meanings in other contexts.

Huddle and Pillay (1996) agree with Fensham and from their study also speculated that learners have problems in chemistry as the language used was not clear or understandable to the learners. Similarly, in his study conducted in Taiwan, Chiu (2005) underlined that most of the words used in chemistry have a different meaning from the same word used in daily life. For example, the phrase 'amount of substance' in chemistry has a different connotation from everyday situations. Thus, this causes even more confusion in learning.

In addition to the language, stoichiometry involves a lot of concepts or terms that all sound the same such as; mole, molecule, molar mass, molar volume, molarity and others and these terms are in most cases misunderstood by the learners (Fach et al., 2007). Fach et al. (2007) reveal that many students who participated in their study conducted in Germany were able to define these concepts, however, they could not figure out the link between them. As a result, the students mix these concepts up. Thus, in solving stoichiometric problems learners need to be encouraged to revisit the definitions of these terms as well as other concepts like ratio, proportion and balancing of equation.

2.3.2. Teaching stoichiometry

Understanding learners' difficulties and misconceptions about stoichiometry as discussed in the previous section can bring about effective teaching of this topic. Herein lies the importance of PCK (see Section 2.3.5). As pointed out by Okanlawon (2010) who highlighted that, for effective teaching and learning of stoichiometry, teachers need to "understand the difficulties that students experience in learning stoichiometry, what students understand (or do not understand) about stoichiometry as it is currently taught, and how students make sense of the information they are learning" (p. 35).

Okanlawon (2010) explores the importance of teachers' subject matter knowledge as well as pedagogical content knowledge (PCK) when teaching stoichiometry. In his study conducted with Nigerian chemistry teachers, through class observation, Okanlawon established that teachers had ample stoichiometry content knowledge. In contrast, however, they did not possess much of the PCK during the presentation of the topic. In other words, they were not able to transform their subject content knowledge to a teachable one. During teaching the teacher should be able to transform the subject content into a form that is accessible to the learners (Geddis, Onslow, Beynon, & Oesch, 1993).

Teaching should bring about conceptual change which can promote interest, curiosity and understanding in the learners (Niaz, 2005). Yet, many teachers use algorithmic strategies in teaching stoichiometry which Niaz (2005) and Schmidt (1997) believe does not promote conceptual understanding in the learners. Instead, the algorithmic strategy simply promotes memorization of the formulas without proper understanding.

As mentioned previously in Section 2.3.2., for effective teaching to take place, Geddis et al. (1993) suggest that the prior knowledge of the learners should be considered. Learners' previous knowledge on a certain concept can contribute positively or negatively to the learning process, negatively in a sense that they may come to the classroom with misconceptions. Thus, in the teaching of any topic the learners' prior knowledge needs to be considered.

Osman and Sukor (2013) argue that most of the students' alternative conceptions (the term they use for misconceptions and pre-knowledge) are extremely resistant to change and thus can have a powerful influence on learning. Consequently, teachers can use these alternative conceptions in developing the best teaching and pedagogical strategies to rectify and reformulate the misconceptions that might arise (Geddis, et al., 1993; Osman & Sukor, 2013).

2.4. Theoretical Frameworks

Theoretical frameworks are different structures around which research can be designed and conducted. This study is based on three theories mainly: Vygotsky's (1978) mediation of learning and social constructivism as well as Shulman's (1986) Pedagogical Content Knowledge (PCK). Blending of these theoretical frameworks enabled me to understand how these teachers mediated learning of stoichiometry. I now discuss each of these below.

2.4.1. Mediation of learning

The concept of mediation is attributed to two psychologists Vygotsky (1978) and Feuerstein (1991) who were both interested in how social interaction influence learning (Presseisen & Kozulin, 1992). The starting point of mediation of learning is the social interaction between the teacher and the learners in order to enhance the learning experience (Presseisen & Kozulin, 1992). Furthermore, "Mediation for learning is an important key to survival and success" (ibid, p. 1).

Vygotsky (1978) maintains that mediation of learning can lead to higher mental development in the learners. He proposes that mediation of learning can be achieved through three tools as identified by Presseisen and Kozulin (1992), namely, material tools, psychological tools and human beings (the mediators).

Mediation plays a crucial role in the learning process. According to Moll (2000), mediation is of importance in that "human being interact with their worlds primarily through mediational means; and these mediational means, the use of cultural artefacts, tools and symbols including language, play a crucial role in the formation of human intellectual capacities" (p. 257). Mediation can therefore be viewed as the tool for cognitive change (Donato & MacCormick, 1994).

Thus, the teaching of stoichiometry should aim at developing knowledge as well as reducing the gap within the learners' zone of proximal development (ZPD), a concept originally developed by Vygotsky. Vygotsky (1978) presented the ZPD as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (p. 86).

The ZPD will therefore be used as an analytic framework in this study. Goos (2004) identified three aspects of the ZPD as; scaffolding, collaboration as well as interweaving. According to Goos (2004), scaffolding is associated with the interaction between the teacher and the learner in which the teacher structures the task and allows the learners to perform the task with gradual support. Constructivist perception suggests that teachers can enhance learning by constraining experiences to provide students with a scaffold to build knowledge in a direction that would not be possible without the influence of the teacher (Tobin & Tippens, 1993). In learning and teaching of stoichiometry teachers thus need to scaffold the learners in order to mediate learning. It was for this reason that I found these aspects of ZPD relevant to this study.

Notwithstanding, the mediation of learning can be done in different forms, using different mediating tools. In the next sections different tools for mediating learning are discussed in detail.

2.4.1.1. Language

The use of language plays a crucial role in the mediation of learning. The importance of language in teaching and learning was highlighted by the work of Vygotsky. Vygotsky

(1978) views language as the most important tool in which knowledge can be constructed. He asserts that children develop their reasoning and problem solving skills through social interaction using speech. In a classroom this can be between the teacher and the learners.

In support of Vygotsky's work are Hodson and Hodson (1998) who indicate that "language creates the possibility of thought, organises the thinking process and both reflects and shapes the human society in which it is used" (p. 36). They further add that language can also be an important tool for learners especially when they are working in groups. Through group work, learners can use language to organize their work in the group and co-construct their knowledge (ibid). During the collaborative group activities, learners use language to interact with one another and explain to others certain concepts in a group.

The use of language plays a critical role in mediation of learning. Hendricks (2003) points out that science is a highly communicative discipline where language is central to the collaborative nature of scientific discourse. Oyoo (2005) echoed the same sentiment by indicating that science does not only involve practical work but it also involves the use of language, written or in the form of teacher and learner talk as proposed by Lemke (1990).

Lemke (1989) also explores the significance of language in teaching and learning, urging that language enables teachers and learners to make meanings in science. He further adds that teacher-learner interactions through language help in identifying and eliminating misconceptions in a science classroom. Language conventions are evident in the way we argue or debate in science, the way we offer hypothesis or communicative inferences, the way we negotiate meaning by questioning, paraphrasing or elaborating during scientific dialogue (Laplante, 1997).

In addition to the language of teaching and learning, learning stoichiometry also involves learning the scientific language. Gerber, Engelbrecht, Harding and Rogan (2005) stress that mastering the subject content is a two-step process. Firstly, the teacher must classify the concepts using everyday language as well as the subject specific language and scientific language. Secondly, learners need to familiarise themselves with the best way of presenting the learned concepts (ibid).

When it comes to stoichiometry, Huddle and Pillay (1996) assert that one reason why learners perform poorly in the topic it is due in part to the stoichiometric language that is not understood by them. Thus, in mediating this topic the teachers need to make the stoichiometric language clear to the learners. Furthermore, learners need to be good in both the everyday language and scientific language (Gerber et al., 2005).

In addition to language, the use of prior knowledge can also help in developing conceptual understanding of the learners. The next section will explore the significance of prior knowledge as a useful tool during the mediation of learning.

2.4.1.2. Prior knowledge

After independence in 1990 the Namibia education system adopted the Learner Centred Education (LCE) approach in order to improve the quality of education in the country (Namibia. Ministry of Basic Education and Culture [MBEC], 1993). Essentially, the point of departure for the LCE approach is that learners come to school with knowledge, skills and understanding from previous experience; be it from home, society or previous schools or grades. Thus, the teachers must make use of this knowledge and integrate it in the teaching and learning process of science (Namibia. MoE, 2008). The curriculum document emphasises that,

> *Teaching which ignores and does not build on that experience and learning will limit the learner's thinking, and the learner will not see the connection between the world outside the school and what is taught or learnt in school.* NIED, 2003, p. 9)

Roschelle (1995) argues that prior knowledge is the foundation for subsequent learning. In other words, new knowledge is built upon or re-uses prior knowledge. He further adds that incorporation of prior knowledge in the learning experience can lead to conceptual change. Although prior knowledge can enhance understanding of different concepts, learners coming with such strong beliefs do need to be assisted in transforming such knowledge into meaningful scientific knowledge (Rennie, 2011).

Rennie (2011) further adds that "assisting students to transform knowledge into a form that can be used where it is needed requires considerable pedagogical content knowledge to determine what students do understand and misunderstand" (p. 23). In other words, teachers

need to have different strategies to help learners make sense of their experiences. They should also have proper and well-developed subject content knowledge in addition to the cultural knowledge or everyday community knowledge. Kasanda, Lubben, Goaseb, Kandjeo-Marenga and Campbell (2005) posit that if the teacher lacks the knowledge, he/she will also find it difficult to direct the learners to appropriate information. Furthermore, if the teacher does not have adequate knowledge on the subject he/she is likely to mislead the learners instead of directing them and this will have a negative impact on the conceptual understanding of the learners.

The study by Stears, Malcolm and Kowlas (2003) revealed that the use of everyday knowledge in the science classroom increases the level of engagement of the learners. Learners become more involved in the lesson. Learners can use this opportunity to defend and elaborate on their experiences. By incorporating learners' everyday knowledge in teaching, this can act as a motivational tool to improve learning as it also encourages dialogues between learners as well as between learners and the teacher (ibid).

In some instances, the concepts used in the classroom might have a different meaning to the everyday meaning and this in Kibirige and van Rooyen's (2006) view may lead to problems and misconceptions if the teachers opt to ignore it. Kibirige and van Rooyen further emphasise that teachers need to familiarize themselves with the everyday knowledge from the society.

When it comes to the mediation of stoichiometry, the problems arise as a result of the prior knowledge the learners possess. Prior to learning stoichiometry, learners are expected to have certain knowledge on some chemistry as well as mathematics concepts such as writing balanced chemical equation and ratio.

2.4.1.3. Analogies

Other useful tools in the mediation of learning are analogies. Aubusson, Treagust and Harrison (2009) refer to an analogy as "a process of identifying similarities between two concepts" (p. 200). Analogies help learners to understand abstract topics like stoichiometry more easily (ibid). With the help of analogies, learners can visualize scientific concepts that are unobservable (Brown & Salter, 2010; Aubusson et al., 2009). By visualizing learners can

link the concepts to be studied to what they already know. Thus the use of analogies can best be utilised when introducing abstract topics (Haglund & Jeppsson, 2012).

For analogies to be fully effective and for them to promote scientific understanding Huglund and Jeppsson (2012) suggest that the analogy should be drawn from learners' real life experiences. For example, Bellocchi and Ritchie (2011) reported one example of a teacher who used the recipe for making a ham sandwich to teach stoichiometry. In addition, the analogy should share a number of features with the concepts to be learned (Glynn, 2008). By doing this it would help to motivate the learners and increase their interest in learning the topic (ibid).

Analogies however are regarded by some researchers as a double-edge sword (Harrison & Treagust, 2006; Glynn, 2008) as despite their usefulness in the mediation of science concepts they can also lead to misconception if they are not well-administered. Aubusson et al. (2009) highlighted that analogies can compromise the learning process especially if the teacher uses analogies that are not familiar to the learners. They further add that learners many at times only remember the analogies and not the concepts under study.

2.4.1.4. Practical activities as mediating tools

In schools, science is regarded as one of the practical subjects. Thus, the teaching of science also involves the use of practical works (Oyoo, 2005). "In fact science belongs in the laboratory as naturally as cooking belongs in the kitchen and gardening in a garden" (Al-Naqbi & Tairab, 2005, p. 20). One of the learning objectives of the Namibia Physical Science curriculum is for the learners to acquire practical skills and ability through experiments and investigations (Namibia. MoE, 2009).

Different authors describe practical activities in different ways, but with common meanings. Millar (2004) refers to a practical activity as any teaching and learning activity that involves learners in observation and/or manipulating of and interaction with real objects. While Maselwa and Ngcoza (2003) refer to them as involving 'hands-on', 'minds-on' and 'words-on' activities. Words-on as far as Maselwa and Ngcoza are concerned reinforces the importance of language in learning science (see Section 2.4.1.1).

The use of practical work has a significant importance in the mediation of science. Practical activities can help learners in making sense and developing conceptual understanding of the

scientific concepts. The handling of real objects and material helps the understanding of theoretical ideas (Millar, 1989), thus it is important to do practical activities. Agreeing with Millar (1989), Maselwa and Ngcoza (2003) accentuate that learners find practical activities an enhancement for understanding scientific concepts as according to them (the learners), practical activities minimize rote learning. Of course, the emphasis should be on key scientific concepts to be developed as Maselwa and Ngcoza cautioned.

In addition, practical activities can eliminate the belief that science is difficult as they create an enjoyment in learning science (Hodson, 1996; Maselwa & Ngcoza, 2003). For instance, as already mentioned as many learners fear stoichiometry this could mean this fear could be eliminated when the teacher mediates this topic using practical work as the practical work will spark their interest.

According to Toplis and Allen (2012) though, most of the time allocated for science lessons is spent on teaching theory. Thus, they suggest that practical activities be used to supplement the theory and provide elucidation and consolidation for the content learned theoretically as the scientific knowledge cannot be effectively learned merely from textbooks (ibid).

Notwithstanding, Hodson (1990) critiques the effectiveness of practical work in schools, expressing that practical work provides little real educational value to learners as it is mostly "ill-conceived, confused and unproductive" (p. 33). He proposes ideas on how practical work can be made useful as a motivational factor and have more validity. Hodson (1990) is of the opinion that practical activities can be more effective if learners are allowed to carry out the work themselves instead of merely observing demonstrations by the teacher. Learners in Maselwa and Ngcoza's (2003) study conducted in South Africa were also in favour of this opinion, arguing that this gave them first-hand experience of science. Furthermore, involving learners in carrying out practical themselves encourages active participation in the learning process (Al-Naqbi & Tairab, 2005), which is the core principle of constructivism and hence this can lead to meaningful learning of scientific concepts like stoichiometry.

2.4.2. Constructivism

This study is underpinned by the constructivist theory, in particular, social constructivism. Constructivism provides ideas on how to assist learners to construct knowledge and make

sense of the world (Hodson & Hodson, 1998). Learning stoichiometry involves making sense of the different concepts involved. Making meaning of the concepts involves active involvement on the part of learners and this is central to constructivism. Thus, I found this theory to be relevant in this study in helping me understand the mediation of learning of the topic on stoichiometry. I now discuss social constructivism in detail.

Social Constructivism

The social constructivism theory explains how knowledge is constructed by human beings in social contexts. According to McRobbie and Tobin (1997, p. 194), "Social constructivism recognises the importance of social and personal aspects of learning". From the social constructivist perspective, learners need to take control of their learning (ibid). That is, learners construct knowledge and understanding through social interactions with others. Moll (2002) further adds that social constructivism recognises learning as an active process of involving learners in tasks associated with making connections between their experience and existing knowledge.

In addition, knowledge can also be constructed through experience and reflections based on those experiences, as Keogh and Naylor (1996) state that learners can only make sense of new situation in terms of their existing understanding. With stoichiometry, for instance, learners should be able to expand their existing knowledge and be able to incorporate the new information. As mentioned earlier, learning stoichiometry requires learners to have prior knowledge in other areas of chemistry (like writing chemical formulas and balancing chemical equations) and mathematics (such as, ratio, proportion and basic calculations). Hence, the learning of stoichiometry should build on these content areas.

2.4.3. Pedagogical Content Knowledge (PCK)

In order to teach a certain subject or topic one needs to possess the required content knowledge. In addition to the subject content, the teacher should use the best strategy to deliver such content to the learners. Thus, Shulman (1986) proposes the notion of Pedagogical Content Knowledge (PCK) which shows a connection between the content knowledge and the pedagogical knowledge, it "goes beyond knowledge of subject matter *per se* to the dimension of subject matter knowledge for teaching" (Shulman, 1986, p. 9). Shulman (1986) is also of the opinion that PCK can bring about understanding of what

contributes to the difficulty of certain topics for instance stoichiometry in the context of this study.

"The PCK for stoichiometry includes teachers' 'bag of tricks' and motivational 'tools' that can be used to develop in students better and more strategic problem solving techniques" (Okanlawon, 2010, p. 30). In other words, teachers should be able to use different methods as they mediate the learning of stoichiometry. In addition, for fruitful teaching of stoichiometry the content knowledge needs to be transformed into a form that is more understandable to the learners (ibid).

Shulman (1987) refers to PCK as the ability of the teacher to transform their content knowledge into a form that is pedagogically powerful. Thus, teachers must know how to present their subject knowledge to the learners effectively so that the learners will be able to grasp it. According to Tobin and McRobbie (1999), in addition to the content knowledge of a certain topic, the teacher needs to be aware of different strategies to present the topic and this includes how to introduce the topic, the type of questions to ask and the practical activity to demonstrate.

Geddis et al. (1993); Mavhunga and Rollnick (2013) pointed out that in order for the teacher to effectively transform their subject knowledge into a meaningful form they must consider other areas of PCK which are: learners' prior knowledge including misconceptions, curriculum saliency, representation including analogies, effective teaching strategies and what makes the topic easy or difficult to understand. So, identifying learners' learning difficulties is of critical importance. Thus, PCK plays a very important role in this study as it involves subject knowledge, prior knowledge of the learners as well as the resources necessary to mediate learning.

2.5. Concluding remarks

In this chapter, I explored the literature relevant to this study. Specifically, I looked at the issue of mediation in the teaching and learning process. It can be seen that mediation of learning can be practised using different tools, among others; language, prior knowledge and practical activities. These tools are essential as they help to enhance conceptual development and hence learners' conceptual understanding. It is also worth noting that stoichiometry is regarded as a difficult or problematic topic in chemistry worldwide and thus the challenges

experienced by teachers and learners in teaching and/or learning this topic were also discussed.

All these were argued in relation to, mediation of learning, social constructivism as well as the PCK as the theoretical frameworks informing this study. In the next chapter, I discuss the research methodology and orientation of the study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Introduction

The focus of the study was to investigate how two selected grade 11 Physical Science teachers mediate the learning of stoichiometry during their lessons. This chapter provides a description of the methodology used in the study. I discuss the research design for this study, looking at the research paradigm and what led me to select the interpretive paradigm in particular as well as a qualitative case study as the research approach in the study.

In addition, I also discuss the various strategies I used to generate data and why those specific techniques were used and how the data gathered were validated in order to ensure trustworthiness of the data. I further outlined how ethical issues were dealt with in this study.

3.2. Research design

Polit, Beck and Hungler (2001) define a research design as "the researcher's overall for answering the research question or testing the research hypothesis" (p. 167). The research design presents a detailed outline of how the study was conducted and includes a description of how data were gathered, what instruments were employed, how the instruments were used and the intended means for analysing data generated (Parahoo, 1997). It also includes a plan of how to deal with different factors which may affect the findings and how the data were validated (Burns & Grove, 2003).

3.2.1. Research paradigm

This study was carried out within an interpretive paradigm which was deemed appropriate for this study as the purpose was to provide me with a deeper understanding of how the teachers mediated the learning of stoichiometry in their classrooms. According to Cohen, Manion and Morrison (2011, p. 17), "the central endeavour in the context of the interpretive paradigm is to understand the subjective world of human experience". The researcher thus needs to

interpret this world in order to understand it (Schwandt, 1994). An interpretive approach seeks to provide more insight into how individuals interact in a society.

An interpretive researcher assumes that meaning is constructed through interaction between the researcher and the participant (Andrade, 2009). Through interaction, the researcher becomes a "passionate participant" (Guba & Lincoln, 1994, p. 115). The researcher is engaged in the meaning construction. Within the interpretive paradigm, a qualitative approach was adopted which I discuss below.

3.2.2. Qualitative case study

This research is a qualitative study. "Qualitative research seeks to probe deeply into the research setting to obtain an in-depth understanding about the ways things are, why they are that way and how the participants in the context perceive them" (Gay, Mills & Airasian, 2009, p. 12). In qualitative research, the researchers are interested in understanding the meaning people have constructed and how people make meaning of their world and the experience they have in the world (Merriam, 2009) and thus uses "a variety of lenses which allow multiple facets of the issue at hand" (Baxter & Jack, 2008, p. 544).

In the context of this study, this qualitative research aimed at exploring how the topic stoichiometry is mediated in the classroom, thus a case study approach was adopted in this study. Yin (2009, p. 18) defines a case study in as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". A case study is advantageous as it helps in answering 'how' and 'why' questions (ibid). Therefore, a case study helped me to understand how the teachers mediate the learning of stoichiometry.

In this study, two grade 11 Physical Science teachers teaching stoichiometry constituted the case and the unit of analysis was mediation of learning of the topic on stoichiometry.

3.3. Research goal and questions

3.3.1. Research goal

The main goal of this study was to investigate how grade 11 Physical Science teachers mediate learning of the topic on stoichiometry during their lessons.

3.3.2. Research questions

To achieve the goal of this study, the following questions were asked.

Main Question:

How do grade 11 Physical Science teachers mediate learning of the topic on stoichiometry during their lessons?

To answer this main question, the following sub-questions were answered:

1.
   (a) What are grade 11 Physical Science teachers' views and experiences on the learners' challenges in stoichiometry?
   (b) In what ways do grade 11 Physical Science teachers deal with the challenges faced by learners in making sense of the concepts in stoichiometry?
2. How do the grade 11 Physical Science teachers scaffold learners to make sense of the concepts associated with stoichiometric reactions?

These two sub-questions were answered using evidence from the classroom observations which were videotaped and transcribed. The observation was followed by the Stimulated Recall Interview (SRI) with the teachers.

3.4. Research site and sampling

The sampling of this study was done purposively as well as conveniently. According to Patton (1990), purposeful sampling is a logical sampling technique used in qualitative research for the selection of information-rich cases. With this type of sampling the researchers can obtain in-depth information as the participants are selected for a specific reason. Convenient sampling refers to the type of sampling whereby the research participants are selected based on accessibility and low cost (Marshall, 1996).

The research was carried out in two secondary schools in Oshikoto Region. Both schools have grades 8 to 12 and they are about forty kilometres away from each other. Both schools are boarding schools. In addition to the fact that these schools are closer to me meaning I will

access them easily, they are also among the best performing schools in the region in Physical Science and also in general.

Two grade 11 Physical Science teachers were involved in the study, with one teacher from each school. The teachers were selected based on their experiences. Both teachers have teaching experience of in excess of seven years, which means they are well experienced in teaching the topic. Both teachers hold the title of the best Physical Science teacher in the region from previous years. Although the study looked at the mediation of teaching of stoichiometry at Ordinary level, these teachers also teach the Higher level at their schools which I believe it is an advantage when it comes to this study.

The study involved a sample of only two teachers so that they can be easily managed and accessed due to the limited time available to collect the data. Although this sample is not big enough to generalize the finding, it was more convenient to manage in order to obtain more in-depth data. In addition, the use of different data gathering tools helped in validating the data obtained.

The study involved grade 11 because the stoichiometry topic is covered in that grade. The teachers involved are the only teachers teaching the grade at the schools.

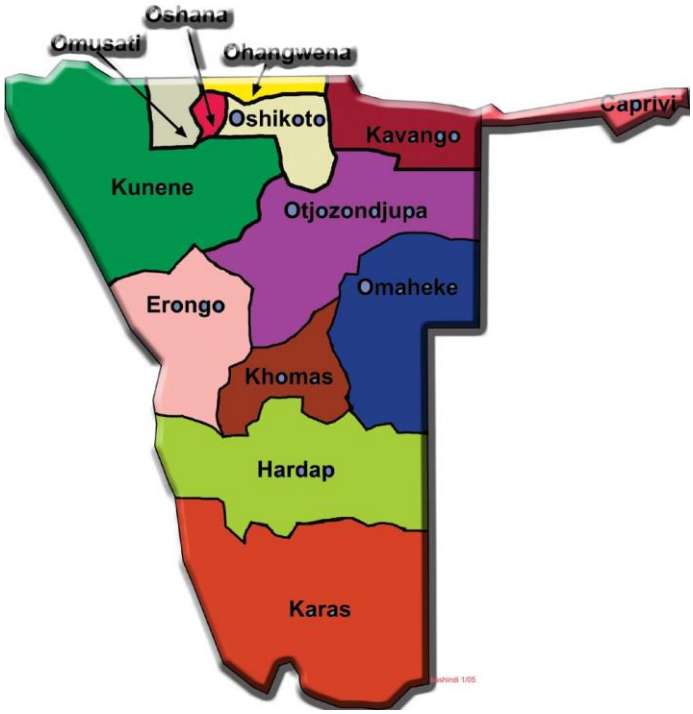


Figure 1: Map of Namibian regions

3.5. Data gathering techniques

In a qualitative study like this one, the data gathered should help in gaining more insights into and understanding of the topic of interest (Gay et al., 2009). Thus, the data to be gathered needs to be descriptive and visual (ibid). Three data gathering techniques were used in this study, namely, document analysis, observation and interviews (*semi-structured and stimulated recall interviews*) in order help me to reveal understanding and meaning of the issue at hand.

McMillan and Schumacher (2001) urge the use of multiple data gathering techniques in order to corroborate the data obtained. Hence the fact that I used numerous data gathering techniques to help in validating the data generated. Furthermore, Cohen et al. (2011) underscore the use of multiple techniques to ensure the trustworthiness of the data. I now discuss each of my data gathering techniques below.

3.5.1. Document analysis

According to McCulloch (2011), a document is a record of an event or process which may be produced by individuals or groups and may take different forms. Document analysis entails a detailed examination of documents across a wide range of social practice, taking a variety of forms, from the written words to the visual image (Wharton, 2006). Document analysis reveals more information on the issue at hand.

In this study, I analysed the Curriculum Documents (the Physical Science Ordinary Level syllabus and the national curriculum), Examiners' reports for 2009 to 2013, three Physical Science textbooks, teachers' lesson plans as well as learners' workbooks and test books (two diagnostic tests, one before the topic was taught and a test afterwards.

Analysing the curriculum document, the Physical Science NSSC Syllabus to be more specific, helped me to be aware of what the learners are expected to know on the stoichiometry topic. It also enhanced my understanding on the type of prior knowledge learners are expected to have before undertaking the topic stoichiometry. Learners' workbooks and test books revealed more information on the challenges learners face when

solving stoichiometric problem. In addition to learners' workbooks, the Examiner's reports were also analysed and this provided more informed data about the problems and misconceptions experienced in solving stoichiometric problems nationally.

3.5.2. Observations

Observation can be used to understand and interpret behaviours (Mulhall, 2003). In addition, through observation one gathers open-ended first-hand information on a specific issue (Creswell, 2012). Thus, observation gave me primary information of what is really happening in the classrooms regarding the mediation of learning of the topic on stoichiometry.

I observed five of Teacher 1's lessons and three of Teacher 2's on the topic stoichiometry. The lessons for Teacher 2 were however all scheduled for a few days before the examination. The teacher had to complete the topic before the start of the examinations. During the observations I was able to see how the teachers presented the topic to the learners including the way they introduced it. The lessons were video-taped with permission from the participants.

3.5.3. Interviews

Interviews are a two-way conversation between the researcher and the participant. The interview aims to "see the world through the eye of the participant" (Nieuwenhuis, 2013, p. 87). Interviews provide in-depth data about the topic under investigation depending on the type of interview used. In this study, I conducted semi-structured interviews as well as stimulated recall interviews with the participating teachers in order to gain as much information as possible about how they mediate the topic stoichiometry as well as their views on the topic.

3.5.3.1. Semi-structured interviews

After observations, I conducted interviews with the two teachers. This helped to obtain more in-depth information about the mediation of learning of the topic. An interview is an interchange of views between two or more people on a topic of mutual interest (Kvale, 1996).

It enables the participants to discuss their interpretations of the world in which they live, and to express how they regard situations from their own point of view (Cohen et al., 2011). Semi-structured interviews were used to generate data as they provide opportunities for the interviewee to provide in-depth information on a topic. Furthermore, a semi-structured interview gives the respondents an opportunity to give more detailed responses and the interviewer a chance to explore further via follow-up questions.

I carried out the interview with both teachers. I used an interview schedule with seven open-ended questions (see Appendix C) to guide me through the interview. As these were semi-structured interviews, I asked follow-up questions when I require more detailed responses. The interviews were audio recorded with the consent of the teachers and were transcribed verbatim so that the information was captured in full. The transcripts were given back to the teachers for member checking (see Section 3.7).

Teacher 1's interview took about 25 minutes while Teacher 2 only took 15 minutes. I however realized that Teacher 2 gave very short and more direct answers hence the interview took a shorter time compared to Teacher 1. During the interviews the teachers gave their views on the topic as well the challenges they face when teaching stoichiometry. However, both teachers could only identify the challenges from the learners and no problems from their side.

3.5.3.2. Stimulated recall interviews (SRI)

"Stimulated Recall Interview is a research method that allows the investigation of cognitive processes through inviting participants to recall their thinking during an event when prompted by some other form of visual recall" (Fox-Turnball, 2009, p. 215). The video recordings are replayed to the individuals to recall their reasoning during the activity (Lyle, 2003).

Stimulated recall interviews were also conducted while watching the videos together with each of the teachers. This gave me an opportunity to ask for clarity on issues that were ambiguous during the observations. I took notes of the comments teachers made during the SRI.

However, this could not be done with all the lessons due to time constraints. For some lessons I only asked for clarity telephonically. Irrespective of these circumstances, the SRI helped in the validation process rather than relying solely on member checking.

Table 1: Summary of data gathering techniques

Technique	Target	Data to be gathered	Purpose
Diagnostic test	Learners of participating teachers	What prior knowledge do learners bring to the lesson	Test learners' prior knowledge on stoichiometry prerequisite content
Document analysis	Curriculum document, Textbooks, Lesson plans, Examiners' reports Learners' exercises or work books Learners' test books	Content and the concepts to be covered Methods and teaching strategies	Find out how teachers plan to mediate learning To find out how learners solve stoichiometric problems
Semi-structured interviews	Participating teachers;	Teachers' perception on the topic of the study	Teachers' experience with teaching stoichiometry including challenges faced
Classroom Observations	Conversations, interaction and behaviours between teachers and learners	Actual teaching strategies used, Teacher-learners interactions	Record teachers practices and categorize them into theme like activities given, language used, feedback and any other action found relevant to the study.
Stimulated-recall interviews	Participating teachers	Teachers' perspectives and more insights on the outcome of the observations	Gain in depth understanding of teachers practice including the way they mediate learning

3.6. Data analysis and framework

Qualitative data analysis aims at making sense of the data by organizing and categorizing it into themes based on noted patterns (Cohen et al., 2011). Since data were predominantly generated through observations and interviews, it was inductively analysed by transcribing videos and audio-taped interactions (interviews and observations) with the teachers.

The data was grouped into themes and categories according to their similarities and were colour coded. For example, I used the colour green for teaching strategies used by the teachers, red for the challenges and yellow for the problems experienced by the learners and so on. Creswell (2012, p. 243) posits that "coding is a process of segmenting and labelling texts to form descriptions and broad themes in the data". Data coding helps the researcher to classify similar information (Cohen et al., 2011).

The themes were then used to come up with the analytical statements which are used for the data interpretation in Chapter 5. During the data interpretation and discussion I used the theoretical frameworks (discussed in Chapter 2) to help make sense of the data and to answer my research questions. I used PCK to understand the teaching strategies used by the teachers during the mediation process and also the challenges faced by the teachers and the approach they use in dealing with these challenges. I used social constructivism to explain different mediation tools that the teachers used such as language and prior knowledge which are some of the key aspects of social constructivism.

During the analysis process I also ensured the trustworthiness of the data. In the next section I discuss how the trustworthiness was ensured and how the data were validated.

3.7. Validation and trustworthiness

Validation of data is very significant for successful and effective research (Cohen et al. 2011). Cohen et al. further add that if research is invalid then it is worthless. Thus, to validate the data in this study, a method of triangulation was employed. Triangulation is a multi-method approach of obtaining data (ibid). The importance of triangulation includes "increasing confidence in research data, creating innovative ways of understanding a phenomenon, revealing unique findings, challenging or integrating theories, and providing a clearer understanding of the problem" (Thurmond, 2001, p. 254). In this research,

methodological triangulation was used. Methodological triangulation involves the use of multiple qualitative and/or quantitative methods to study the program (Guion et al., 2002). I used different data gathering tools to generate the data for this study.

Data generated through interviews were validated by member checking (Harper & Cole, 2012). Member checking is a quality control process in qualitative research through which participants receive the opportunity to review their statements for accuracy (ibid). In this study, the interview transcripts were handed back to the participants so they could check for accuracy. However, only Teacher 1 managed to go through the whole transcript although she did not make any changes apart from few grammar and spelling errors. Teacher 2 indicated that there was no need to go through the transcripts as he was too busy. Furthermore, I also used a colleague to help in verification of the interview transcripts.

As explained earlier, stimulated recall interviews were also used to validate the data gathered while watching the videos with the teachers. This helped me to get better idea of the issues which were not clear from the observations as well as more detailed information on why the participants acted the way they did during their teaching.

3.8. Ethical considerations

This research was carried out with the consent of all the participants. Before the research began, I sought permission from the Director of the Oshikoto Region through the school inspectors of the respective schools and the principals of the two schools to conduct the research (see Appendices A to B). Furthermore, I obtained consent letters from the teachers who participated in the study. Diener and Crandall cited in Cohen et al. (2011) define informed consent as a process in which a person chooses whether to participate in an investigation or not.

Written letters were given to the participants to assure them of full confidentiality as well as anonymity. To ensure the anonymity of the participants, pseudonyms were used. The participants were known as Teacher 1 and Teacher 2 and the schools were referred to as School 1 and School 2. Furthermore, the consent respects the right of self-determination and places some responsibilities on the participant (Cohen et al., 2011). The interviews and lessons were audio- and video-taped with the consent of the participating teachers.

3.9. Limitations

This study was limited to only two schools in the Oshikoto Region involving only two teachers. Therefore, its results cannot be generalised. Although the sample was a small one, I do feel that useful insights on how to mediate learning of the topic on stoichiometry were obtained from this study.

3.10. Concluding remarks

In this chapter, I presented the research design of the study. I described how data were gathered and how the methods I employed helped me to answer the research questions. Triangulation was presented as a way to validate the data gathered. Furthermore, ethical issues which were put into consideration are also deliberated. I conclude with a description of the limitations of the study.

In the next chapter I present the data which I obtained during the data gathering process.

CHAPTER 4

DATA PRESENTATION AND ANALYSIS

4.1. Introduction

Here I present the data I obtained using the different data gathering techniques I used in this study, namely, document analysis, semi-structured interviews, and lesson observations as well stimulated recall interviews while watching the videos with the teachers.

The chapter commences by outlining the teachers' profiles which I consider crucial for proper contextualization of the data.

4.2. Teachers' profiles

Two teachers from two different schools were involved in this study. Both schools are located in the rural areas of Northern Namibia. Both teachers are also Heads of Department for Mathematics and Natural Sciences at their respective schools.

Teacher 1 from School 1 teaches Physical Science, grades 8-12. At the senior grades (11 and 12) she teaches both Ordinary level and Higher level. She has eight years' teaching experience; 3 years teaching at a combined school (grades 8-10) and five years at a secondary school (grades 8-12) where she is currently teaching. She holds a Basic Education Teacher Diploma (BETD), a Higher Education Diploma (HDE) and is currently doing her Bachelor of Education (Honours) in Science Education.

Teacher 2 from School 2 has nine years' teaching experience at secondary school (grades 8-12). He holds a Bachelor of Education degree in Physical Science and Mathematics. He is currently teaching Physical Science, grades 11 and 12.

4.3. The selection of themes from each data set

From the data I gathered employing the different strategies described in Chapter 3, a number of themes emerged during the analysis process. The themes are selected with the intention of answering the research questions indicated in Chapter 3. These themes are:

- The use of prior knowledge;
- Challenges faced by the teachers during the mediation of the topic;

- Teaching strategies used to mediate the topic; and
- Improving learners' sense making of stoichiometric concepts.

4.4. Document analysis

As mentioned in Chapter 3, five documents were analysed in this study.

4.4.1. Curriculum documents

4.4.1.1. The National Curriculum for Basic Education (NCBE)

The curriculum is the official policy document for teaching and learning and it is the place to go to find directions on how to plan and implement the teaching and learning process.

The curriculum also specifies the teaching and learning approach which must be used during the teaching and learning process. It proposes that a learner-centred education (LCE) approach should be applied where learners play a crucial role in the learning process. The curriculum emphasises that "learners learn best when they are actively involved in the learning process through a high degree of participation, contribution and production" (p. 26). In addition learning with understanding is also encouraged.

4.4.1.2. Physical Science Ordinary Level Syllabus

A syllabus is a policy document that guides the teachers on the topics that need to be covered in a specific grade as well as the learning competencies required for the topic. In addition to the topic outlines and competences, the Physical Science syllabus also outlines the aims and assessment objectives of the subject.

The learning content is set out in three columns: topic, general objectives and specific objectives. Stoichiometry, the topic being investigated in this study is topic 3 under the chemistry section. The table below is an extract from the syllabus illustrating how this topic is presented in the syllabus.

Table 2: Physical Science NSSCO Syllabus extract on the learning objectives for the topic Stoichiometry

TOPIC	GENERAL OBJECTIVES Learners will:	SPECIFIC OBJECTIVES Learners should be able to:
3. Stoichiometry	• know terminology and calculation used in stoichiometric calculations	• use the symbols of the elements and write the formulas of simple compounds • deduce the formula and name of a simple compound from the relative numbers of atoms present • determine the formula of an ionic compound from the charges on the ions present • construct word equations and simple balanced chemical equations • define relative atomic mass, A_r , of an atom as the ratio of the average mass of one atom of the naturally-occurring atom to 1/12 of the mass of a carbon-12 atom • define relative formula mass M_r, of a molecule or chemical compound as the ratio of the average mass of one molecule or compound in the simplest form, of the naturally-occurring atom to 1/12 of the mass of a carbon-12 atom (Note: The term relative molecular mass, M_r, may be used for molecules) • state the relative formula mass of the molecule or compound in the simplest form, is the sum of the relative atomic masses of all atoms present in that molecule • calculate it as the sum of the relative atomic masses /relative formula mass • deduce the balanced equation of a chemical reaction, given relevant information • define concentration in g/dm^3 and mol/ dm^3 (Note: The word molarity expresses the concentration of a solution only in mol/ dm^3 and is no longer in use) • calculate stoichiometric reacting masses and volume of gases (taking the molar gas volume as $24dm^3$at room temperature and pressure rtp) • calculate stoichiometric reacting masses and volume of solutions, solution concentrations being expressed in g/dm^3 or mol/dm^3, (calculations based on limiting reactants may be set (questions on the gas laws and the conversion of gaseous volumes to different temperatures and pressures will not be set)

From the specific objective it emerges that the first four basic objectives are also present in the grade 10 syllabus. This means that the learners should be knowledgeable about this subject content. Although one of the assessment objectives of Physical Science according to the syllabus is practical skills and abilities and the syllabus provides suggestions for possible

practical work to be carried out under each topic, no practical work suggestion is given under the stoichiometry topic.

The provision of the glossary of terms or action verbs used is found to be very helpful to the teachers as well as the learners. It gives them guidelines of what is expected of them. For example, what is expected when it says 'state' or 'suggest' or 'deduce' and so forth.

4.4.1.3. Textbooks

Three textbooks were analysed to find out how the topic stoichiometry is presented in these textbooks. These are the textbooks which are used at the two schools.

a) Discover Physical Science H/IGCSE localised for Southern Africa

This textbook includes a chapter on stoichiometry titled *'how much*'. The textbook includes more detailed content which can help in developing learners' contextual understanding. In addition the textbook introduced the concept of *'Mole*' using analogies linking the concept to other concepts that are used in everyday life.

> *"This number is known as a* ***mole*** *just as 12 is known as a dozen and 144 is known as a gross…. Knowing this number allows as to count atoms and molecules by weighing them, just as bank clerk often count money by weighing it".*

The textbook also includes practical activities that could be useful in enhancing learners' understanding. In addition, worked examples in the textbook are explained in detail on how to solve problems. At the end of each section there are questions which the learners can use for the purposes of practice and testing their understanding.

b) Macmillan Physical Science for Southern Africa

This textbook starts the chapter by presenting objectives. The objectives match those presented in the syllabus.

The textbook introduces the concept of mole by using an analogy of a dozen. However, there is no coherence in the way concepts are introduced. For instance, there is no clear link made between the mole and Avogadro's constant. In addition, the content is presented in a very simplified way something which compromises learners' conceptual understanding. For example, the formulas are represented using a triangle and yet this does not really show how the formulas are derived. The textbook also provides worked examples and revision questions at the end of the chapter.

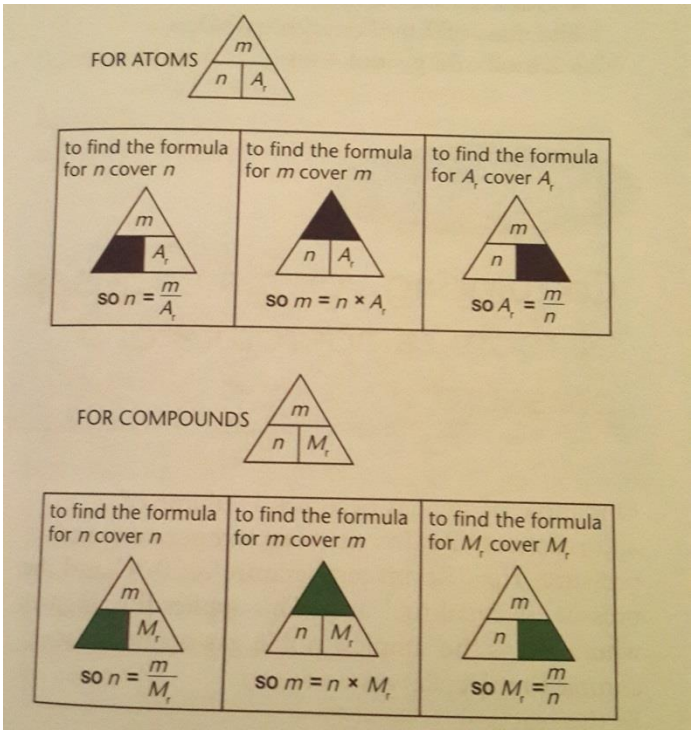


Figure 2: The way formulas are represented in the textbook

c) Physical Science Module 3

This textbook is a module meant for Physical Science part-time learners. This textbook, like the first one, starts off by presenting the objectives of the topic. Since it is written for part-time learners, the objectives are presented exactly as they appear in the NSSCO Physical Science syllabus. However, the content is presented in a very shallow manner and not much content is given in this module.

Although scant theory is given in this textbook especially on the topic of stoichiometry, a number of worked examples are given regarding stoichiometric calculations. There are also a number of activities which the learners can use to test their understanding at the end of each unit section as well as the end of the unit (chapter). For the activities, the time needed to spend on each activity is also allocated.

Furthermore, the textbook uses diagrams to explain the different concentrations of solutions. Unfortunately, these are the only diagrams in the whole unit of stoichiometry. The figure below shows the diagrams used to differentiate the concentration of different solutions.

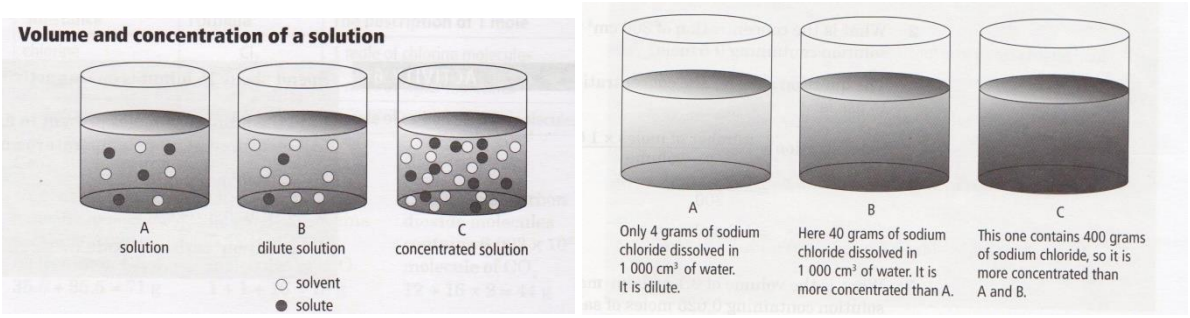


Figure 3: The diagrams used to explain concentration of solutions in Textbook 3

4.4.2. Learners' activities books (per school)

4.4.2.1. Learners' activities book at School 1

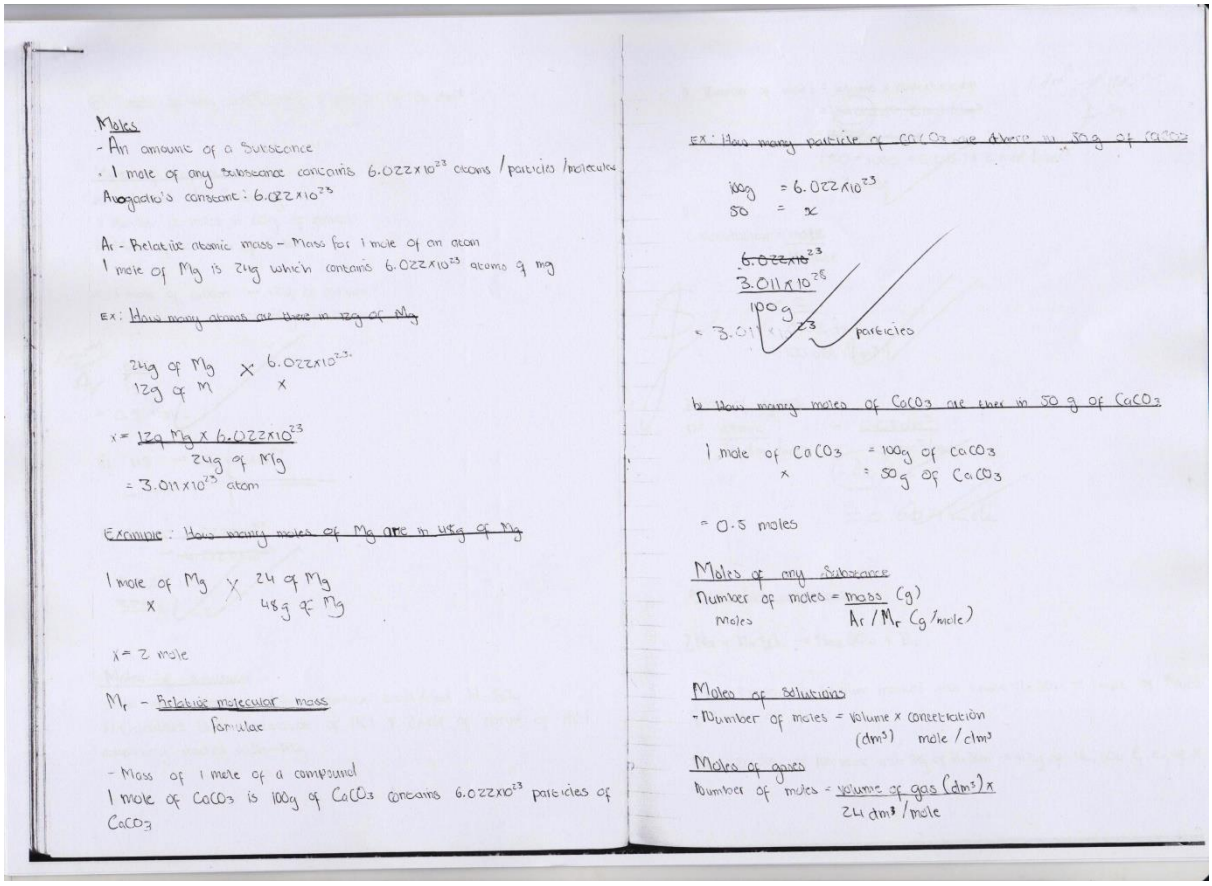
The learners at the school all have a prescribed textbook and that is what is being used in the classroom. Learners also have notebooks but they only use them for examples being done in the classroom. Most of the activities were done in groups and a number of tests were given individually and these tests were marked and recorded.

4.4.2.2. Learners' activities book at School 2

Learners have notebooks where they write their notes from the chalkboard as well as class work. The notes given on the chalkboard were more in the form of points and were very simplified.

Class work activities are given during the lessons to test learners' understanding of the concepts discussed. However, not all the learners' work is marked or monitored. Nevertheless, feedback is given for all the activities and learners have to correct their own work. Since the class activities were not properly monitored some of the learners were reluctant to do the work. Referring to this, the teacher indicated that he does not have enough time to monitor all the work of the learners during the lessons. He further added that he encouraged the learners to do their work fast as only a few who finish first are usually marked. The figure below shows the notes taken by the learners and some of the class exercises.

a)



b)

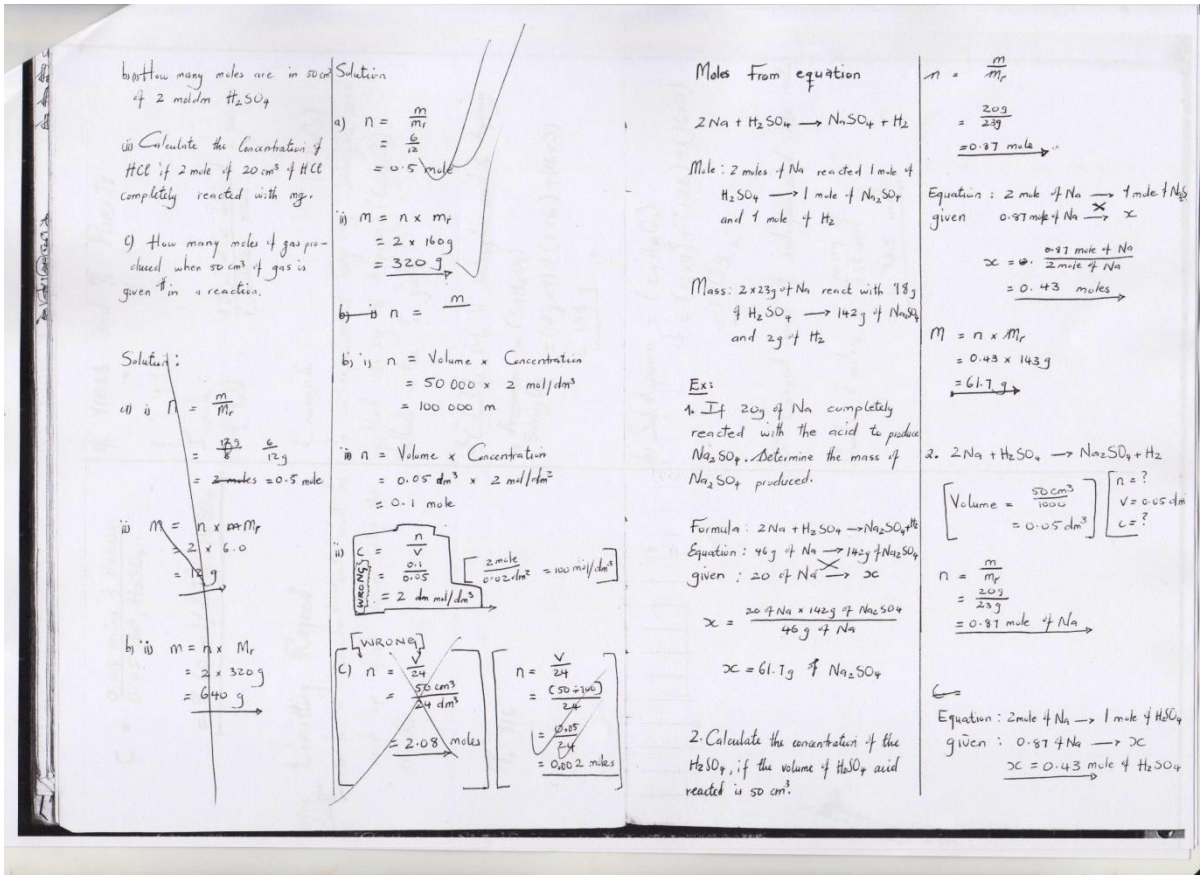


Figure 4: (a) and (b): Notes and exercises for the learners at School 2

4.4.3. Examiners' reports

Examiners' reports provided evidence and confirmation that the topic was not understood by the learners in the final examinations. Therefore these were analysed to determine the key issues that the NSSCO examiners discovered during the marking of the final grade 12 examinations on questions related to stoichiometry.

The reports indicated that candidates could not correctly write down balanced chemical equations, let alone write the correct formulas. In most of the cases the formulas are written carelessly, for instance, learners wrote Co instead of CO for carbon monoxide. Thus, the examiners constantly urge the teachers to put more emphasis on writing formulas especially the use of capital letters and lower case. The reports further indicated that most learners could not make use of mole ratio from the balanced equation to determine the required quantity. In general, the questions on stoichiometry are always performed poorly in the exams.

4.5. Interviews

Pre-interviews with the teachers were conducted before lesson observation to get their perspectives and experiences of teaching stoichiometry. Similarly, stimulated recall interviews were conducted after the observed lessons while watching the videos with the individual teachers. What follows is an account of what emerged from the interviews with each teacher. The interviews were semi-structured which gave me room to explain the questions or probe for further detail should the need arise and an interview schedule was used as a guide (Appendix C).

4.5.1. Interview with Teacher 1

The interview started with the teacher responding to the question on how she introduces the topic of stoichiometry, and specifically the mole concept to the learners. The teacher links the topic to other concepts that are used in real life experiences. In her own words she said: *"I introduce it using the concept of a dozen like referring to amount. I would give a scenario of or ask them, have you ever heard of the word a* ***dozen****?* The teacher uses the term dozen to indicate to the learners that a mole refers to the amount of substance, just like the term dozen refers to an amount of twelve. The teacher added that the topic leads on from subject content covered in previous grades (grades 8-10, so she starts off by referring them back to what was covered in those grades. *"I would usually take them back to as far as grade 8 and I ask. I start first ask them the simple, asking them writing the formula of simple molecules, I can for*

example start asking; which element on the Periodic Table exist as diatomic molecules?" (I-T1: 101)

When asked about the **knowledge** that the learners should possess prior to studying the topic of stoichiometry, Teacher 1 revealed that there is a lot of prior knowledge that a learner is expected to have before they study the topic of stoichiometry. She identified concepts such as *writing formula of compound, balancing chemical equations, proportionality* as some of the concepts that learners are expected to have prior to the stoichiometry topic. Teacher 1 however indicated that the mole concept itself is not difficult but it is only made difficult because the learners lack the pre-knowledge required. She said:

> "*I realized it through my experience that the teaching of this mole concept, the mole itself is not difficult as such because it entails just calculations of either moles of elements and compounds, moles of solutions, moles of gases, but the problem lies within the writing of formulas of molecules and writing the formulas ionic compounds".* (I-T1: 60-63)

Answering the question regarding the type of learning and teaching support materials (LTSMs) the teacher uses in teaching this topic, Teacher 1 said she sometimes does experiments involving chemical reactions and she also relies more on the Periodic Table as she thinks that the topic is not teaching aid oriented as it involves mostly calculations. "*But it is not really a teaching aid oriented topic, apart from the Periodic Table and the chemicals"*.

4.5.2. Interview with Teacher 2

The response from Teacher 2 on how he introduces the concept of moles to the learners was exactly the same as that of Teacher 1. "*I introduce things like, when you talk about things like **a pair** of shoes; those are two, when you talk about a **dozen** eggs they are like twelve eggs in a pack"* (I-T2: 21-23). It became clear during the interview that the teachers make use of **analogies** to introduce the topic.

Likewise, Teacher 2 identified the *Periodic Table, writing formulas and balancing chemical equations* as the most important knowledge the learners need to have prior to learning stoichiometry. "*If a learners doesn't know how to write a chemical formula then that learner cannot do anything when it is coming to stoichiometry because, there you need to know how to calculate for example relative molecular mass or formula mass and if the learner cannot write the formula it is very difficult to write out some of those"* (I-T2: 34-37). The teacher

indicated that most of these topics which are regarded as a prerequisite are covered in the previous grades as well as in the topic preceding stoichiometry.

When it comes to the LTSMs, the teacher tries to help the learners to understand the topic. Teacher 2 further responded that giving learners worksheets for them to practice how to solve the stoichiometric problems helps a lot. He added that the use of practical activities can also strengthen the theory that they learn. He stressed that during practical activities learners also engage in the learning process which should help them gain a deeper understand of the topic.

Challenges experienced when teaching stoichiometry

Both teachers pointed out that the challenges arose mostly from the learners' side. However, neither of them pointed out the challenge they themselves face as teachers when teaching the topic apart from those arising from the learners.

Table 3: Challenges faced by teachers when teaching stoichiometry

Teacher 1	Teacher 2
The abstractness of the topic	
Learners perceive the topic as difficult even before being introduced to it.	Learners have beliefs that the topic is difficult.
Learners have a negative attitude towards the topic	Atom and particles cannot be seen and it becomes difficult for learners to visualise them
	Learners fail to understand mole as a concept and mole as the units
Learners lack of prior knowledge on the topic	

How do the teachers deal with the challenges experienced when teaching stoichiometry?

Teacher 1 always tries to link the topic to other topics and uses learners' prior knowledge in order to explain to the learners that the topic is not completely new as it builds on the other topics which the learners are already familiar with such as writing formulas and balancing chemical equations.

Teacher 2 indicated that most of these challenges can be eliminated by doing proper planning. Both the teachers added that they always try to motivate the learners in order to remove the conviction that the topic is difficult.

The teachers were also asked how they assess learners' understanding of the concepts and the subject. Responding to this question they both said that they use worksheets and tests with Teacher 2 adding the use of quizzes.

4.6. Lesson observation

As explained in the previous chapter, some of the data for this study were generated through lesson observations. The lesson observation provides first-hand information of what is really happening in the classroom during the mediation process. The observation was aimed at complementing the data generated through document analysis and from the teachers themselves during the interviews.

During the lesson observation I was able to observe how these teachers interacted with the learners during the lesson as well as the different teaching methodologies that they used to help learners to make sense of the concepts being discussed. I also witnessed the challenges experienced by the teachers and learners in the teaching and learning of stoichiometry.

I observed five lessons for Teacher 1 and each lesson was approximately 45 minutes long. For Teacher 2, I managed to observe 3 lessons which were all scheduled in two consecutive days. Lesson 1 took about 40 minutes and lesson 2 which was a double lesson took about 70 minutes. All the lessons were video-taped. In the next sections I present the data as obtained during the lesson observations of the two teachers. I also incorporated the teachers' responses from the Stimulated Recall Interviews (SRIs) which were conducted with the teachers subsequent to the lesson observations.

4.6.1. Teacher 1

Lesson 1

This lesson was on the introduction of the mole concept. The teacher started off by referring to what was covered in the previous lessons about relative atomic mass, relative formula mass and relative molecular mass. The purpose of this according to the teacher was to create a link between the topics as with the mole concept learners also need to know how to

determine the relative atomic mass (RAM), relative formula mass (RFM) as well as relative molecular mass (RMM) as prerequisites to the topic.

She then introduced the concept of mole using the concept of a dozen.

T1: So, we are going to move on now with the new concept, but before I introduce the new concept I want to find out from you. Have you ever heard about a word a DOZEN? You heard about it?

LLL: Yes

T1: So what is the meaning of that?

L: When two atoms molecules combine.

T1: When two atoms molecules combine? That is interesting, okay. I think he is confusing it with diatomic molecule.

L: A dozen is twelve.

T1: A dozen is 12, 12 what? Is it specific to say a dozen is 12 of anything?

LLL: Yes.

T1: So a dozen is 12 objects or 12 things. So when we are talking about a dozen we are always taking about 12 things.

The use of the concept of a dozen aimed at preparing the learners for the new concepts. At the same time, the teacher was assessing what general or prior knowledge the learners have which can be linked to the concept of mole. During the stimulated recall interview the teacher said she used the concept of the dozen because that is what many learners are used to in their daily lives at home and it puts them at ease as many of the learners usually fear the topic of moles.

During the lesson the teacher used more of a teacher-centred approach. In this lesson the teacher spent most time either lecturing or solving problems on the chalkboard. Most of the questions asked were closed questions whereby the possible answers were either yes or no or where learners were requested to give a numerical answer. The teachers indicated through a stimulated recall interview that she uses a more teacher-centred approach as the concept of mole is new to the learners and also due to the abstract nature of the topic.

T1: So let see now, what is the correct chemical formula of magnesium when they react with oxygen? Magnesium is in which group?
LLL: Group 2
T1: So it will have a charge of?
LLL: 2/ 2 plus
T1: Oxygen is in group?

LLL: 6
T1: It will have a charge of?
LLL: 2 minus
T1: So we know that magnesium in group 2 loses 2 electrons, oxygen is in group 6, it gains….
LLL: 2 electrons
T1: So what will be the formula then?
LLL: [learners mumbling] magnesium oxide, Mg…….
T1: How many magnesium and how many oxygen?
LLL: 1 magnesium, 1 oxygen
T1: So the formula is MgO.

The teacher also explained how to determine the number of moles of elements, molecules and compounds. Examples on how to solve problems on determining the number of moles of elements, molecules and compounds were done on the chalkboard. By the end of the lesson learners were given homework on calculating the number of moles and mass.

Lesson 2

In the second lesson, the teacher started off by looking at learners' homework and then giving feedback to the homework questions on the chalkboard. The learners were involved in this activity and were given an opportunity to solve the questions on the chalkboard with the teacher's help along the way.

L: (Explaining her work on the chalkboard)

So the RAM for nitrogen is 14 g and for hydrogen is one and hydrogen atom are four . So I have to multiply 1 by 4 to give me 4 for 4 hydrogen

Mass = moles × RFM

= 0,02 × 18 g (so I have to add to the 4g to 14 to give 18, this is the RFM for ammonia)

= 0,36 g

As the learner explained the teacher emphasised some of the points made by the learner.

L: 3 moles of oxygen. Oxygen is diatomic molecules.

T: Did you get that information? Oxygen is a …

LLL: Diatomic molecules

T: It exists as a diatomic molecule. Remember when we did bonding we suppose to know which one give the diatomic molecules on the Periodic Timetable. Oxygen is one of them. What else?

LLL: Hydrogen, Nitrogen and Halogen.

T: Halogens the group 7 elements. So you should know which elements are the diatomic molecules. So go ahead.

By using this technique, the teacher made sure that the learners did not miss any points made by the fellow learners as some learners tended to relax when explanations were provided by a fellow learner. As one learner was busy solving the question on the chalkboard, the teacher moved from one learner to the next assessing their written work and giving them individual explanations when they went wrong.

After the discussion of the homework question the teacher went on to introduce a new concept of concentration. As in the first lesson the teacher linked the concept to a real life situation. For example, she referred to a juice concentration as well as the concentration of sugar in tea or coffee and making *óntaku'* (an Oshiwambo traditional drink).

The learners were then provided with the formulas involved when calculating the number of moles in a solution. Thereafter the class was engaged in applying the formulas in the form of examples done on the chalkboard with the guidance of the teacher.

Lesson 3

This lesson was on moles and gases as well as stoichiometric reactions. The teacher started the lesson by asking questions about what the learners had gained from the previous two lessons. The teacher emphasised the main points of the previous lessons. In this way the teacher cleared up any misconceptions that the learners had from those lessons.

During the lesson the teacher provided the learners with the formula to use when calculating moles of gases. When it came to the stoichiometric reactions, the teacher emphasised the importance of writing correct formulas and balancing chemical equations.

Do you see where these… the importance of writing the correct chemical formulas come in. So like in this case you are just like given two chemical substances reacting together you must now be able to write the correct chemical formulas of these. So as most of you indicated correctly that hydrochloric acid the formula is HCl so I hope you remember the relationship between the periodical table and the structure of an atom. In which group is hydrogen?

Again before we go on with the calculations you need to understand the importance of writing correct chemical formulas for the mole concepts. Because if our formulas are not correctly written, when we are going to carry on with the calculations we will not get the correct answers. So, let see, are all those formals of the compounds correct? Let us start with calcium chloride. In which group is calcium?

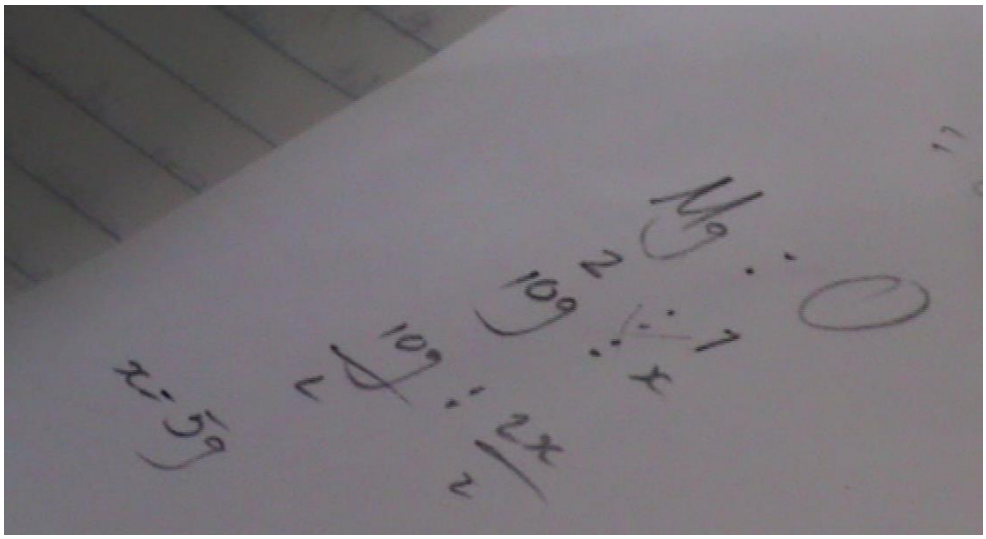
The teacher also introduced the concept of mole ratio and explained how to use the balanced chemical equation to determine the mole ratio. Linking the concept of ratio to ratio and direct proportion in mathematics helped the learners to understand the concept better. The lesson concluded with examples of problem solving.

Lesson 4

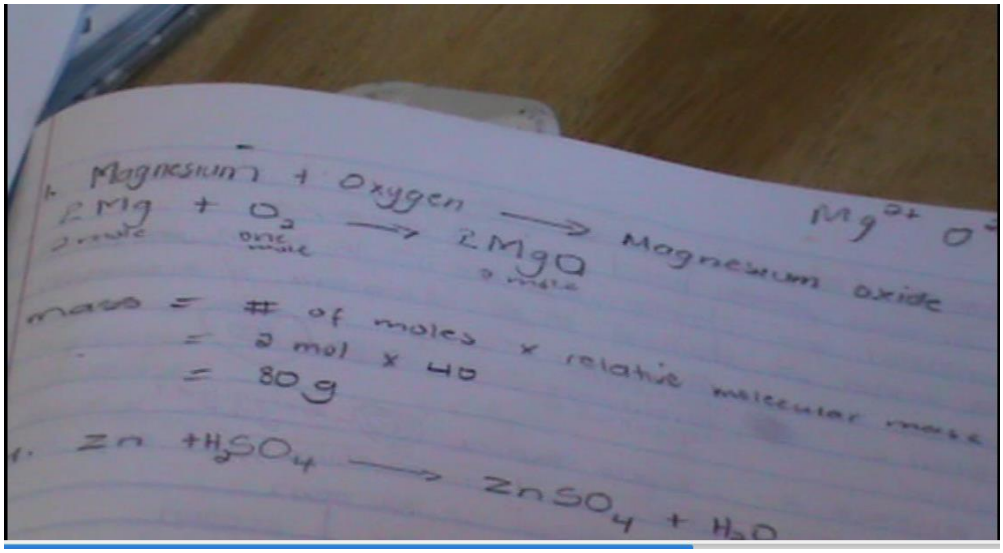
During this lesson the learners were provided with worksheets with questions which they had to solve in groups. The questions covered what had been discussed in the previous three lessons but focused more on the stoichiometric reactions.

Before the learners started with the group activity, the teacher highlighted some of the points from the previous lessons which she thought were useful when solving the questions in the worksheet. Giving the learners worksheets helped the teacher to assess if any learning had taken place and allowed her to determine what content the learners still did not grasp.

The first question and the only question out of four which the learners managed to attempt was: *10 g of magnesium is burned. What mass of magnesium oxide is formed?* In answering this question, the teacher observed that some learners still had problems writing the chemical formulas and using the mole ratio from the balanced equation. It was also clear from the observation that the learners knew which formula for calculating moles should be used, however, they failed to substitute the right information. The figures below show some of the learners' workings.



In the figure above, the learners failed to first determine the number of moles of magnesium used in the reaction.



The figure above shows that the learners managed to come up with a correct balanced equation for the reaction, however, they could not use the information given in the question (10g) instead they used the coefficient of magnesium oxide from the equation as the number of moles produced in the reaction.

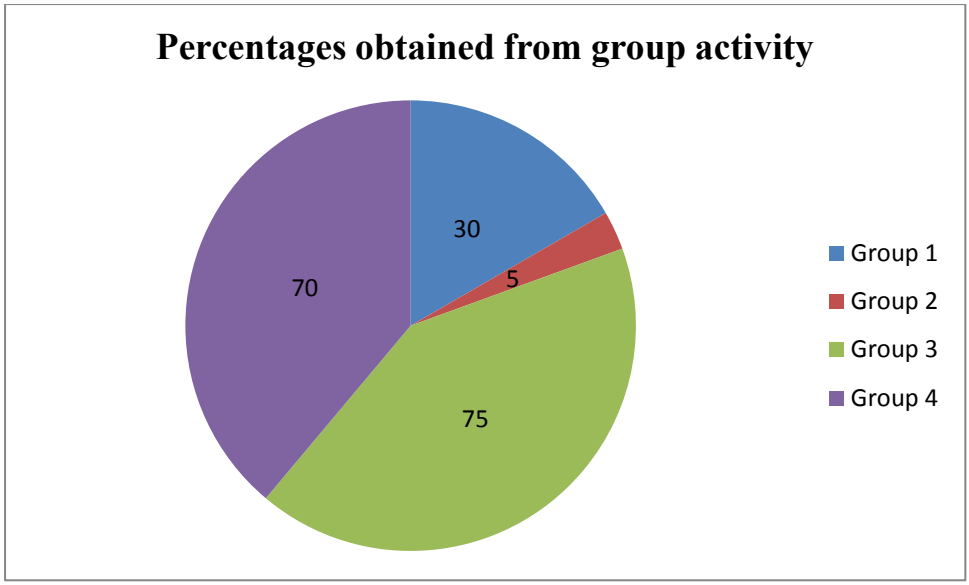
The last 14 minutes of the lesson were spent discussing the first question. The teacher outlined the common mistakes the learners made when solving the problem. She explained to the learners how they should go about solving similar problems.

Lesson 5

The main objective of this lesson was to give feedback and discuss the homework, this was done in groups. The performance for the activity differed from one group to the other; some did very well and others did poorly. The table below shows the result of the group activity.

Table 4: Results for group activity at School 1

Group	Mark obtained/20	%
1	6	30
2	1	5
3	15	75
4	14	70



The teacher indicated that the challenge was with the writing and balancing of the chemical equations because for the questions where a balanced equation was provided most of the learners did very well. "*You don't have much challenge. You don't have a challenge of writing a…. writing the chemical formulas, you don't have the challenge of balancing the equation. You got the equation, the reactants and the products already balanced. So you have to do, you just have to … to use the information that you have in order to answer*", the teacher indicated to the learners on the first question. The teacher thus emphasised the balancing of a chemical equation, which is the biggest challenge for the learners when it comes to solving stoichiometric problems.

It then emerged that some learners experienced problems balancing equation because of the misconception they have that the number of moles for the reactants should be equal to the number of moles of the products as it is with the masses.

L: *Ms, does that means that the number of mole they don't need to be balanced?*

T: *The number of mole…*

L: *They don't need to be balanced?*

The teacher went back explaining the law of conservation of mass and this time she used a reaction which was well known by most of the learners; the production of glucose from carbon dioxide and water. After the explanation the teacher went on to explain how to go about solving other questions. This was done through discussion whereby the teacher asked learners to explain the steps to follow.

Synthesis of the best practices and missed opportunities from lessons 1-5

The teacher introduced the concept by linking it to everyday knowledge and making use of analogies. Various examples were given and this helped the learners to apply the knowledge they had acquired during the lesson.

Even though group work was used in lesson four where the learners got a chance to interact with one another, the rest of the lessons were more in the style of a lecture and thus lacked teacher-learners interactions. Furthermore, the questions asked during the lessons were of lower cognitive demand and learners answered them in a chorus.

4.6.2. Teacher 2

For Teacher 2, three lessons were observed. The following outlines describe the lessons observed.

Lesson 1

Teacher 2 started off by stating the lesson objective; which is the introduction of the mole concept and mole calculations. He introduced the concept of mole using the concept of a pair and a dozen. During the interview he indicated that he used the concept of the dozen as this is what the learners are familiar with as they use it in everyday life. He later linked that to moles. He referred to the mole as *'an amount of substance'*. Before he went to the moles, he introduced the Avogadro's constant and discussed how to calculate the number of particles or molecules in an element or molecule. The teacher always used real examples to help the learners to understand the concepts being discussed.

To calculate the number of molecules and atoms in a molecule or element respectively, the teacher used the idea of proportionality. The extract below shows how the teacher explained how to determine the number of atoms in 12 grams of magnesium.

T: *How many atoms. Ooh! I just say atom. How many? This is quite simple ne. Yes, the simplicity is that, you know already that 12grams of magnesium contains how many atoms*

LL: *six point…*

T: *6.022×10^{23} atoms. Then 12grams that are given of magnesium contains x,*

L: *Uhmm*

T: *you simple cross multiply.*

L: *Yes*

T: *Then x is going to be is equal to (writing on the chalkboard) 12g of magnesium times 6.022×10^{23} atoms divided by 24grams of magnesium, than what are you getting here? x is going to be equals to*

After the introduction of each concept, the teacher gave the learners a class activity to assess their understanding and feedback was given on the chalkboard after the time allocated to do the activity elapsed. For the activities given, only a few of the learners' workbooks were marked. During a stimulated recall interview as to why he only marked a few learners, he indicated that *"it encourages them to work faster and in addition there is not much of the time to wait and mark all the books, otherwise I will not do anything during the lesson, only marking.*" It however it is reflected from the observation that the learners were not happy with the teachers' decision to mark only few books. The following extract shows how the learners reacted:

T: *Opuwo, (it is over)*

LLL: *(those not marked complaining) Aaye.. you are not fair*

T: *You are not fair also. Eee; you are saying I'm not fair, Wilbart, what is your problem? Some people are attention seeker. They seek attention very good.*

L: *(girls laughing)*

T: *Okay! Okay!*

LLL: *(Calling again the teacher) sir, sir… here*

T: *..., I even extended for more than five.*

Concerning the mole calculations, the teacher provided the learners with different equations and formulas which are used to calculate the number of moles on the chalkboard. However, the teacher did not explain how they came about; instead the learners were simply expected to use them as they were given by the teacher. In his own words he said: "*I'm just giving you the equations … These are the three equations you will use… these are the three equations you will use in moles.*"

It was also observed that the teacher-learners interaction during this lesson was only present when the teacher referred to something learners used in their everyday situations. For example, at the beginning of the lesson when the teacher used the concepts of a pair and a dozen I observed some interactions. Similarly, teacher-learner interaction was observed when

the teacher provided feedback to the class activities through his questioning, however, the answers were given in a chorus.

Lessons 2 & 3

These lessons were a continuation of the previous lesson (lesson 1). The teacher started by writing the question on the chalkboard on calculating the number of moles in a substance, in gasses and in solutions. The learners then spent about 25 minutes answering the questions given as a class activity. Although the activity was meant to be done individually, most of the learners discussed the problem in pairs or groups of three and four. During these discussions, learners used both English and Oshiwambo.

During this lesson, the teacher interacted with individual learners as he was moving around the class doing the marking. Furthermore, the teacher also used that opportunity to explain to individual learners who experienced difficulties in solving the questions although the teachers dominated the conversations in most cases.

T: *Where did you get this one from?*
L: *From then question*
T: *No! it is mass we are looking for, the mass of copper sulphate. Then you see is equal too number of mole times Mr.*
L: *Okay*

The teacher's explanation to the learners as he moved around from one learner to the other was as follows:

T: *Mass is equal to number of mole times Mr, number of mole you are given in …… Mr of copper sulphate …… here you are shown one* dm^3 *it is a thousand* cm^3 *now is what?*
L: *cross multiply*
T: *yes, you cross multiply*
T: *(Shifting to the next learner) VL if things are out, what is this? You are calculating Mr or mass? Mr is not you are using this. Mole okay is fine, you don't abbreviate mole. Let us not abbreviate moles. Here, you did not asked for one solve you get it one time it's okay.*

After most of the learners' notebooks were checked the teacher gave the answers on the chalkboard before going on to stoichiometric reactions which was done in a more teacher-centred way. This according to the teacher is because stoichiometric reaction is very challenging to the learners thus the only way they can understand it is when he gives deep and detailed explanations.

Synthesis of the best practices and missed opportunities from Teacher 2's lessons

During the lessons the teacher related the concepts to be learned to learners' everyday lives and experience by using different analogies. The use of analogies in this case helped the learners gain interest in the topic as well as increasing their understanding.

In addition, the teacher made use of the chalkboard and this boosted the learners' understanding as they followed the steps in solving stoichiometric problems. By using a chalkboard, it also made it easy for the learners to take notes which they could refer to at a later stage.

However, during the lessons the teacher used the term '*relative atomic mass, A_r'* and *'relative molecular mass, M_r'* interchangeably whereas A_r can only be used for atoms while M_r for the molecules and compounds. Furthermore, the teacher encouraged the learners to round off their answers for stoichiometric calculations. This is discouraged by the examiners as it does not give the exact correct number of substance either produced or related. This actually arose because the teacher did not prepare the activity questions beforehand in order to determine whether the answers would be exact or not.

4.7. Concluding remarks

In this chapter, I presented and analysed data generated from document analysis, interviews as well as lesson observations. The documents analysed were: the curriculum documents, learners' works, textbooks as well as Examiner's reports. These documents revealed that, the topic stoichiometry is well articulated especially in the syllabus and textbooks. The Examiner's reports have shown that the topic is not well presented to the learners thus learners experience a number of difficulties when presented with questions on stoichiometry.

The data generated through lesson observations and interviews revealed that the participating teachers have ample knowledge on stoichiometry. It was however noted from the pre-interviews that the teachers have an idea of how to present the topic using different teaching strategies but this works mostly in theory as the lesson observation shows only one teaching strategy was used which is the teacher-centred method as opposed to practical activities and others being mentioned during the interviews.

In the next chapter, I interpret and discuss the findings presented in this chapter.

CHAPTER 5

INTERPRETATION AND DISCUSSION OF FINDINGS

5.1. Introduction

In this chapter, I interpret and discuss the research findings as presented in the preceding chapter on how teachers mediate the learning of the topic stoichiometry in Physical Science. The interpretation and discussion is based on the data obtained in Chapter 4. In the discussion, I draw on the literature explored in Chapter 2 as well as my viewpoints in order to structure the interpretation of the data.

From the data gathered using different strategies as outlined in Chapter 3, a number of themes emerged which I discuss with a view to answering the research sub-questions presented in Chapters 1 and 3. These sub-questions are:

1. What are grade 11 Physical Science teachers' views and experiences of the learners' problems in stoichiometry?
2. How do the grade 11 Physical Science teachers scaffold learners to help them make sense of the concepts associated with stoichiometric reactions?
3. In what ways do grade 11 Physical Science teachers deal with the challenges faced by learners in making sense of the concepts in stoichiometry?

From the themes that emerged from the data, four analytical statements were developed. Table 5.1 outlines the analytical that were drafted.

Table 5: Analytical statements responding to research questions

Theme	Analytical statement	Data source	Research question addressed
Learners' prior knowledge and experiences	1. Integrating learners' prior knowledge in teaching enhance learners' understanding	Interviews and observations	2
Mediational tools in teaching and learning	2. Tools for mediation are essential in sense making of the stoichiometric concepts.	Interviews, observation and document analysis	1 and 2

Teaching strategies used to mediate stoichiometry topic	3. Effective teaching strategies enables learning of stoichiometry	Interviews and observations	2 and 3
Challenges faced in mediating stoichiometry	4. Teachers' PCK is crucial in election of an effective teaching strategy and identifying and overcoming of challenges when mediating stoichiometry	Interviews observations and document analysis	1 and 3

In the following sections the analytical statements presented in Table 5.1 above are discussed.

5.2. Analytical Statement 1:

Integrating learners' prior knowledge in teaching for enhancing learners' understanding

Learners' prior knowledge is central to the learning of new concepts as it affects the way learners perceive new information. Ignoring learners' prior knowledge can lead to learners missing what they are supposed to learn (Roschelle, 1995). Thus, teachers need to understand what prior knowledge their learners have in order to create a learning experience that will allow them to accommodate new learning experiences (Meyer, 2004).

Both teachers participating in this study acknowledged the importance of prior knowledge in teaching stoichiometry as pointed out by several authors like Stears et al. (2003); Roschelle (1995); Svinicki (1994); Kibirige and Van Rooyen (2006) and others. During the interview with the two participating teachers, they both indicated that without the required pre-knowledge for stoichiometry it is difficult for the learners to construct new knowledge on the topic. The teachers are essentially in agreement with Roschelle (1995) who asserts that prior knowledge is the point of departure when it comes to new knowledge acquisition.

Prior knowledge can be used to test the readiness of the learners. During the pre-interviews, both teachers were asked to point out the prior knowledge that learners were required to have in order to manage the topic and they both identified writing chemical formulas; writing and balancing chemical equations as well determining relative atomic and molecular masses. A pre-activity was given to assess what the learners already know and which area would need extra attention. If one did not establish at the beginning what learners already knew then learners would find it difficult to understand stoichiometry.

Based on Fisher's (2004) argument that learners do not come to school as empty vessels just waiting to be filled with information, prior knowledge should be used as a starting point for explaining new concepts. And this is what emerged from the lesson observations for Teacher 1. In her first lesson, for instance, Teacher 1 started by referring to what was covered in previous lessons by saying *"last time we talked about relative atomic, relative molecular mass and relative formula mass….. how do we get the relative formula mass again?*".

The incorporation of prior knowledge in the lesson did not only take place during the introduction phase but throughout the lesson as the teacher kept referring to what learners had learned from previous lessons or what learners already knew, for example, the teacher always gave equations which were familiar to the learners. In his lesson five, for instance, Teacher 1 said *"let's just give an example of photosynthesis, the photosynthesis equation that you are familiar with*". Integrating learners' prior knowledge throughout the lesson is what is advocated by Stears et al. (2003). In contrast, Teacher 2 only referred to learners' everyday knowledge at the beginning of the lesson. This in my opinions also limits learners' engagement with the lesson.

According to Stears et al. (2003) learners become actively involved in the lesson if the subject content is linked to their everyday knowledge. However, from my observation learners' engagement was still limited regardless of the teachers' incorporation of their prior knowledge. As a result, there was a lack of dialogue during the lessons. Although the involvement of the learners was minimal, however, the use of prior knowledge acted as a motivational factor for the learners as no learner was seen to be distracted in the lessons during the observations of both teachers. This correlates with Rennie's (2011) opinion that integrating everyday knowledge in science motivates the learners. In Oloruntegbe and Ikpe's (2011) views, learners become frustrated when studying a certain topic if their prior knowledge is not addressed.

Svinicki (1994) proposed that prior knowledge incorporated in the lesson should not only be content knowledge but any other knowledge possessed by the learners can also be of importance in the acquiring of new information; this can be cultural knowledge or personal knowledge. This is also what is emphasised in constructivist theory (see Section 2.4.2) which informed this study. In this regard, the two teachers made use of analogies during their teachings. Glynn (2008) urged that using analogies in teaching can act as a motivation for learning science. However, learners' responses to some questions showed that in some cases

they linked everything to content knowledge they learned in the class. For example, when the teacher tried to link the moles to the dozen one learner responded as follows: *inspiration*

T1: *Okay…. So, we are going to move on now with the new concept, but before I introduce the new concept I want to find out from you. Have you ever heard about a word a DOZEN? You heard about it?*

LLL: *Yes*

T1: *So what is the meaning of that?*

L: *When two atoms molecules combine.*

T1: *When two atoms molecules combine?*

That is interesting, okay.

I think he is confusing it with diatomic molecule.

The data revealed that prior knowledge plays a critical role in the mediation of learning. However, for this to be real, teachers must be skilled in how to integrate this knowledge into their lessons.

5.3. Analytical Statement 2:

Tools for mediation are essential in sense making of stoichiometry concepts

As discussed in Chapter 2, different tools can be used during the mediation process. Evidence arose from this study that teachers use different mediational tools during teaching in order to make the topic stoichiometry more relevant and understandable to their learners. One of these tools, the elicitation of learners' prior knowledge has been discussed in the previous section (Section 5.2). In this section other mediational tools are discussed as they emerged during the data gathering process. These are: language, analogies and practical activities.

5.3.1. Language

Language is the central tool which can be used during the mediation process. According to Vygotsky (1978), cognitive skills are developed through the use of language. Hodson and Hodson (1998) stressed the importance of language in relation to social interaction which is the backbone of mediation and the foundation of social constructivism. During the lessons that I observed for Teacher 1 and Teacher 2, they used different languages to help the

learners in making sense of the topic; this included everyday language as well as scientific language.

The teachers used the language to define the terms used in stoichiometry like mole, molar mass, concentration and molar volume. Teacher 1 defined almost all the terms used in contrast to Teacher 2 who only defined a few terms namely mole and molar mass. They both defined the mole as *the amount of substance*. This is in accordance with Laplante's (1997) recommendation that new terms used in science must be taught in order to promote effective communication. To some extent Teacher 2 falls within the teachers described by Laplante as those having a belief that there is no need to define new vocabulary as learners will figure it out themselves from the context in which they are being used.

In addition, the teachers used everyday language as well as chemical language. Chemical language included: symbols for elements, writing formulas, writing chemical equations (Glazar & Devetak, 2002). Several authors highlighted that most of the problems experienced by the learners in stoichiometry arose from poor chemical language (Glazar & Devetak, 2002; Marais & Jordaan, 2000; Danili & Reid, 2004). The Examiner's reports confirm the findings of these authors as in the Examiner's reports teachers are urged to pay attention to the chemical language. One of the problems raised in the report is, for example, the use of capital letters and lower case letters. For instance, during the exams learners may write the formula for carbon monoxide as Co (which is a symbol for cobalt) instead of CO.

Learners' work however showed contradicting results as most of the learners did not seem to have problems with writing formulas and symbols, although a few did experience problems interpreting symbols and formulas with subscripts and coefficients. When learners were asked to do stoichiometric calculation based on the equation $2ZnO + C \rightarrow Zn + CO_2$, some learners failed to recognise that 2ZnO means 2 moles of ZnO and calculated the molar mass of zinc oxide as 162 which is in fact the mass of two moles instead of one. Apart from these mistakes, from the lessons I observed of the two teachers it emerged that they took the time to explain to the learners the importance of formulas and how to interpret the chemical equations in terms of moles.

Teacher 2 in his teaching interpreted the equation:

$2Na + H_2SO_4 \rightarrow Na_2SO_4 + H_2$ as follows

T: *In terms of mole, the equation tells me that, two moles of sodium reacted with one mole of the acid producing one mole of sodium sulphate and one mole of a hydrogen gas. I'm now telling what the equation is telling me about mole.*

The teachers made sure that the stoichiometric language was clear to the learners as stressed by Huddle and Pillay (1996).

As indicated earlier, language plays a role during classroom interaction between teachers and learners and also between learners themselves. Lemke (1990) and Laplante (1997) express that language makes the scientific dialogue more productive. Unfortunately, in this study this did not appear to be happening as there was limited teacher-learners interaction in the classes. Instead, the lessons were more dominated by the teachers meaning there was no balance between the teacher-talk and learner-talk in the classroom for the two participating teachers. The only instance when learners were given an opportunity to talk occurred when responding to the short questions asked and this was done in chorus.

5.3.2. Use of analogies

Analogies are used to introduce non-observable entities when teaching science (Harrison & Treagust, 1996). Haglund and Jeppsson (2012) share the same sentiment adding that analogies can be used to compare unfamiliar entities to more concrete and familiar entities which make the learning process and science concepts like stoichiometry more meaningful.

Textbooks and teachers both use analogies to explain certain concepts. The data gathered in this study however shows little evidence of the use of analogies of stoichiometry in the textbooks. Out of the three textbooks that were analysed, only one used the analogy of a *dozen* to explain the concept of mole as referring to the amount of substances.

Teachers also used the analogies of amount of familiar substances like *fruits* and *shoes* to introduce the concepts of mole. Another analogy used by Teacher 1 was the preparation of *'Ontaku'* (the Oshiwambo domestic drink) which she used to compare with the preparation of a solution linking it to a concentration. Although the teachers did not use many analogies in their teaching, the few that they used they explained in detail and explained to the learners why using those analogies were useful to understand the target concepts. In other words, the teachers used what Harrisson and Treagust (2006) refer to as 'enriched analogies'. This helps

to promote *elaboration* (Glynn, 2008) which is very crucial when it comes to the constructivist framework which underpins this study.

5.3.3. Practical activities

The importance of practical activities in the mediation of science is discussed in Chapter 2 (Section 2.4.1.3). Practical activities minimize rote learning and as a result help learners to develop conceptual understanding of the abstract topic (Millar, 2004; Maselwa & Ngcoza, 2003).

During the interview the two teachers in this study acknowledged the importance of practical activities and are in agreement with authors like Millar (2004) that having the learners involved in doing practical work and handling real material increased learners' understanding. With Teacher 2 saying that supplementing the theory with practical work would also promote learners' engagement in the lesson and this way they would understand better. Moreover, active participation is one of the critical issues when it comes to constructivism as it helps learners to construct knowledge. In addition, the Physical Science syllabus advises teachers to make use of practical activities to boost learners' understanding as one of the learning objectives of the subject is to acquire practical skills and this can only be achieved if learners are involved in hands on work.

Despite the above mentioned learning objective for Physical Science and teachers' recognition of the importance of practical activities in the mediation of learning, none of the participating teacher used practical activities during their teaching of stoichiometry. During the stimulated recall interview, Teacher 1 indicated that *"stoichiometry is very much linked to other topics like acid, base and preparation of salt and also extraction of metal, therefore practical related to stoichiometry can still be done when teaching those topics. For example when I teach titration I can still bring in stoichiometry ...."*. This means that the Stoichiometry topic should not be taught in isolation but needs to be integrated with other topics in the syllabus as this would help to make it more relevant.

Teacher 2 attributes the lack of practical activity to time constraints, supporting Adesoji and Arowosegbe's (2007) views that teachers tend to rush through the topics in the chemistry syllabus without carrying out practical activities because the allocated teaching time is not sufficient. As a result, learners perceive topics as difficult and lose interest in them. Figueira, Coch and Zeplca (1988) also revealed that learners lose interest in stoichiometry because they

are not presented with real problems as the importance of practical during the teaching is not made visible to them.

Data obtained from document analysis further shows that the syllabus does not suggest any practical activity under the stoichiometry topic unlike with other topics in the syllabus. In my opinion this could be a contributing factor to why teachers do not incorporate practical activities when teaching this topic, as pointed out by Olurontegbe and Ikepe (2011) that many teachers are driven by the syllabuses which they have to complete for examination purposes. So, adding something which is not in the syllabus will take up valuable time.

5.4. Analytical Statement 3:

Effective teaching strategies and use of LTSM enables learning of stoichiometry

According to Sedumedi (2014, p. 1346), "Teaching in general and science teaching in particular is a complex process with unpredictable outcomes". Thus, teachers opt for different teaching methods in order to deal with this challenge (ibid). For positive teaching outcomes one has to opt for the best teaching method for an effective mediation process. In the following sections I discuss the different teaching strategies and learning and teaching support materials (LTSMs) that were used to scaffold stoichiometry.

5.4.1. Lecturing and questioning

The lessons for the two participating teachers in this study were dominated by the lecturing method which falls under a teacher-centred teaching strategy. During the lessons the teachers provided most of the information to the learners as opposed to the learner-centred approach which is underpinned by the constructivism theory of learning. During the lecturing, the learners were observed listening and copying whatever the teacher wrote on the chalkboard, and no active participation in the learning process was observed. Hence, the lecturing method did not promote conceptual understanding of stoichiometry; instead it only promoted memorisation of facts and rote learning. According to Schuh (2004), lecturing does not give learners an opportunity to fully grasp the information provided to them by the teacher. Thus, they cannot construct their own knowledge.

Although the curriculum documents advocate the use of a learner-centred approach to teaching and learning, the teachers in this study defended their use of teacher-centeredness

during the stimulated-recall interviews arguing that the topic is too abstract and most of the concepts used in the topic are new to the learners. This however contradicts what the teachers said during the pre-interviews that the stoichiometry topic is not completely new as some of its aspects have already been covered in previous grades like writing formulas and balancing equations. Hence, the teachers' use of the lecturing method could mean that they did not take the learners' prior knowledge into account.

In addition to lecturing which I feel is a less effective method to mediate learning, the teachers also used the questioning strategy to scaffold the learners. According to Chin (2007), questioning is the key component classroom talk and can contribute to effective mediation of learners' knowledge construction as it can arouse their thinking.

The teachers in this study used both written and oral questions. The oral questions were however more closed questions and these were in most cases answered in chorus so these types of questions could not develop learners' cognitive skills. Furthermore, most of the questions were simply meant to assess what the learners' knew.

By determining what the learners know, the teacher can determine where they are within the Zone of Proximal Development (ZPD). The ZPD is the distance between what a learner can do with and without help from the teacher (Vygotsky, 1978). When the level of ZPD is determined the teachers can then properly scaffold the learners. According to Goos (2004), the ZPD can be set up through scaffolding and collaboration.

The written questions were answered by the whole class and some were done as individual work. The teachers first guided the learners on how to solve the problems and thereafter let them work on their own after determining that they had reached a point where they could proceed on their own.

5.4.2. Collaboration and group work

The lessons for the participating teachers were supplemented with collaboration and group work. Davis (1999) asserts that working in groups helps the learners to master the content and promotes critical thinking. During group work learners are actively involved in the lesson and can learn from one another as they interact in the groups. Letting learners work in groups as Teacher 1 did in Lesson 4 was a good method to encourage the learners to interact with one another. Learners who could not understand the content during the teacher's instructional teaching were able to ask others and be helped by others in the groups.

Although Teacher 2 did use formal groups in his teaching, learners discussed with one another when given activities to do. Learner-learner interaction shapes a collaborative ZPD.

In addition, during group work and individual activities the teachers moved around from one group to the other to assess the group's progress and performance. I found that helping learners in small groups like this more effective than working together in one large group.

The use of collaboration and group work is in line with the learner-centred approach to teaching in which learners are the centre of the learning process. A learner-centred approach is central to a constructivism classroom in which learners interact with one another. Additionally, Moll (2002) posits that meaning can be constructed through collaboration

5.4.3. Use of a chalkboard

The two teachers made use of chalkboards as a one of the LTSMs during their teaching. The chalkboard was used for different purposes including: writing notes, writing new concepts, solving problems and giving feedback on the given activities. All this made the chalkboard a great tool for teaching as it can be used as a visual teaching aid. Learners had the chance to see or visualize what the teacher was saying.

Probyn (2005) supports the use of the chalkboard in teaching as in promotes language development of the learners. The teachers in this study constantly wrote the new concepts and their meanings on the chalkboard which is a good move especially when working with the learners whose first language is different from the language of teaching and learning as was the case with the two teachers. These teachers also wrote the equations used in calculating different quantities on the chalkboard which is good if they are well explained. For instance, Teacher 1 explained how using proportionality formulas came about and this gave the learners a deep understanding of the concepts unlike Teacher 2 who just wrote the formulas on the chalkboard without any explanation. Using Teacher 2's approach promotes rote learning which is in conflict with the constructivist theory.

Furthermore, the chalkboard was also used as an interactive resource (Probyn, 2005) where for example, Teacher 1 gave the learners an opportunity to solve problems on the chalkboard. During this time the learners also acted as peer teachers as they were given the chance to explain to the whole class. This approach not only motivated the learners but also helped the teachers to assess the learners' understanding.

Furthermore, in giving the learners an opportunity to act as peer-teachers, the teachers promoted collaboration, an aspect that Vygotsky regards as vital in the ZPD theory. Goos (2004) posits that peer interaction gives learners an opportunity to evaluate their understanding. Goos adds that during collaboration teachers' effort is still crucial. In other words, the teachers still need to facilitate the collaboration process and give support to the learners. As the learners were explaining the teacher kept prompting the learners with questions so they could elaborate further.

5.5. Analytical Statement 4:

Teachers' PCK is crucial in the selection of an effective teaching strategy and identification and for overcoming challenges when mediating stoichiometry

For the effective teaching of stoichiometry the teacher should possess Pedagogical Content Knowledge (PCK) as proposed by Shulman (1986). PCK is the ability of the teacher to transform the subject knowledge into the knowledge that is more accessible to the learners. When teaching a certain topic, for example, stoichiometry in the context of this study, the teacher should first understand the content so that he/she can present it to the learners. PCK involves among other things (a) the understanding of learners' learning difficulties; (b) identification of the misconception that learners have about the topic and (c) the knowledge of specific teaching strategies that can be used to address learners' learning difficulties (van Driel, Verloop & de Vos, 1998).

5.5.1. PCK and teaching strategies

As indicated in the preceding section (Section 5.4), the teachers in this study used different teaching strategies during their teaching. The teaching or instructional strategy being used in transforming the content knowledge is determined by the PCK of the teachers (Carpenter, Fennema, Peterson & Carey, 1988). Hence, the more knowledgeable and effective the teaching strategy, the higher the PCK of the teacher.

The more dominant strategy employed was the lecturing method that falls under the teacher-centred approach. Van Driel et al. (1998) indicated that experienced teachers can make a better choice when it comes to selecting appropriate teaching strategies to teach a certain topic as they have developed a conceptual background about the topic. As alluded to in Chapter 4 under the teachers' profiles, both teachers are experienced teachers and have been teaching for more than seven years. This means that they are both familiar with the

stoichiometry topic. However, their years of experience were not reflected in their choice of the main teaching strategies used. Van Driel at al. (1998) indicated that teachers tend to use a teacher-centred approach which is associated with more teacher-talk than learner-talk (Lemke, 1990) when they are inexperienced and unfamiliar with the topic.

5.5.2. Challenges experienced when teaching stoichiometry

The findings of this study revealed that teachers experience several challenges when teaching the topic stoichiometry as indicated in Chapter 4. Most of the obstacles are similar to those revealed by other researchers like Gauchon and Méheut (2007); Furió et al. (2002); Upahi and Olorundare (2012) just to mention a few.

Using their experience in teaching stoichiometry the teachers were able to identify the difficulties experienced by the learners over the years. In this case I would say the teachers used their PCK to understand learners' difficulties and misconceptions which is in accordance with Shulman's (1986) notion of PCK.

One of the challenges indicated by Teacher 1, for instance, is that the topic is very abstract and this makes it difficult for the learners to understand. This is in agreement with Furió et al. (2002) who indicated that the abstract nature of stoichiometry and mole concepts causes many problems when teaching the topic.

Another challenge identified by the teachers is the lack of prior knowledge which is required to learn the topic. These include writing formulas and writing and balancing chemical equations. In addition, stoichiometry requires mathematics skills like ratio and proportion in addition to general calculations. The findings from the lesson observations and analysis of learners' workbooks did not confirm that the learners much difficulty in writing formulas and equations. However, balancing equations and determining the mole ratio from the equation seemed to be the problem most of the learners encountered. These findings resonate with a previous study conducted by Upahi and Olorundare (2012) in Nigeria that found that students find it difficult to solve problems that involve chemical equations due to their inability to balance the equations. Instead of using information from the equations they simply use the direct formula to calculate a required quantity be it mole, mass or volume. Schmidt (1997) in his study found that university students experience the same obstacles in applying ratio when doing stoichiometry calculation.

During the interviews, both teachers indicated that the main challenge to the teaching of the topic stoichiometry or moles is the negative attitude and perception the learners have about the topic. They perceive the topic as difficult even before it is formally introduced to them. Unfortunately, I could not find any previous study done on learners' attitudes to and perceptions of stoichiometry and this could potentially be an area for future research.

5.5.3. Dealing with challenges experienced in teaching stoichiometry

The teachers used different ways to deal with the challenges as discussed in the section above. Firstly, the teachers tried to gain learners' interest in the topic by eliciting their prior knowledge and showing them that the topic was not a completely new topic to them. Teacher 1, for example, started off the topic by indicating how the topic is linked to other topics which had already been covered like relative atomic mass and molecular mass. The importance of prior knowledge in introducing stoichiometry is supported by Okanlawon (2010) saying that it can enhance learners' achievement. Hailikari, Katajavuori and Lindblom-Ylanne (2008) shared the same sentiment adding that prior knowledge can improve learners' ability to apply higher-order cognitive problem-solving skills like the one required in stoichiometry.

The use of analogies helps in dealing with the challenge of abstractness and non-relevance of the topic to the real world. The teachers however only made use of analogies during the introduction to the topic although they could have made use of different analogies throughout their teaching of stoichiometry. In this case, one could say that the teachers failed to recognise the value of analogies in teaching stoichiometry. Glynn (2008) posits that analogies are effective in teaching complex topics that are hard to visualize, like stoichiometry as they increase learners' interest in the topic.

"Most of the challenges can be dealt with simply by proper preparation of the lesson" that is what Teacher 2 said during the pre-interview. Proper preparation of the lessons makes the teaching more effective. Although the teachers indicated that proper planning can help neither of them used lesson plans during the observation. However, Teacher 1 had pre-prepared activities for the learners as evidence that she did some sort of preparations, contrary to Teacher 2 who thought of questions as he wrote on the chalkboard.

5.6. Concluding remarks

In this chapter, I discussed and provided an interpretation of the data gathered and presented in Chapter 4. This was done according to the four analytical statements which were developed in order to answer the research questions. The findings from previous studies or researches that support and/or contradict the findings of this study were used as a reference point.

The findings demonstrate that teachers find mediating stoichiometry problematic, one of the main obstacles being the learners' negative perception of the topic and their inadequate pre-knowledge required to learn the topic. However, because of their long teaching experience the teachers did their best to cope with these challenges.

The teachers used different mediational tools to scaffold learners in making sense of stoichiometry. The use of prior knowledge, language, questions and lecturing were the tools used extensively. The use of LCE which is in line with the constructivist learning theory and the use of practical work as well as analogies were used minimally.

In the next chapter I provide a summary of the findings and make recommendations arising from the data. I also make suggestions for areas for future research as well as submit a critical reflection on my research journey before the final conclusion.

CHAPTER 6

SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1. Introduction

The main aim of this study was to investigate how grade 11 Physical Science teachers mediate the learning of stoichiometry. The study was motivated by the fact that as a Physical Science teacher I experienced problems with the learners' attitude towards the topic. In addition, learners' performance in this topic is poor; a finding supported by the marks in the final examinations and the Examiners reports.

In this chapter I sketch a summary of the research findings. Some recommendations and suggestions for future research will also be provided. I present the limitations of this study before making a brief reflection on my research journey. The conclusion of the research follows.

6.2. Summary of the findings

The study reported on how two selected Physical Science teachers mediate the learning of the topic stoichiometry in the Namibian context, one of the perceived difficult topics in the NSSC Physical Science syllabus. The study was motivated by my personal experience as a Physical Science teacher as I wanted to gain insight into how other experienced teachers help learners in making sense of this abstract topic. The findings of this study reveal the teaching strategies used to mediate learning as well as the challenges faced by the teachers during the scaffolding process and how they deal with these challenges.

The study was a qualitative case study, framed under the mediation of learning together with PCK and constructivism as the theoretical frameworks. Document analysis, lesson observations and interviews were used to generate data.

It emerged in this study that the teachers use different mediating tools to help learners in making sense of the stoichiometry concepts. This includes the use of prior knowledge which the teachers have integrated well during their lessons. The elicitation of learners' prior knowledge as emphasised by Roschelle (1995) and Stears et al. (2003) helps the learners to conceptualize the concepts being taught.

In addition to prior knowledge, teachers made use of analogies, although it was only done during the introduction phases of the lessons. Harrison (2008) indicated that the use of analogies can promote learning through constructivism as they help the learners to be actively involved. In addition, the use of analogies arouses learners' interests about the topic.

The participating teachers make excessive use of the traditional lecturing method which is more of a one way communication so this could not really enhance learners' understanding of the concepts. In agreement with this are Bloom, Engelhart, Furst, Hill and Krathwohl (1956) who urge that lecturing is not effective for higher levels of learning and comprehension. This suggests that the teachers in this study failed to select an appropriate teaching strategy and this could be attributed to their limited PCK as well as a lack of lesson pre-planning.

The findings further revealed that both the learners and teachers face challenges during the teaching and learning process. The pre-requisite knowledge learners are expected to have prior to the leaning of the topic is limited. Thus, this makes it very difficult for the teachers as they first have to teach some of those concepts which learners are supposed to have learnt already. Furthermore, most of the learners struggle with the topic because of the mathematics aspects involved more especially the ratio and proportion aspects, and this could be an area for future research.

The teachers try to overcome these challenges by giving learners the opportunity to practice doing problem solving as well as providing more working examples. Likewise, the nature and quality of the problems selected could potentially be an area of future research. Practical activities could be one way to deal with the challenges faced by the teachers but the shortage of resources to carry out practical work as well as the limited time available to complete the syllabus was a hindrance according to the participating teachers, especially as there was no specific requirement for practical work in the syllabus.

In sum, the findings of the study provided me with answers to my research questions. The teachers try to use their limited PCK to mediate the learning of stoichiometry using different mediational tools. In addition, they made use of different LTSMs such as worksheets and the chalkboard in dealing with the various obstacles they face during the mediation process.

6.3. Recommendations

Considering the findings of this study, the following recommendations are made.

- The findings revealed that practical activities are neglected when teaching this topic. Therefore, there is a need for the Physical Science syllabus to be reviewed so that it can guide the teachers for its effective implementation. Likewise, the stoichiometry topic should be linked with other relevant topics in the syllabus. In addition, possible practical activities on the stoichiometry topic should be suggested as is done with most of the topics in the syllabus.
- Although the curriculum and the subject policy propose that teachers should prepare well in advance and have written lesson plans, there was no evidence of this in the lessons I observed. Thus, the teachers are encouraged to plan their lessons well in advance. The preparation should include the selection of appropriate teaching strategies they plan to use as well as the activities they intend to give to the learners either as examples or exercises.
- The regional office specifically the advisory services department should organise workshops for the teachers through which they can update their subject content knowledge. During the workshop teachers could share their expertise on the topics with one another as well as the problems they experience during the teaching of the topic plus different ways to tackle these problems.
- The literature reviewed for this study indicated that the use of analogies in teaching stoichiometry can increase learners' conceptual understandings. However, the findings of this study revealed that teachers are not really aware of the different analogies to use when mediating stoichiometry in particular. Therefore, I recommend that the teachers familiarise themselves with different analogies to incorporate in their teaching in order to stimulate learners' interest in the topic as well as increasing their conceptual understanding.
- The textbook writers should include the origin of the topics and more explanations instead of just providing calculations. Analogies and other activities like quizzes and games on stoichiometry need also to be included in the textbooks and topic modules.
- The teachers need to use the Examiners' reports when planning their lessons.

6.4. Limitations of the study

This case study involves a small sample of only two teachers from Oshikoto Region as a result this study cannot be generalised. However, insights on how teachers help learners make sense of the topic stoichiometry were gained. Moreover, due to time constraints and learners' perceptions on how the teachers help them to make sense of the stoichiometric concepts could not be established and this would have strengthened the findings.

Most of the data especially those obtained via lesson observations and analysis of learners' workbooks could only be obtained by the end of term 2. This delay might have had an effect on the data gathered as the teachers were rushing to complete the syllabus for the term.

The participants were not able to do the member checking of the transcripts for the observations and interviews due to time constraints and this might have compromised the validity of the study. However, the use of triangulation helped to validate the data, such as the added use of stimulated recall interviews.

The participants and I were not able to co-develop the unit of work on the topic (as it was originally proposed) which could be used to improve the teachers' practice in order to help learners in making sense of stoichiometry. So, only the SRI was used to answer the third research sub-question.

6.5. Areas for future researches

- A similar study could be conducted but with a larger sample to get a more generalizable picture on how teachers mediate learning of the stoichiometry topic.
- A study could be conducted with the learners to investigate the areas where they experience difficulties or challenges when it comes to stoichiometry.
- A study could be conducted on learners' perceptions of and attitudes to stoichiometry.
- Further research could be done on the learners' readiness for the topic stoichiometry.

6.6. Reflections on my research journey

My research journey started at the beginning of the MEd programme in 2013 when I had to make a decision on the research topic. However, having been introduced to different themes in the first year (which were: Prior knowledge, indigenous knowledge, practical activities or

scientific investigations; language and gender in education) this helped me in deciding on the area in which I wanted to do my research.

With the themes mentioned above and the teaching experience I have, I finally decided to look at the mediation process of a topic many learners find difficult in Physical Science; that is *stoichiometry*. After reading literature on stoichiometry, I realized that there were no studies done on this topic in Namibia and this motivated me even more to research it. Doing a study in this area helped me gain insights about teaching and learning and all other aspects associated with it. With great support from my supervisors and MEd colleagues I managed to come up with a research proposal which was then approved.

After the approval of the research proposal more challenges occurred, more than I anticipated, I thought everything would be as easy as coming up with the proposal but at times I even thought of quitting. Writing the literature review was a headache, however it was very educational. Doing a lot of reading helped me to improve my reading skills. It also helped me understand and discover different theories and concepts some of which I had never heard of before. This includes concepts like pedagogical content knowledge (PCK); mediation of learning; zone of proximal development (ZPD); scaffolding and many more.

In addition, my data gathering process started very late as the participating teachers could only teach the topic almost at the end of term two (that is, end of July) and they had to rush through as the examination was approaching. This was very stressful. Having both the participating teachers as Heads of Departments (HODs) at their respective school was also a reason why the teachers had to teach the topic late as at some point the teachers were acting principals for their schools and had to attend a lot of management meetings either at the circuit or regional level.

Nonetheless, the whole research process helped me learn many things and skills. For instance, when conducting interviews I realised that one needs to be a good listener so that he/she can ask relevant follow-up questions otherwise the data gathered via the interviews will be too vague. For instance, I realized that during the interviews my follow-up questions sometime did not really help in gathering the answers needed. However, the stimulated recall interviews (SRI) helped to fill the gaps. So, the SRI is an important tool for gathering more comprehensive data. In addition, it is also important to develop a good rapport with the research participants so that they feel at ease during the interviews as well as observations.

Data analysis and interpretation was the most challenging part of the research and I must admit that it requires a lot of skills which one has to master. Coming up with the analytical statements and finding the data which answers the research questions from the abundant data gathered was not easy and it really requires a lot more time than I anticipated.

In summary, doing the MEd course have been very educational and it has helped be to be critical and reflective practitioner. However, one needs to be very patient and committed to go through the research journey.

6.7. Conclusion

This chapter provides the summary of the research findings. The recommendations as well as the areas for possible further research were also presented as well as the research limitations. The chapter concludes with a brief reflection of my research journey.

This study provided some insights on how different mediation tools could be used in scaffolding learners to make sense of the stoichiometry concepts. The research also established that teachers still use the traditional lecturing method which is associated with more teacher-talk with the learners being passive listeners.

In addition, the study suggests the need for teachers to undergo continuous professional development for their professional growth and development. Furthermore, the teachers need to work together and share the best teaching strategies which they can use to help learners in making sense of the stoichiometry concepts.

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APPENDICES

Appendix A: Letter to the Inspectors of Education

Mwene K. Kanime
P. O. Box 847, Oshakati,
Cell: 0811247960, E-mail: mwene24@gmail.com

16 April 2014

To: The Inspector of Education
[redacted]
Oshikoto Region

Dear [redacted]

Re: Request for permission and access to do research at [redacted] Secondary School

I, Mwene K. Kanime- a part-time registered student at Rhodes University (student number: 09K6346) and a teacher at Iipundi Secondary School, am hereby requesting for permission to conduct a research study at [redacted] Secondary School as from May 2014. I am doing a Master's degree in Science Education (coursework and a half thesis). It is a two year course and I have successfully completed my first year which was a coursework and have currently registered for my second year which focuses on Research Study (Half Thesis).

My topic of study is: ***An investigation into how Grade 11 Physical Science teachers mediate learning of stoichiometry during their lessons: A case study.***

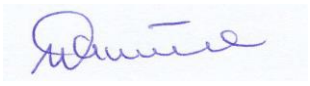
Researches have shown that stoichiometry is one of the chemistry topics in which many learners experience difficulties. Thus, this research study (which is composed of two phases) will help in understanding how teachers scaffold learners in order to enhance their understanding of the topic. In the second phase of this study, the researcher (I in particular) together with the participants will develop a module on stoichiometry which I believe will be of importance to learners as well as teachers in general.

I am therefore kindly requesting your good office to grant me permission and an access to the participants that I am seeking to interview and/or observe, and also permission to review some educational documents that may be helpful in my research study.

I would like to assure your office that, should I be granted permission, the research ethics will be applied at all time when carrying out my research. The insights generated from this study will however be published in a thesis form which will become available to future researchers to use as reference and to anyone who finds interested in it. I assure the school and the participants that everything will be handled with highest confidentiality and anonymity; and I will not use the real names of the school and participants.

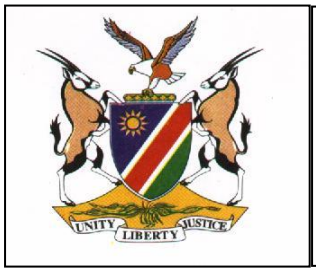
Your humble understanding in this regard will be highly appreciated and I am looking forward to hearing from you.

Yours Sincerely,



Mwene K. Kanime (Ms)
Masters' student: Rhodes University

Appendix B: Response from the Inspector of Education



REPUBLIC OF NAMIBIA

OSHIKOTO REGIONAL COUNCIL

DIRECTORATE OF EDUCATION

ONYAANYA CIRCUIT

Enquiries: Gerhard Ndafenongo
Tel: 065 248863 Fax: 065 285607 Cell: 0812313886
E-mail: ndafenongogs@gmail.com

Private Bag X2028
Ondangwa

Ref: S.8/12

14th June 2014

Addressed to: THE PRINCIPAL
[redacted]
OSHIKOTO REGION

Dear [redacted]

Re: Consent for Ms Mwene Kanime to conduct an academic research toward her Master of Education, Rhodes University

The above mentioned student is a part time Master of Education (MEd) of Rhodes University, South Africa. She has been granted permission to conduct a research on Science Education as part of her specialization. This research would be conducted with the support of our science teachers and grade 11 – 12 learners who are currently studying in the field of Natural Sciences in [redacted].

I urge that the colleague be given an opportunity to conduct her investigative study with minimal interruption, during a class or afternoon session. Ethical issues of confidentiality and anonymity should be respected and retained throughout this activity i.e. voluntary participation, consent from participants, and parents of learners involved.

Both parties should understand that this permission could be revoked without explanation at any time.

Yours Sincerely

.....

GERHARD NDAFENONGO
INSPECTOR OF EDUCATION
ONYAANYA CIRCUIT

Appendix C: Interview Schedule

1. What are your views and experiences of the topic on stoichiometry?
2. How do you introduce the topic on stoichiometry to your learners?
    a) Prior knowledge (how do you make use of learners' previous experience when teaching the topic)
    b) What prior knowledge is learners expected have before starting with stoichiometry topic?)
3. What type of learning support materials (LSMs) do you use to support the teaching and learning process of stoichiometry?
4. How do you ensure that learners are actively involved in the lesson?
5. What strategies do you use to scaffold learners so that they make sense of concept of stoichiometry?
6. How do you asses learners' understanding of stoichiometric reactions?
7. What challenges do you experience when mediating learning of stoichiometry?
    a) How do you deal with these challenges?

Appendix D: Interview transcript for Teacher 1

Interview transcript: Teacher 1

M: Alright let's start [redacted]

E: Ok

M: So how are you

E: I am doing fine. How are you Meem?

M: Fine

E: Good

M: Thank you for accepting the interview. I just want to find out some information on the teaching of stoichiometry.

E: Ok

M: of course from your good experience as a very experienced teacher.
Yeah…
To start with, how do you introduce the topic of stoichiometry to your learners?

E: Ok, thank you for the question. This topic stoichiometry normally I introduce it especially when I reach the part of mole itself. I introduce it using the concept of a dozen like referring to amount. I would before I go further with explaining to the learners what mole is and what it entails I would give them a scenario of … or ask them, have you ever heard of the word a dozen? Then they like, some would may be one or two would have heard about it then I would ask, what does it entails? What is a dozen then they would like indicate now, a dozen of things is like 12 eggs or 12 things and I will take it from there. That okay, when we talk about a dozen of anything we are always referring to 12 things, whether it is eggs or oranges, water melons or whatever different fruit, it is always referring to 12 things. But then those 12 things can then have different masses then I will give for example like, let's say we have a dozen of eggs, a dozen of oranges, a dozen of water melon, then let's say one egg have got a mass of 100 g, one orange have got a mass of 500 g, one water melon have got a mass of 1000 g, then now when you have 12 aaa… 12 eggs, if each egg is if each egg is 10 g for instance, how.., what would be the mass of 12 eggs. Then they will give the response; the mass of 12 oranges, then they will give the response, the mass of 12 water melons, they give the response. So I always want to indicate to them that, the number, the dozen refers to 12 number as a quantity of fruits or whatever but then the masses are different and then from there I relate it to the periodic table that now on the periodic table we have got different elements then different elements have different relative atomic masses, I explain but I refers to them that when we talk of a mole is just like we are talking about a dozen. That one mole of any substance always have a certain number 6.023×10^{23} particles; it can be atoms, it can be molecules, ions, whatsoever, but as long as you are talking about a mole it … you talk about that number which is called the Avogrdro's constant. Then I take it from there that so one mole of any element on the periodic table will always equal to the relative atomic mass of that element; one mole of any molecule or compound it will be equal to relative molecular mass or relative formula mass. So more or less I relate mole to a dozen then I take it from there.

M: Okay… aa apart from that, maybe when the learners to do the topic, what prior knowledge are they expected to have before the topic if there is any.

E: yeah. There is quite a lot of prior knowledge that these learners are expected to have.

M: for example?

E: mhhh…. Writing formula formulas of molecules for instance. And this is something that they expected to know from grade 8 because they start doing covalent bonding in grade 8 for example. Writing formula of ionic compounds as well because from grade 9 to grade 10 they do ionic bonding. So this is the knowledge that is actually expected from them. Also, what

they do from grade 10 is balancing of chemical equations, so that is the pre-knowledge, so I expect them at least to know how to write the formulas of molecules, diatomic molecules, polyatomic molecules, formulas of ionic compounds, balancing of chemical equations; these are the requirements of the mole concept.

M: So you are saying if they do not know these two then it might be difficult for them to understand the topic.

E: Yees, very difficult. I realized it through my experience that the teaching of this mole concept, the mole itself is not difficult as such because it entails just calculations of either moles of elements and compounds, moles of solutions, moles of gases, but the problem lays within the writing of formulas of molecules and writing the formulas ionic compounds. Because learners need to know the relationship between the Periodic Table, the structure of the atom and the writing of molecules and compound formulas; and also thy need to know how to balance… to know how to correctly balance chemical equations. Because when they are not able to do so this is where the problem comes in regarding the mole because the mole is dependent largely on those aspects.

M: Okay

E: Mhmm

M: eee, in your teaching, what learning and teaching materials do use when you are teaching the topic? If there are some extra of special.

E: Eish.. this topic is a bit so to say basic on mathematics, it is a bit abstract, so the first thing I usually rely on, 100 %, I rely on the Periodic Table, but additional materials it depend not which part of the mole I am dealing with for example if it is moles of solutions then in that case I would carry out some experiments on chemical reactions involving for example acids and bases, acids and metals, acids and carbonate or neutralization reaction, titration. I would normally then in that case use the apparatus in the lab.

M: Okay…

E: But it is not really a teaching aid oriented topic, apart from the Periodic Table and the chemicals.

M: so it is more calculations and mathematics

E: Yeah

M: Ok

E: and then in your teaching, how do you ensure that these learners are involved?

E: Ok, I try to really draw on the …. Because, I this topic I know it is so dependent on a lot of things that are supposed to be done in the previous grades, but sometimes learners have done the topic in the previous grade, grade 8 to 10 for instance in this case but still you find perhaps the learners have forgotten when they come to grade 11 or maybe they didn't understand well, so I would usually take them back to as far as grade 8 and I ask. I start first asking them the simple, asking them writing the formula of simple molecules, I can for example start asking; which element on the Periodic Table exist as diatomic molecules? Then some would remember, for example, nitrogen, hydrogen, oxygen plus the halogens. Some would remember from grade 8 and then I would ask; I would just try to ask some of the simple questions related to what they are supposed to have studied in grade 8 but majority do

remember. And then, I try to start from the very simple formulas so that they doesn't challenge them as such.

M: Okay… Aaa. Sometime you say the topic is very abstract, so how do you really help the learners to ensure that they understand such an abstract topic? To make sense of what is really happening with the topic?

E: Yeah…. I should admit that this topic is really abstract. Most of the time they are dealing really with things that or when they deal with it they really some cannot make sense in most cases. So, I would for example relate… I like to start using the simple example of water for example. Say, water, we all use water I our everyday life I would ask now; How do you use water in your daily life? Then say, ok now; how is water formed and what is the formula for water? Then they would give those who can recall from the pre-knowledge. Ok, now water is made up from hydrogen and oxygen, now let's look into this chemical reaction. Then we would take the chemical reaction of water, they we would like, okay the hydrogen molecule diatomic reacting with oxygen to form one molecule of water. Then now using the concept of relative atomic masses and also relative formula masses I would for example without the balancing of the equation, I would ask; okay we said that… we talked about the relative atomic masses of the elements relative molecular masses of the molecules and relative formula mass of compounds, so now tell me or let's calculate the relative molecular masses of these equations; hydrogen, oxygen, water. Then they would for example, say: Okay hydrogen since it is two atoms is 2 grams, oxygen 16t times 2 is 32, water which is formed is one oxygen atom two hydrogen atoms is 18 grams. Then I would ask: now, if you have got 2 grams of hydrogen and then 32 grams of oxygen how come it only form 18 grams of water? I would ask like that; then they would like no… then I use the principle of indicating to them that the mass of the reactants should always be equal to the mass of the products when you are doing these equations. And therefore, we should… that is why we are always asked to balance the equation. Now… then I would now take then through the balancing of the equation of water formation. Then after balancing we will say; okay when we balance the hydrogen will give us 4 grams, the oxugen is 32, now when we calculate for water once we balance for water we put a 2 infront of the H_2O then it will give us 36. So when we have 4 grams of hydrogen molecule plus the 32 grams of the water molecules it will give us 36 grams of water. Then they will realize that only after the balancing of that equation it is when you see that the mass of the reactants will be equals to the mass of the product.

M: Okay
E: Yes

M: And when it comes to assessment,

E: Yeah… when I assess I assess actually step wise. I would for example first start asking then to calculate relative molecular and relative formula masses, for them to know how to calculate then relative molecular and formula masses of molecules and ionic compounds. Then from there once I introduce the mole calculation, calculating the moles of element, of compounds, moles of solutions moles of gases then I will give them…. Because this mole topic is actually… it is dependent of other topics like acids, bases and salts. So because I would apply this mole to either preparations of salts, reactions of acids with metals or acids with bases, acids with carbonate; I would also sometimes link it to the extraction of metals from their ores, yeah, normally this mole topic is linked to other topics in chemistry. But in most cases I emphasis it when it come to the topic acids, bases and salts.

M: Okay. And the types of assessment that you use mostly.

E: I use mostly worksheets. Where I would first for example give them a prepared worksheet or provide some questions to them which we use to just work out some relative atomic masses of somethings; I would show them how given and I would give them related examples.

M: Okay… then in your teaching, what challenges do you experience when it come to this whole topic?

E: Eish… I should admit that this topic is quite a challenge because first of all as I have been teaching physical science across from grade 8 to grade 12, I would find myself while I am teaching the grade 10 they are already asking me 'Ms, we heard from the grade 11s and/or grade 12 that there is a topic in grade 11 and 12 'mole' which is difficult. So that is my greatest challenge, because it is about their beliefs; so the moment when they come in grade 11 they already have these beliefs that the mole topic is such a difficult topic. So it is very… it is really difficult. That is why I try to link them from their previous grades then I try to explain to them that this topic of mole or stoichiometry as you have heard from maybe your friends who completed grade 12 that it is a difficult topic; really to be honest with you this is a topic that you have been doing from grade 8 without knowing because when you start doing covalent bonding in grade 8 when your are writing those formulas you are already dealing with moles concepts as such up to grade 9 through to grade 10, actually you have been doing this concept of mole without it being been brought really under your attention that now we are doing the mole. So I try to make them… I try to take away that belief, because if I just start decide to start like that with that belief they have then they will just have this negative attitude toward the presentation and whatever I try to explain to then, they will just take is as you… one can even just get it from their expressions. Like when you just… you see one mole of what thn thy goes Óh..' yaa…just a simple thing they are already trying to make themselves get confused because of that belief that they have. So I try to work on the belief to maybe like a counselling I don't know how to call it or motivation it I may put it that way. And then I take them back to just writing of the correct chemical equations take them back to the balancing of equations and so, by the time I explain mole itself then I have already dealt with those aspects; the prior knowledge. So the main thing here I try not to assume that, since they have done this balancing and so on in grade 8 to 10 they understand but I always try to take them beck not to base my explanation on assumptions because if I decide to assume that no let's balance this without really taking them through first then it becomes a challenge. But normally when I just start from this basic, from the very foundation then the chances of overcoming the challenges are high.

M: So you say from the side of the learners it is just the beliefs that they come with?

E: Yes, it is a belief and I… as I say that I have been responsible for Physical Science from grade 8 to 12, so I have already… I don't actually notice this one necessarily in grade 11 and 12 but I notice it more especially in grade 10. It is when they will start asking 'Ms we heard there is a mole topic which is difficult in grade 11 and 12', so from there I can already foresee that this learners if they are already asking me like this when they are in grade 10 so by the time they reach grade 11 and 12 it is a challenge. And I think it is more of a challenge to secondary schools which cater for grade 8 to 12 because as they are I n the hostel when you are busy teaching the grade 11 this topic of mole then when they go to the hostel they tell each other óh today we were taught moles' these types of things but I think because like when I started my teaching I started at a combined school I was never asked these types of questions like for the three years that I taught at a combine school. They never ask such a question like 'we heard there is a difficult topic' but the moment when I started teaching in a secondary school that was now from 2010 it is when I started hearing these questions. Like recurring every year especially from the grade 10s, they would always ask.

M: Okay. And when you start the topic in detail, how is their reaction or maybe going to the end do they then change attitudes or …

E: Yeah to some extend with more practice yes. With more practice they really start realizing that…. Especially those, I realize also that mathematics also plays a role here. Those who are very good in mathematics, they normally end up catching up faster than those whore are poor in mathematics. Because like for example the mole itself like when we look at the calculation of moles of element and… now the moment when bring it across to them like 'one mole of any substance is equal to the relative atomic mass and it is also equal to the relative molecular mass. So which means for example I would ask then 'so, one mole of let's say an element carbon, one mole of carbon will have a mass of 12 grams now what if you have two moles of carbon?' then they would say one mole is 12 they would then use direct proportionality then two moles would be 24. What about if you have half a mole of carbon? Okay, half of 12 would be 6 grams, they I will take it from there. Then this direct proportionality is the one which was then used to come up with the formula that to calculate the mole, it is equal to the number of moles is equal to the mass… the given mass divided by the relative atomic mass or the relative molecular mass. Yaa, once they capture or once they see the link, the direct proportionality that exist then they would…. Then now when it comes to moles in solution then I would for example say 'ok now mole of solution was taken as a standard that if you take one mole of a substance and you dissolve it in one litter which is now regarded as one cubic decimetre of water so the concentration that now where the concentration comes in. Concentration, explaining now what is meant by that it is refer to the amount of the dissolve substance per volume of the solvent and they we take it from there that let's sodium chloride I can ask them for example to say calculate the relative formula mass of sodium chloride. They would calculate it. Sodium is 23 plus chlorine is 35 it will give 58. Then I would say now if you take 58 grams of sodium chloride and you dissolve it in one litter of water, now because we know that one mole of any substance is equal to relative molecular mass, now rather than saying it is 58 grams per litter we just say it is one mole. Because we know that, that 58 grams is that one mole. Then I take it from there that so this is what we do now when we are referring to mole of the solution, then can explain to them that just like you make tea at home. So if I tak e58 grams it is one mole of that one per litter; it I take 116 grams it is 2 moles, if I triple then it will be 3 moles, just like at home you can put 1 teaspoon of sugar in a cup then in another cup 2 spoons and in a third one three spoons you will see that the sweetness in those three cups it will be not the same. So this are the concentrations, different concentrations that we are talking about.

M: Okay…Aaaa.. thank you very much Ms….. you really helped me a lot this will really help me to finish up my study. Unless maybe you have something else that you would like to add.

E: Yaa maybe it is just to thank you also for this opportunity, and this are really good questions that you have brought forward because this topic really it is one of the most challenging topic as I should say in the syllabus and it is good that you came up with these as it could also help me to make some changes as far as the teaching of this topic is concern.

M: Okay

E: Thank you. All the best with your studies.

M: Thank you.

Appendix E: Interview transcript for Teacher 2

Pre-Interview transcript: Teacher 2

R: Alright Mr…. good afternoon.

T2: Yes, afternoon and how are you?

R: I am okay and how are you?

T2: Okay

R: Our interview is on teaching of stoichiometry, mole concepts to be more specific. To start with, I just want to hear more based on your good number of the years of experience how you teach this topic. How many years again?

T2: around seven eight there yeah…

R: Okay, so how do you introduce this topic of stoichiometry to your learners?

T2: Mhhh… the topic is a challenge, but most of the time when you come to the topic, yaa apart from now first teaching the learners how to write chemical formulas, balancing chemical equations and all that. The major problem is when you talk about moles, moles is where learners fail to… to get really to understand what is a mole therefore sometimes you get to know and look for things that are normally like… introducing things like, when you talk about thing like a pair of shoes; those are two shoes; when you talk about doxen of eggs they are like 12 eggs in a pack then they are called a dozen, then all those things. At least to get learners to know that some amount of substance can have a single word that can be called as just like when you refers to moles. Yaa.

R: Okay. Then coming to this topic, what are some of the prior knowledge which learners need to bring before you go into the detail of the topic? What do learners need to know before?

T2: Yeah.. the first one is writing a balanced or first writing chemical formulas.

R: Emmhhh

T2: If a learners doesn't know how to write a chemical formula then that learner cannot do anything when it is coming to stoichiometry because, there you need to know how to calculate for example relative molecular mass or formula mass and if the learner cannot write the formula it is very difficult to write out some of those. And even how to balance a chemical equation, without a balanced chemical equation then again you cannot proceed into the topic of stoichiometry; it is going to be very very difficult.

R: So, you are saying balancing equation and writing formula is the most….

T2: That is the most important thing.

R: And have they done those things already from grade 10?

T2: From grade 10 yes.

R: Okay. So when you then go into moles or stoichiometry in detail, what learning material do you use to help in this topic?

T2: yeah….yaa, commonly most of the things, the topic itself if you don't really have a very equipped lab, then you only have to give more worksheets and then learners practice more rather than just giving examples then you let off go. You give more activities like the worksheets and so forth. But the other thing also that should supplement is, that topic is more practical if you have a very nice equipped lab then you can engage learners in measuring some volumes of liquids, like acids; you engage them in measuring mass, you engage them in measuring mass of compounds and then they calculate right away there then they get to understand what they are doing better than just teaching them because when you ask them for example to calculate the amount of copper reacted with an acid it is better when you bring the acid and the copper there, then you measure their mass then you mix you react them; it work out for them. Than just teaching them theoretically.

R: So you are saying it is best to do practical with them during the topic than just giving them theoretical information.

T2: Yees…

R: Okay. In case then you do not have those ones, how would you ensure that learners are also involved in the lesson?

T2: Yeah, if you don't have them, those practical then the best one is to do practice mostly; practice you bring in worksheets and you monitor learners during the activities then you help them on how to do things. But it is also good if you can also prepare like some kinds of posters then those posters containing formulas and all those things then they will also get to understand as they interact with the formulas on the daily bases.

R: Aaaa… and when it comes to mole, it come with a lot of concepts which some of them are even sound similar like you have mole, molar, molar mass, molar volume and others. How do you… what strategies do you use to make sure that they really got all those concepts right?

T2: Yaa… you start with the mole, you see sometimes it become difficult because sometime when you say calculating moles then learners they get to understand mole as a concept itself as a quantity but they should also understand that the number of mole can be can also be measured in moles. Now, when you talk about the number of moles and the unit is mole then sometimes that is one of the concepts that will confuse them, but you have to make them understand. Then when it also comes to things like the volume concentration for example mole per dm^3 those ones they can only understand better if you teach them how derive from the chemical equation and when you refers to terms like molarities they will understand already that, oooo! So when you have the concentration then you measure in that because sometimes it is also maybe good that some of those terms you explain to them before you go into the concepts so that they begin to understand that the mole and the molar volume and what are you referring to.

R: Okay.. so you need to explain them initially at the beginning.

T2: Mhhh.. and also teach them how to derive the unit from the formula than just knowing the unit.

R: Mhhh… then apart from the worksheets that you have mentioned that you need or the learners need to do more practice, is there any other way in which you use to asses then learners' understandings?

T2: eehhh..

R: What are those ones?

T2: Eee… through tests, you can tests also then there they can also help to check the learners' mastery level. You can also give them quiz, you can also use quiz then, they helps better. Because like you bring it in terms of…. There are some nice worksheets that you can use mostly on mole like you can use it like a game that they play or a kind of a puzzle. Then it also become interesting and it can arouse the interest to other and tend to it.

R: Okay. So those are other things that one can do.

T2: Mhhh….

R: So, in you teaching, what challenges do you experience during your experience of teaching the topic?

T2: Mmhhh….

R: Either from your side as a teacher or from the learners side

T2: Yaa… one of the biggest challenge is the…. That misconception with many learners that mole is difficult. When they believe that mole is difficult then they begin to already take it that way that no this topic, that thing. That is why you really have to work hard to make it understand. But also the other challenge on the side of the teaching when you talk about the mole you see it is something that people like think if you talk about the particles or atoms are things that learners cannot see and you have to convince them because when it comes to things like Avogadro's number how it was found and all that. Sometimes learners tend to switch off that ahh! This things how do they do it, how do they see it and then all those questions then they…. It already bring the misconception in the topic itself. But any how you have to try and be smart in order to convince them because of they did not believe it then it will be very difficult for them to do better in the topic.

R: Eee… you have mention that learners come with misconceptions that the topic I difficult. Where do you think that one is coming from if they are having the topic for the first time?

T2: Yaaa… that one, most of the learners we are teaching here they are in a secondary school. Then sometimes they get it from the…their peers, their friends who are already doing the topic while they are not yet in that grade; sometimes also it come from the teachers themselves that they indicate to learners that the only topic that can be difficult is that topic, stoichiometry then learners will only begin to build up a fear that yaaa even the teacher say it is difficult.

R: So how do you deal with those challenges that you have just mentioned?

T2: Aaa, number one is to prove the learners wrong. When you have a proper presentation and a proper……. Proper presentation and proper planning on how you are going to approach the topic, that is one. And again remove the things that maybe, motivate learners that to you that is one of the best topic that you like or is what …. Is one of the topic that can be very easy. And also maybe also try to motivate them that they should by all means try to understand that topic because if they do not understand it, most of the chemistry concepts are based on it. Then, they will be motivated to learn then giving up, because if they give up then it is like they are giving up the whole chemistry.

R: Yes… so you are saying that the topic is very important when it come to the whole chemistry?

T2: Mmmh.

R: can you then maybe in which ways can this topic be very important?

T2: Yaa.. number one is, if you look at chemistry whether now it is… the parts of chemistry, whether it is organic , chemistry and others you come across formulas of compounds and the only way that you can understand those formulas of compounds, the only way that you can calculate their masses, their whatevers, the moles, it is only when you have mastered that one. Because now most of the times that topic is now a combination of…. It is then like a prerequisite to most of the topics. Even if you talk about the… going to talk about equilibrium constants you still need to bring in a lot of things coming from here. That is now, without that idea, without anything there, then everything will be very difficult. But if they know that topic very well, when you talk about formula of any compound the learners understand, then there will be no problem. otherwise it is very few where you find a topic in chemistry alone which does not talk about a formula of a compound or which does not have anny chemical reaction to be written, it is really very rare. Only maybe parts of... but most of the chemistry you have to use equations, you have to write formulas and all that.

R: Okay. Alright I think we have come to the end. Thank you very much for your time.

T2: Yeah, thank you.

R: Alright.

Appendix F: Samples of Video-taped lesson transcripts for Teacher 1

Classroom Observation
Teacher 1
Lesson 1 (02. 07. 2014)

Keys:
T1: Teacher 1
L: One learner talking
LLL: Whole class (Chorus)

The teacher start off the lesson by referring to what done in the previous lessons.

T1: Last time we talked about relative atomic, relative molecular mass and relative formula mass. Where the relative atomic mass is for elements, *and where do we get that from?*
LLL: From the Periodic Table.
T1: Then we talked about the relative molecular mass for molecules and relative formula mass for ionic compounds. So how do we…., just for us to recall; *how do we get relative formula mass again?* Let say you are asked to find the relative molecular mass for calcium carbonate, so what do we do? Anybody?
L: We add the atomic mass together of the element.
T1: Okay, we add the relative atomic masses. Like in this case, what do we do?
LLL: Calcium is 40 plus 12 for carbon plus 16 times 3
T: Okay. Then what do we get?
LLL: 100
T1: Okay. So, that is how we, because as we say that the relative formula mass is the sum of the relative atomic masses of the atoms which are present in a molecule or in an ionic compound.
So, we are going to move on now with the new concept, but before I introduce the new concept I want to find out from you. *Have you ever heard about a word a DOZEN?*
[the teacher wrote the word **dozen** on the chalkboard]
You heard about it?
LLL: Yes
T1: So what is the meaning of that?
L: When two atoms molecules combine.
T1: When two atoms molecules combine?
That is interesting, okay.
I think he is confusing it with diatomic molecule.
L: A dozen is twelve.
T1: A dozen is 12, 12 what? Is it specific to say a dozen is 12 of anything?
LLL: Yes.
T1: So a dozen is 12 objects or 12 things. So when we are talking about a dozen we are always taking about 12 things.
Now, let me give a scenario:
Let me say you have got 3 different objects or food substances; eggs, oranges and water melons and let these objects different masses.
Let say 1 egg has a mass of 10 grams, 1 orange has a mass of 100 grams and 1 water melon has got a mass of 1000 grams.
Now we take a dozen of each of these, eggs,…..If one egg has a mass of 10 grams, then the dozen will have amass of how much?
L: 120 grams
T1: Are we to get 120
LLL: Yes
T1: 12 times….
LLL: 10g

T1: one dozen of oranges?
L: 1200
T1: 12 multiplied by 100, because one orange has a mass of 100 g, so that is 1200 grams. And the dozen of water melons?
LLL: 12 times 1000
T1: 12 times 1000 equals…….
12 000 grams [teacher and learners]

T1: Now, when you look at these comparisons, we have different food substances here, two fruits and eggs. Now, when we are talking about one dozen of each type of these for each one we are just talking about 12 things irrespective of the mass, we are just talking about quantity. In other words, we are looking at how many eggs. When we are talking about one dozen of eggs, how many eggs is it?
It is 12. How many oranges? It is 12, how many water melons? It is still 12. [the teacher ask questions and answer them herself, no chance given to the learners to answer the questions]
So, we are just looking at the amount of objects that we have. Now this is independent of the mass. So now this is just a general or daily or everyday like example of the amount of objects or substances.

The teacher continues to explain linking the example given to chemistry.

Now, in chemistry to be more specific, when are talking about the amount of substances involved in a chemical reaction we are talking about a MOLE.
Just like we talk about a dozen, it is exactly the way we talk…. We mean when we talk about a mole.
A mole we are referring to how much. Because so far we have just look at, when a chemical take place for example, carbon react with oxygen to form what? What is formed?
LLL: Carbon dioxide.
T1: Carbon dioxide, fine. So far we just look at what. When hydrogen react with oxygen, what is formed? Carbon reacts with oxygen, what is formed? Magnesium reacts with oxygen, what is formed? Now this part of chemistry we are interested in looking at; how much? When I have this substance reacting with this substance, how much product is formed? I just do not want to know that whenever hydrogen reacts with oxygen water is formed, but I am also interested in knowing how much water is formed. How much hydrogen is involved in the reacton, how much oxygen is involved in the reaction?
So, this is what we refer about when we talk about the mole concept.
So, what is a mole?
[The teacher answers her question]
When we are talking about a mole, one mole of any substance is equal to this number [pointing at 6.023×10^{23} she wrote on the chalkboard]. It is a very big number. It is just like when you say a dozen is equal to 12.
1 dozen equal to 12 so, 1 mole is equal to 6.023×10^{23} particles. So, I can say I have one mole of atoms that is equal to that number. I have one mole of molecules is equal to that number, I have one mole of ions, it is equal to that number. So, when we are talking about the mole we are actually dealing with how much of the chemical reaction, not only to know what is produced when these substances reacts with this substance but we also want to know how much of the product is formed, how much of the reactants is involved in a chemical reaction.
Now, furthermore, it was found that, one mole of any element in the Periodic Table is equal to the relative atomic mass of that element.
So, if you have the element on the Periodic Table, let say for example hydrogen; so we are going now to compare.
We have got hydrogen as an element, alright? Then we look at carbon as an element, we look at calcium then we look at a compound such as calcium carbonate.
Now, we have already worked out the relative molecular mass of calcium carbonate which is equal to 100 grams. Now I want you to get the relative atomic masses of these elements. What is the relative atomic mass of hydrogen?

LLL: It is one

T1: One gram, normally the relative atomic masses are expressed in grams. The relative atomic mass of carbon?

LLL: 12

T1: The relative atomic mass of calcium?

LLL: 40

T1: So what are we saying?
It is just like we compare with the dozen, okay.
One dozen of egg is equal to 120 grams if one egg is 10 grams
One dozen of oranges……. one dozen of water melons…….

So, we can have 1 dozen of different things, but the masses are not necessarily equal because these objects have their own respective masses per object. It is like what we have here, when we have different relative atomic masses of different elements in the Periodic table each of these is equal to a mole. Meaning that, in each of these (H, C, Ca and $CaCO_3$) element or compound, we find 6.023×10^{23} particles. Even hydrogen with only one gram as relative atomic mass, the number of atoms which are present is equal to this amount, even carbon. Now because this is such a big number and we know already that the number of particles in a relative atomic mass and relative molecular mass is just constant which is equal to this numbers called Avogadro's constant, the scientist who found out about this, that each element in the relative atomic mass there are that amount of particles. So the scientist who found about this is Avogadro and so the number was given the name Avogadro's constant.
Now, since we know already that if we have the relative atomic mass of any element on the Periodic table or the relative molecular mass of any molecule or the relative formula mass of ionic compound it always consist this number of particles then I rather work with the relative atomic mass or relative molecular mass.
So that is what leads us to the calculation or using the mole in form of calculations because we know that one mole of any substance is equal to the relative atomic mass or relative molecular mass.
So now what if I know, let say 1 mole of carbon is equal to 12 grams, what if I have 2 moles of carbon?

LLL: 24 grams

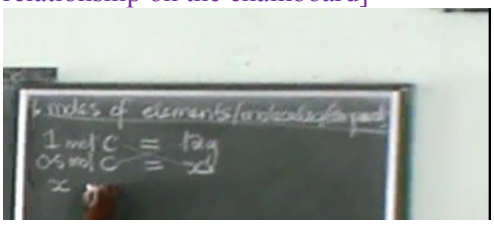
T1: That will be 12 x 2 which is equal to 24 g. what if I have 10 moles of carbon?
LLL: 12 times 10…. Equals 120 grams

T1: If I have got half a mole of carbon, 0.5 mole of carbon?

LLL: Is 6

T1: So this leads as now to mole calculation. There are three ways of calculating moles. We calculate moles of elements, molecules and compounds. We calculate moles of solution, we calculate moles of gases. So in this lesson since we a just looking at the introductory part of the mole, we will just calculate the moles of elements or compounds or molecules.
Now looking at the direct proportionality that exist between the number of moles and relative atomic mass or relative molecular mass or relative formula mass. There is direct proportionality and that direct proportionality relationship is the one which was used in order to derive the formula of calculating the moles.
Let us again revisit the direct proportionality in terms of carbon.

We say that if 1 mole of carbon is equal to 12 grams, then say 0.5 moles is equal to x; then how do we find x.
[the teacher wrote the relationship on the chalkboard]



LLL: Cross multiply
T1: Cross multiply, so x equals to

LL: 12 times 0.5

T1: Equals to 6. So this is how the formula was derived.
Let us use another figures. Mhhhh…
1 mole of carbon is equals to 12 grams, so when I have 60 grams of carbon, how many moles is it? What do we do in this case?

LLL: Cross multiply

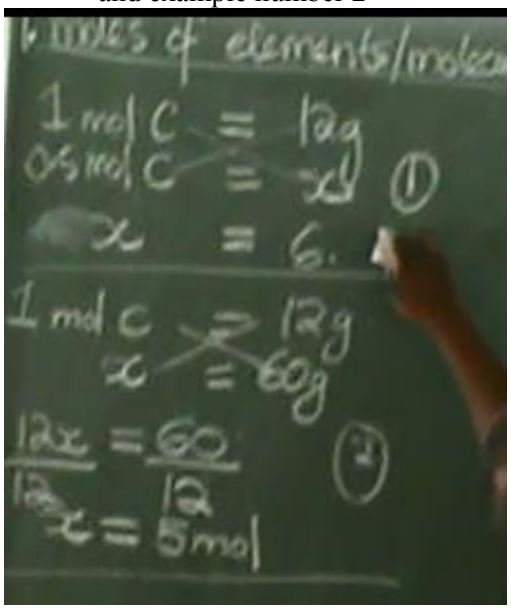
T1: Cross multiply, so 12x is equal to….

T LLL: 60

T1: Divide both side by 12, so x is equal to?

LLL: five

T1: x is equal to 5 mole.
So this is how the formula of calculating mole of elements, molecules and compound was derived. So the number of mole, I want us to look at these two examples, example number 1 and example number 2



In this example (example 1), what were we looking for?

LLL: Mass

T1: We were looking for the…. Mass. Now how did we get the mass? Now this mass was x, isn't it?

LLL: Yes

T1: How did we get this mass? We say x is equal to, this 12 which is the? Relative atomic mass. So, that x is equal to, the relative atomic mass multiplied by?

LLL: The number of mole [together with the teacher]

T1: That is given. In this case [pointing at example 2], x is the number of mole, so to get this x we said, x is equal to? This 12 is what? [pointing at 12 on the board]

LLL: The mass/ relative molecular mass

T1: (together with some learners) Relative atomic mass
T1: of carbon. And 60?

LLL: Mass/Relative atomic mass (in chorus)

T1: So 60 is also a relative atomic mass

LL: No, it is a molecular mass

T1: 60 is just a mass that is given that okay, this is the relative atomic mass of carbon, now that the relative atomic mass of carbon contain 1 mole of carbon; now, what if I have 60 grams of that same element? Because, the relative atomic mass of that particular element is equal to 1 mole. Now what if I am given any other mass of that same element, how many moles will it be? So that is just he given mass. So the relative atomic mass is now the one which is specific for the element, while the given mass is the mass that we use in order to determine how many moles are in that particular mass by comparing it with the relative atomic mass.
So in this case to obtain the number of moles, we divided the mass by the relative atomic mass.
So what is our general formula?
Our general formula of calculating the number of mole of… elements, molecules and compounds, number of moles, given as a small letter n, is equal to the mass, whatever mass you are given of that particular element or compound or molecule divided by the relative molecular mass or the relative atomic mass.
So I want us now to do few examples on page 151 in our textbooks.
I want us to do some three examples on how to apply this formula then I will give you an activity.
There are three examples and I want us now to explore these three examples in relationship with the formula that we have here, because this formula mathematically you are all doing mathematics this formula we can represent it in a form of a triangle.
Now which one do we put at the bottom?

LLL: m / the mass

T1: What do we put at the top?

LLL: The mass

T1: then we have n and the relative molecular mass
Now let us follow how these formulas have been applied to the examples.

Example 1 says: *how many moles of calcium carbonate ($CaCO_3$) are used in a reaction if 10 g of the solid is used?*
Now, how many moles is 10 g? We know calcium carbonate we calculated the relative formula mass, [repeated how to calculate the relative formula mass of calcium carbonate as it was done at the beginning of the lesson] which is equals to 100 g.
So this means 1 mole of calcium carbonate is equal to……100 grams. Now it is not always in a chemical reaction or in an experiment, it is not always that we are going to use 100 g which is equal to 1 mole, we can be given any mass of calcium carbonate in an experiment for example. So now in this particular case they are saying that, if we are given 10 grams of calcium carbonate, how many moles are there? Because in 100 g there is 1 mole. Now what about if we have 10 grams? So what are we looking for?

LLL: Moles

T1: We are looking for the number of moles. So number of moles, we apply the formula as it is, is equal to the mass divided by the relative molecular mass. The mass which we are given is how much?

LLL: 10

T1: is 10 g, and the relative molecular mass of calcium carbonate?

LLL: 100

T1: So, the number of moles in 10 grams is?

LLL: 0.1

T1: And this one you can even get it through direct, as I said the formula was just derived through direct proportionality, because it is just to say:
1 mol = 100 g
x = 10 g, them in this case we say 100x = 10, divided by 100, so x = 0.1
so we are just using direct proportionality. And it make sense, because in 100 g there is 1 mole, so 10 g is 10 times smaller than 100, isn't?

LLL: yes

T1: So we expect the number of moles there also to be 10 times less. That is why in 1 mole there is 100 g while in 10 g there is 0.1 moles. So in this way we have use the formula in order to calculate the number of moles.
Now, look at the second example. The second example says:
To make10 moles of water by burning hydrogen, we must burn 10 moles of hydrogen. What mass of hydrogen is this?
So now we are looking for?

LLL: The mass.

T1: We are given the number of moles, the relative molecular mass of hydrogen we must find it. Hydrogen molecule is H_2 so the M_r of hydrogen is?

LLL: two

T1: Because hydrogen the relative atomic mass is 1 g. So the diatomic molecule of hydrogen 1 g times 2 is equal to 2 g. Now this is the relative molecular mass. Now they are asking, because from this relative molecular mass this is equal to 1 mole of hydrogen molecule.

Now they are saying that, what if we 10 moles, because 1 mole = 2 g. What if we use 10 moles? So we use the formula now to find the mass.
The mass is equal to?

LL: Number of moles times relative molecular mass.

T1: So the number of moles we are given that 10 mole, the relative molecular mass…. 2 g. So this now will give us?

LLL: 20 g

T: So 1 mole, you see that this also make sense using the direct proportionality. You see that one mole is equal to 2 g
1 mole = 2 g
So, 10 g = x so x = 2 x 10 = ?

LLL: 20

T1: So you can see, is direct proportionality that is involved here.
Okay, *just few minutes before the end of the lesson.*
We can quickly look at the third way of using this equation then I will give you the homework.
The very, very important aspect here in the moles as we have already look at how to calculate the relative molecular mass relative formula mass of the compound, that is mainly the challenge. And as again we have already look at the part of aaaa…. Balancing chemical equation, writing correct chemical formula, so once you get all these correctly, then you will not go wrong with the…because calculation is just the simple formula which you are just applying depending on the information that you are given. But let say for example like here if they say hydrogen molecule, now you know that hydrogen exist as a diatomic molecule but you don't use it like that in the calculation, you will not get the correct answer. Are we together?

LLL: yes

T1: So, if you just use it as hydrogen atom, you will not get the correct answer. Or let say for example maybe calcium carbonate, if you happen not to write the formula correctly, it means when you are going to calculate the relative molecular mass again you won't get the correct relative molecular mass and as a result you end up….because these calculation themselves are not really the problem, guys. Just make sure that you take it very serious, you revisit again the activity that I am going to give you. You must go back to calculating the relative molecular mass, looking at the chemical equation, writing correct chemical formula then from these once you get the relative atomic mass or whatever you are given, then you just calculate the missing information. So we have so far use this formula to calculate the number of moles, we have use the formula to calculate the mass, now the 3rd example is saying:
0.2 moles of magnesium oxide are formed when 0.2 moles of magnesium burn. The mass of the oxide formed is 8 g. What is the relative molecular mass of magnesium oxide?
Now, you see what I was talking about? Writing the correct chemical formula.
Now here they just give us the name, chemical name, magnesium oxide. Now what is the….because if we are not able to correctly write the chemical formula of magnesium oxide, of course we will not get the correct relative molecular mass. Will we?

LLL: No

T1: So let see now, what is the correct chemical formula of magnesium when they react with oxygen? Magnesium is in which group?

LLL: Group 2

T1: So it will have a charge of?
LLL: 2/ 2 plus
T1: Oxygen is in group?
LLL: 6
T1: It will have a charge of?
LLL: 2 minus

T1: So we know that magnesium in group 2 loses 2 electrons, oxygen is in group 6, it gains….

LLL: 2 electrons

T1: So what will be the formula then?

LLL: [learners mumbling] magnesium oxide, Mg……

T1: How many magnesium and how many oxygen?
LLL: 1 magnesium, 1 oxygen

T1: So the formula is MgO.
If you go wrong here, let say some of you maybe got confused then you write MgO_2, it means even when you are going to correct…… because if you work with Mg_2O, from the Periodic Table relative atomic mass of Mg is 24; O is 16, but now since your formula is wrong you are going to have 16 x 2 which is 32, 32 + 24 which is 56.
Now in that way you have calculated but your formula is already wrong so even when you calculate the relative molecular mass, everything is already wrong. So the problem start with writing of the formula because there in most cases you just given the word Magnesium what what react with what to form this product, so as I said that this mole concept it is not really independent topic on its own, it is normally applied to other topics that we are going to do mainly in term 3 like, acids, bases and salts; you have done some introductory of this topic in grade 10, isn't it?

LLL: Yes

T1: Chemical reactions, like extraction of metals and so on, where the chemical reaction take place is where now we apply the mole…..
We need then to know how to write formulas of ionic compounds, molecules and so on in order to calculate.
So let us go back to our question, therefore the relative molecular mass of magnesium oxide is?

LLL: 24

T1: Plus

LLL: 10, which is 40 grams

T1: Okay, sooo….what the question, the information we get in the question it say that, 0.2 moles of …….. [Repeating the question]
So now, we are given mass, 8 grams; number of moles, 0.2 and we are calculating M_r. So M_r is equal to…..

LLL: mass multiplied by; mass divided by….. [in a chorus]

T1: Mass [the teacher start writing the formula on the chalkboard]

LLL: divided by mole [after seeing a hint in the formula]

In a chorus, teacher and learners: Mass is 8 g divided by 0.2 moles

T1: Which is equal to?

LLL: 40 g

T1: Just grams?
40 g/mol, because 1 mole, that is the mass of 1 mole of that one compound.

T1: So grade 11 in short that is just the introductory part of mole as I said there are different ways of calculating the moles, the moles of element, molecules and compound; the mole of solution and the mole of gases.
So, sol far we look at this equation (n = $\frac{m}{Mr}$). In this lesson we focused more on this equation of calculating number of moles, but we can also use it to calculate the….. in a given chemical equation.

So your homework is going to be on page 153.
9.1 (b & c), 9.2 (g & h), 9.3 (f & g)
Yaa, all of them, just have to do with the equation but the main thing is, you are given the the the formula and then you must work out the relative molecular mass of these substances. So make sure that you ouk out the relative molecular masses of the….correctly so you can use it to apply to the equation. Right?

Okay learners, see you tomorrow, have a nice day.

LLL: Same to you Ms.

Classroom Observation
Teacher 1
Lesson 5 (02. 07. 2014)

Keys:
T1: Teacher 1
L: One learner talking
LLL: Whole class (Chorus)

The teacher start off the lesson by distributing learner papers for the homework they did in the group.

T: The group of Jonas, Kanime's group, Kali's group, Enlean's group, David's group and Andreas's group.

Yaa… we are going to start off with the activity as you did it in it in groups. So, aaa… if you have look at your performance with regard to this activity, the questions were three you realize you did either very well or you have done very poorly. Why? As I said… I have been saying that theae questions on moles they follow a flow and they are based on a chemical reaction that take place. Starting off from the balancing of the equation to the mole ratio, to the calculations. So in otherwords if you get everything, you have scored

about an A already 80%, but some if you miss something mong the details that you need to use throughout the question then in that case aaa… you will not go well. Some of you even got $\frac{1}{20}$.

LL: True

T: Let see, as we said we learn from our mistakes, let see what we supposed to do in these questions. We start with question number one.

Now question 1 was a very easy question because, the equation which you we given is already ….

T+LLL: Balanced 02:15

T: You don't have much challenge. You don't have a challenge of writing a…. writing the chemical formulas, you don't have the challenge of balancing the equation. You got the equation, the reactants and the products already balanced. So you have to do, you just have to … to use the information that you have in order to answer.

So the first question says: *The equation below show one of the reactions in the extraction of zinc metal from the ore zinc blende. In an experiment 25 g of ZnO is used to produce Zn and CO_2. (a) calculate the Relative Formula Mass of ZnO. The relative formula mass of ZnO (teacher repeat)*

Where did you go wrong? What is the correct answer? How do we calculate the Relative Formula Mass?

We have already done that as part of the introduction or in the beginning of the topic. How do we calculate the relative Molecular Mass? Tell us. Or Relative Formula Mass in this case since it is an ionic compound. How do we calculate?

L: You add together the atomic number of the total…

T: Atomic number?

L: No, mass

T: We add together the atomic… the relative Atomic Masses of the element in the compound. So that is zinc oxide the formula is already given as I said you don't have much of the challenge here. So, the M_r of zinc oxide. What is the relative atomic mass of zinc?

LLL: 67

T: We got this one where?

LLL: From the Periodic Table.

T: So the relative atomic mass of zinc is?

LL: 67

LL: 65

T: 65, the relative atomic mass of oxygen?

LLL: 16

T: 16, so this equals to?

LLL: 81

T: 81 grams 05:12

So the relative formula mass of zinc oxide is 81 grams. Now some of you where you went wrong, you multiplied with that 2 in front of ZnO, the two which is used to balance the equation. Now, it is very important for you to understand, RFM, RMM, RAM because this is the mass of one mole of the substance. Now according to the equation, according to the equation, let just write down the equation.

(*the teacher write the equation on the chalkboard*) $2ZnO + C \rightarrow 2Zn + CO_2$

Then the equation was balanced as 2 mole ZnO react with 1 mole of carbon too form 2 moles of zinc and one mole of carbon dioxide. Now those people who multiplied by 2, what you have calculated is the…

LLL: The relative molecular mass of….

T: Two moles of zinc oxide because…. Not necessarily the RMM but what you have calculated is the mass of 2 moles of zinc oxide. Because when we are talking about RAM, RMM or RFM this one is the mass of one mole. That is why you don't, when you are calculating this that is why for element you just get it straight from the Periodic Table. And for molecules you just add together the RAMs of the atoms present without considering the number used for balancing. Because that number used for balancing is an indication of how many moles are involved in the equation.

Let just give an example of photosynthesis, the photosynthesis equation that you are familiar with. (*the teacher writes the equation on the chalkboard)*

$CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$, Now normally this equation if you remember when, when we balance the this equation (*the teacher balances the equation*)

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$, you remember that percent of glucose. If you remember that we… during this process of fermentation of glucose using carbon dioxide and water, so 6 moles of carbon dioxide react with 6 moles of water to form one mole of glucose plus 1 mole of oxygen.

LLL: 6 moles of oxygen

T: Sorry, this is 6 moles of carbon dioxide to 6 mole of water to 1 mole of glucose to 6 moles of oxygen. Now when they ask: 'calculate the relative molecular mass of carbon dioxide', you just take the formula CO_2 as it is, so CO_2 the relative molecular mass. Because in CO_2 molecule there is 1 carbon atom and 2 …

LLL: Oxygen atoms

T: So it will just be the relative atomic mass of carbon plus…

LLL: Oxygen

T: the relative molecular mass of the O_2 which is 16 times 2 and then you get…

LL: 44 09:14

T: Then you get 44 grams. You don't consider this (6 moles from the balance equation) because the relative molecular mass is just the mass of one mole. Now when you multiply this one (44g) by the 6 used for balancing now the mass that you are going to get is the mass of 6 moles of that substance. So whenever they ask you to calculate the relative molecular mass or the relative formula mass, you don't consider the number that you use for balancing because the relative molecular mass or the relative formula mass is the mass of one mole of the substance. So that is where some of you went wrong. Now the thing is that when you go wrong, when you go wrong from the beginning then the rest of the questions which are based on that information you are not going to get the correct information because the starting point is wrong.

L: Ms, does that means that the number of mole they don't need to be balanced?

T: The number of mole…

L: They don't need to be balanced?

T: They do, they do. What I am emphasising here is that when you are sked to calculate the RMM, what I am concentrating on this question. What is the RFM of Zinc oxide? Which is the mass of one mole of zinc oxide, of course the numbers need to be balanced because if the number is not balanced then the mass of the reactants will not be equal to the mass of the products. But as I said that in this equation it means that for you to… for the production of glucose of for the balance, the equation to be balance you can't just leave it without being balanced.

(The teacher writes the equation for the production of glucose on the chalkboard)

Let just calculate the masses of these ones without balancing the equation. Okay. We have carbon dioxide reacts with water to give glucose plus oxygen. Now this equation is not balanced and what is the law of conservation of mass or in any chemical reaction then: the mass of the reactants must be equal to the mass of the products. Now with this equation which is not balanced, then the mass of the reactants it is not likely to be equal to the mass of the product. That is when the balancing comes in. Because, the chemical reaction must take place in such a way that the mass of the reactant and the mass of the products must be equal. But what you need to remember is that RMM is for one mole of that substance that you are talking about. So as I said already that, because you can't say you don't need to balance, we need to balance to have, (12:19)

LLL: Equal masses (*from the teacher's body language)*

T: On the left as well as on the masses but that will mean this 44 g is the mass of 1 mole of carbon dioxide when we multiply by the 6 then what we get is the mass of 6 moles. Now I hope you have you Periodic Table in front of you, we don't do this without a Periodic Table. And I was disappointed some of you, there is one group which used the RAM of zinc as 64. Why should you work without a Periodic Table? Even if you think you know the masses by

heart or whatever the reason why we give you a Periodic table at the end of the question paper is not for decoration, it is not just to decorate the question paper but it is for you to use the information from the Periodic Table in order to answer the questions. Now those are some of the things, you end up writing the RAM of zinc as 64 while on the Periodic Table it is indicated as sixty….

LLL: sixty five *(13:34)*

T: Those are the things; use the Periodic Table that is why you get it at the end of the question paper. Now, quickly the RAM of carbon,

LLL: 12

T: Plus, oxygen?

LLL: 16

T: 16 x 2, then *(14:00)*

T: Now I want us now to add these masses together to see if they are equal to those

44g plus 18 g and for glucose?

Learners do the calculations

T: 12 times 6 (14:53) Please add you have the calculators

LLL: 84

T: Uhmmm…. Use your calculators just the same way you don't what to use the Periodic Table…

LL: 180

T: The total?

LLL: Yes

T: 180 g, now if you add this 44 plus 18 do you get 180?

LLL: No

T: No, so that is the importance of balancing the chemical equation. Because here you will realize that when the equation is balanced, the mass of the reactants and the products is equal. Now the $6CO_2$ will be equal to… we just quickly make the….make 44 times 6

LLL: 264

T: 264?

LLL: Yes

T: Okay, then $6H_2O$ 18 times 6

LLL: 108

153 T: one zero eight?

154 LLL: Yes

155 T: so those are the masses of the reactants. Then we go to the products. $C_6H_{12}O_6$ and $6H_2O$, the
156 mass of glucose molecule and the mass of 6 moles of water molecule

157 $C_6H_{12}O_6 = 180$

158 L: The other product is oxygen not water.

159 T: Oooo… Thank you (the teacher erase water and replace it with oxygen). So 6 moles of
160 oxygen molecule

161 LLL: 192

162 T: Okay, now let's see if we add these two (284 + 108 and 180 + 192)

163 LLL:

164 T: This means in order to produce glucose we need 6 moles of carbon dioxide molecule, 6
165 moles of water to produce 1 mole of glucose and 6 moles of oxygen. But I emphasise,
166 RMM the mass of one mole of the substance, the mass of one mole of the substance
167 (*Repeat)*. That is the RMM or RFM. Okay. So back to our question:

168 The number of mole is 25 grams of zinc oxide, question (b). So we are given the mass of
169 zinc oxide and what we are asked to calculate is the number of mole of zinc oxide. So what
170 do we do with this question? (*after few seconds)* Mupupa *(18:59)*

171 L: We take the mass of zinc divide with the molar mass of zinc oxide. (19:18)

172 T: The mass we are given 25 g divided by…

173 LLL: The molar mass

174 T: The relative formula mass which we have calculated which is 81 grams for one mole. So
175 this is equals to how many moles?

176 LLL: 0.31

177 T: To two decimal place 0.31 moles. So this are the number of moles of zinc oxide in 25g of
178 zinc oxide because in one mole of zinc oxide there is 81 grams so in 0.31 moles there are
179 25g. (*20:16)*

180 Now (c): the number of moles of carbon dioxide produced from 25 grams of zinc oxide.
181 *(Repeat)* the number of moles of carbon dioxide produced. How do we calculate the number
182 of moles of gases? Number of moles of gases, What is the formula the formula to calculate
183 the number of moles of gases

184 LL: *(mumbling)* volume divided by….

185 L: Volume divided by 24 dm^3 (*in one group)*

186 T: Number of mole in gases. Yes (*giving one learner a chance)*

187 L: Volume divided by 24

188 T: Volume divided by 24 dm^3. Now are we given the volume of carbon dioxide produced in
189 this question?

190 LLL: No

191

192 T: So what do we do? *(21:30)* what do we do? So what did we said about the balanced
193 equation? We said that when you have a balanced chemical equation like this (*pointing at*
194 *the equation for the reaction*), the moment when you have calculated the number of mole of
195 any of the substances in the equation then it means you have calculated the number of mole
196 of everything because you just make use of the ratio. Like in this equation in this equation
197 the ratio is:

198 TLLL: 2 moles of ZnO : 1 mol C: 2 mol Zn: 1 mol CO_2.

199 T: So the moment when you have just get the number of mole of zinc oxide or any information
200 if we could have been given even just the volume of carbon dioxide then they say calculate
201 the number of carbon dioxide once we get the number of moles of carbon dioxide it means
202 you have got the number of mole of everything in there in the equation because you just
203 apply the mole ratio then you get the number of moles of whatever you are asked. So in this
204 case the number of moles of carbon dioxide, were not given the volume of carbon dioxide
205 therefore we cannot apply this formula ($n = \frac{V}{24\ dm^3}$) for the number of mole of gases we
206 have to use the mole ratio. Now the ratio of ZnO to CO_2 is 2:1 so the number of mole of
207 ZnO is ..

208 LLL: 0.31

209 T: 0.31 mole and the number of mole of CO_2 is x. So what do we do?

210 LLL: Cross multiply

211 T: Cross multiply, $2x = 0.31$

212 Divided by two (*on both side)* x=…

213 LLL: 0.16

214 T: 0.155 moles, I considered or normally we consider to two decimal places then it will be 0.16
215 mol so that is the number of moles of carbon dioxide produced from that mass of zinc oxide.
216 *(24:13)*

217 Then the mass of zinc produced, asking now for the mass of zinc produced. *(pause for 20*
218 *seconds)* (d) asking now for the mass of zinc produced.

219 LL: It is not the mass but the volume

220 T: Oh, I am sorry I am reading at (e) so (d) is the volume of carbon dioxide produced at room
221 temperature and pressure. So volume of gas equals?

222 LLL: Number of mole times 24 dm^3

T: (write the formula on the chalkboard). So we have determined the number of carbon dioxide already which is 0.16 moles times 24 dm^3 which is equal to?

LLL: 3.84

T: Then (e) the mass of zinc… mass of zinc. Then we are done with the correction. How do we calculate the mass of zinc?

L: You multiply the number of moles times…

T: We multiply the number of moles with?

L: Times molecule

T: times molecules?

L: Relative molecular mass

T: With the relative molecular mass. Now do we have the number of moles of zinc?

LL: Yes

T: Of zinc?

LL: Yes… yes

T: We have for carbon dioxide and for zinc oxide, do we have for zinc?

LLL: Yes…yes we have

LL: Ah, no

T: Now we have two unknown, we are looking for the mass but we don't have the number of moles. We are looking for the mass and we don't have the number of moles. *(27:09)*

Ndapandula… you are just pressing your calculator? What should we do?

LL: We use the mole ratio

T: Mole ratio between? The ratio of…

TLLL: zinc and zinc oxide

T: Which is?

LLL: 2:2

T: 2:2 which is 1:1 so that one is straight forward. If zinc oxide is 0.31 then zinc is also 0.31 because it is 1:1 ratio

0.31 time the molar mass. And here is where one group use 64. Can you see how you are losing marks unnecessarily? You have the Periodic Table and you are using 64 as the relative molecular mass. So this (0.31) time 65

LL: 19.5

T: (*write the answer on the board)* here the answer also varies depending on how you have rounded off. So that is based on number 1. *(28:40)*

So what we can conclude from number 1 is that: the information that we got from the beginning is the information about zinc oxide, the mass. We were given the mass of zinc oxide from there we have to calculate first the RMM of zinc oxide then after that we have to calculate the number of moles using the given mass 25 g and the RMM of zinc oxide, so we calculate the number of moles. Then from there we were asked the number of moles of carbon dioxide, and what do we make use of? MOLE RATIO very important. That is why this question was not really supposed to be a challenge to you because it was given to you already with an equation and it was already balanced, so you did not struggle anything. *(29:40)*

Then the second one, also in the second one you got an equation. Hydrated copper sulfate (*the teacher writes the equation on the chalkboard)* *(30:00)*

$$CuSO_4.5H_2O \xrightarrow{heat} CuSO_4 + 5H_2O$$

Hydrated copper sulfate, that large complex compound was heated to give anhydrous copper sulfate plus water. (*Pointing on the equation)* This is hydrated copper sulfate and this is anhydrous copper sulfate meaning that the water of crystallisation has been removed from the salt. Now it is a salt anhydrous salt it doesn't have any water of crystallisation in it but when it is hydrated it contains water of crystallisation in molecule. So the first question was to determine the mass of one mole of hydrated copper sulfate. Again this one was a very easy question. Just a matter of addition; that is why normally that is why I said always that if you are asked: calculate the relative molecular mass of water, now you thing water is easy than hydrated copper sulfate. There is no difference, you are just adding together the relative atomic masses of all the atoms present in the compound. Use your Periodic Table. So but most of you got this one correctly only a few may be you were confused because this one is the… is a complex compound. *(32:00)*

Relative atomic mass of copper

LLL: 64

T: *(writing on the chalk board)* 64, or is this where you got confused some of you when you use 64 for zinc? It could be; sulfur?

LLL: 32

T: *(writing on the chalk board)* 32, Oxygen

LLL: 16 times 4

T: *(writing on the chalk board)* 16 x 4, water, 1 times

LL: 5

T: 10 or 5 times 2 *(writing on the chalk board)* plus 16 times 5. So quickly can you add.

$$64 + 32 + (16 \times 2) + (10 \times 2) + (16 \times 5)$$

290 Calculate, calculate, calculate

291 LLL: It is 250

292 T: The answer is 250 g.

293 A mass of 38g hydrated copper sulfate was heated until it become anhydrous. Calculate the
294 number of moles of water that is liberated. The number of moles of water that is liberated.
295 Now what we got or the information we have is the mass of what? The mass of what; is it
296 the mass of water?

297 LLL: No, hydrated copper sulfate

298 T: We always start to calculate with the information that we are given. So we are given the
299 mass of hydrated copper sulfate which is 38g and we have calculated the relative molecular
300 mass of hydrated copper sulfate, so what do we get

301

The teacher wrote this as she talks

$n = \frac{m}{Mm} = \frac{38\ g}{250\ g/mol}$

$= 0.15 mol$

302 LLL: 0.15

303 T: 15 moles but this are the number of moles of…

304 LLL: copper sulfate

305 T: Hydrated copper sulfate but what are we asked in the question? The number of moles of
306 water. So again mole ratio. According to the equation, according to the equation how many
307 moles of copper sulfate produce how many moles of water? What is the ratio? Copper
308 sulfate to water

309 The ratio of hydrated copper sulfate to water

310 LL: one to five

311 T: The ratio is one to five (*writing on the chalkboard)* that means if you got 0.15 moles of
312 hydrated copper sulfate it will be equal to *x* moles of water. Then cross multiply then *x* is
313 equals to… 0.75 moles

314 So the number of moles of water liberated is equals to 0.75 moles *(35:41)*

315 The mass of anhydrous salt remaining after the experiment? The mass of anhydrous salt
316 remaining after the experiment

317 (*writing on the chalkboard)* Mass is equals to the number of moles multiplied by the relative
318 molecular mass. Do we have the number of moles of the anhydrous salt?

319 LLL: No

320 T: *(pointing to $CuSO_4$ in the equation)* this one do we have it?

321 LL: No

T: We only have for hydrated copper sulfate and for water. So number of mole, the ratio of hydrated copper sulfate to anhydrous copper sulfate, what is the ratio… what is the ratio according to the balanced equation?

LLL: One to one

T: One to one, so 0.15 = 0.15, then we apply that one in the equation (*m = n x Mr)*. What else do we need? Ah…we do not have the relative molecular mass of copper sulfate.

LL: Yes

T: Relative molecular mass of copper sulfate

LL: 160

T: 160?

LL: Yes

T: 64 + 32 + (16 x 4), 160 g…. So what is our answer?

LL: 24

T: Our answer is 24 g. Then the last question, the last question we are given, sodium hydroxide and hydrochloric acid. *(Writing formulas on the chalkboard)* sodium hydroxide and hydrochloric acid. What were we given here?

NaOH we are given the volume but we are not given the concentration and for HCL we are given the volume as well as the concentration. *(39:05)*

Balance chemical equation for this reaction just quickly *(the teacher writes the balance equation on the chalkboard)* [$NaOH + HCl \rightarrow NaCl + H_2O$] The mole ratios?

LLL: One to one

T: 1, 1, 1, 1 they are asking for the concentration of sodium hydroxide. So ford us to calculate the concentration of… sorry…for us to calculate the concentration of sodium hydroxide, concentration is equals to

LLL: Number of moles

T: Divided by

TLLL: Volume

T: But the problem is we do not have the number of moles of sodium hydroxide *(40:00)* we only have volume, but we have concentration and volume of hydrochloric acid. So what do we do first of all?

LLL: The number of moles

T: First of all we calculate the concentration… I mean the number of mole. *(writing on the chalkboard)*, number of moles of hydrochloric acid which is equals to concentration

multiplied by volume. The concentration we are given 1.5 mol/dm^3 and the volumes 25 but we are working with cubic decimetre

LL: we divide by 1000

T: Correct. So that is 0.025 dm^3 times 1.5 that is 0 point….

LLL: 0375

T: *(Repeat)* 0.0375 mole, this are the number of moles of hydrochloric acid. Now are our ratio, 1:1 which means if hydrochloric acid is 0.0375 then sodium hydroxide is also 0.0375. the ration is one to one. Therefore the concentration of sodium hydroxide is: number of moles…..

LLL: Divided by volume

T: *(Write the formula on the chalkboard)* so 0.0375 divided by volume. The volume we should also divide by 1000

LLL: 0.04 dm^3

T: *(Write silently on the chalkboard)*

LL: 0.94

T: 0.94 mol/dm^3

L: So if the number is not exact we need to write it to 2 significant numbers? Like this

T: What does the rules of mathematics say?

L: If the number is exact….

T: If the number is exact we don't need to round off? *Can we ask Ms Kanime for assistance; Ms Kanime*. What do we do in this case, the answer is 0.9375

K: I think it depends on how many significant figures is required and I think we use mostly 3 significant or two decimal place

T: Yaa, but now that rule normally applied if the degree of accuracy is not specified and the answer is not exact, but the answer is exact in this case. But I just think that 2 decimal place is also accepted. In that case it is four decimal places. So decimal placed or three significant figures.

(Correcting the work given the previous day) the learners who got this papers

Appendix G: Video-taped lesson transcripts for Teacher 2

Classroom Observation
Teacher 2
Lesson 1 (29. 07. 2014)

Keys:
T1: Teacher 1
L: One learner talking
LLL: Whole class (Chorus)

1	**T:**	(*Writing* on *the chalkboard)* Moles. Moles are refers to an amount, or mass of an amount
2		of a substance, sometime you ask people to know they ask this question, in English we
3		have this words that describing amount of substance. If I'm having…. Yes!
4	**L:**	What are these papers for?
5	**T:**	Which papers? No those one you leave it. Okay now, moles if you have (teacher moving
6		toward one learner and take her pair of shoes) can I use them for experiment.
7	**L:**	This?
8	**T:**	Yes what is the problem, you remove them already
9	**L:**	(a boy with a deep voice) they are smelling. (All learners laughing)
10	**L:**	(another boy shouts out loud) they are stinging.
11	**T:**	No, is not about the shoes that are bad or what, what are these?
12	**LLL:**	(all respond same time) shoes,
13	**LL:**	pair of shoes, pair of shoes.
14	**T:**	One pair of shoe. Good! If you look now, is a pair of shoe. (Asking a question to all the
15		learners) why are we saying they are pair of shoe?
16	**LLL:**	(shouting different answers) they are not the same….they are two
17	**T:**	Two, when we talk about pair, refers to an amount of substance. Pair of shoes. Now if we
18		go to things like eggs, normally we have a dozen.
19	**LLL:**	(all answer) uhmm.
20	**T:**	a dozen, how many eggs are there?
21	**LL:**	twelve
22	**LL:**	twenty four… eighteen,
23	**L:**	six, some are hundred.
24	**T:**	Is a good thing when you start debating with these things.

L: yes. Nor sir

T: Yah you see. Some words, generally some words refers to amount of substances.

LL: Yes.

T: That's why, even a mole, define an amount of substances.

Time: 2:44

LLL: Ooo.,,,,

T: In chemistry, it becomes very difficult when you have to measure, or when you have to define amount of substance, of compound, of gas produced, of liquid for example. We know already, a liquid like this (*a teacher took a bottle)* hydrogen peroxide is a 2.5L, isn't?

LLL: Yes.

T: But if I ask you, how many molecules of hydrogen peroxide are there?

LL: Molecules?

T: What first question are you going to answer me?

L: is a liquid measured?

T: Now let me start by this way, I ask you, Uukule have ten classrooms. Ten classes

L: uhmm

T: Then I ask you, how many learners are in Uukule? Ten classes, how many learners are in Uukule?

LLL: Oh

LL: Aye…How?

L: How many learners are in each class?

T: No I ask you a question, and is now not you to ask me, but is you now to stand your voice. You are just a new, a new person. To cone to Ukule.

LLL: (still unclear with the teachers' question and shouting different answers) more than one, more than two

T: None of learners to …

LLL: more than twenty, more than ten,

L: how many learners ….

T: No, I did not say to repeat the question.

LL: Two learners.

T: There is, you came to me, you said Mr Mbekele, how many learners are in Uukule, then I told her, no Ukule have ten classes. Than what next question will you ask me?

LL: how many learners in each class room?

T: How many learners are in each class?

LLL: yes.

T: That would be a smart question. **4:44**

LLL: yes

T: Then from there you would be able to work out these things, then I will tell you there are forty learners in a class.

LLL: Ooo…

T: you can even start to calculate yourself.

LLL: Is four hundreds.

T: Very good. Now when we talk about amount of substances that is the same way we are dealing with this compound. (*the teacher took a container of hydrated copper (II) sulfate)* If I tell you this is a 250g of copper sulphate, then I ask you, how many particles or how many, how many particles of copper sulphate are here? Then it's not going to be easy. Because you first question will ask, how many particles are in.

L: Let me count

T: if I say start counting you will not count them. Will you finish even if I put a million?

L: (laughing) yes.

T: You will count them?

L: Yes

(The rest of the class laugh loud)

T: I will give this boy a job, because he is so smart than I will look if he can find this even for a month I see start count.

LLL: *laughing*

T: But now what we know is… what scientist have found out is that one mole of any substance, this substance contains 6.022×10^{23} ….

LLL: Oh, aaye

T: ... atoms or particles or molecules, it will depends which are you refering to, if its element we talk about atoms, other compound and we refers to particles or molecules. Now meaning that a mole of a substance contains that amount and this number is called Avogadro's number which is this. Now, now this number makes us to, to understand the

relationship. You know the atoms are very tiny, a single atom you don't see it with your naked eyes. What we see, we see things their when you have millions and millions of them joint together we say okay now we see this is a compound of copper sulphate. Now what we are say is, one mole of a substance we are talking about, if we go back to a Periodic Table I was talking about A_r the other day. What is Ar again?

LLL: the relative….

T: The Relative what?

LLL: (*learners shout different answers*) molecule… atomic

T: Ah! Ah! 8:04

LL: Relative mass

T: A_r is relative what?

LLL: Relative Atomic

T: Relative Atomic…

LLL: Mass

T: (*writing on the* chalkboard) Relative Atomic mass. This one meaning that is a mass for one mole of an atom. And where we find this Ar for atoms or for an element for example, where do we find them?

LLL: In the Periodic Table.

T: In the Periodic Table. We get the A_r from the Periodic Table if all can go there you will find them. That means one mole of magnesium, one mole of magnesium is 24g according to what you see. Uhm?

LLL: Yes.

T: If you go to, to the Periodic Table, the mass of magnesium is 24. Isn't?

LLL: Yes.

T: Okay! Then which contains, which contains 6.022×10^{23} atoms of magnesium. Meaning that one mole of magnesium because here we say, one mole of any substance contains this number. If one mole is 24g that means in that 24g of magnesium there are these amounts of atoms. Are we together there?

L: Ummh.

T: But what if I ask you this now? (*Writing the question on the chalkboard*) How many atoms are there in 12grams of magnesium, how many atoms are there in 12grams of magnesium?

After some seconds and no answer from the learners

T: How many atoms. Ooh! I just say atom. How many? This is quite simple ne. Yes, the simplicity is that, you know already that 12grams of magnesium contains how many atoms

LL: six point…

T: 6.022×10^{23} atoms. Then 12grams that are given of magnesium contains *x*,

L: Uhmm

T: you simple cross multiply. 11:14

L: Yes

T: Then *x* is going to be is equal to *(writing on the chalkboard)* 12g of magnesium times 6.022×10^{23} atoms divided by 24grams of magnesium, than what are you getting here? *x* is going to be equals to

T+LLL: 3.011×10^{23}

T: Some times this one becomes even easier; you see what I use to tell learners, I said when you are working with standard forms especially when you are calculating numbers with degrees, this numbers you leave it as it is. What changes if, if you do this you get two there, this is one that just you cross multiply, you just this you divided by two than the exponent two then remain as it is.

LL: Ohoo!

T: Sometimes it does not requires you to go and find out, but you just to look at the ratio. You just have to look at the ratio. You can also be given; you can also be given these things in terms of; of mole I can also ask you this in terms of mole. I will say for example,

(Writing on the chalkboard) how many moles; how many moles are 48grams of magnesium or are in 12; how many moles are in 48grams. How many moles, these are still mole of magnesium, or how many mole of magnesium is 48grams. Okay! This is still the concept here, because you know there is already link. I will still not be challenged if I say; one mole of magnesium is how many grams?

LLL: 24

T: 24, that is what we know, that is what we know already that one mole of magnesium is 24grams. Then, *x* mole will be 48grams of magnesium. Isn't it?

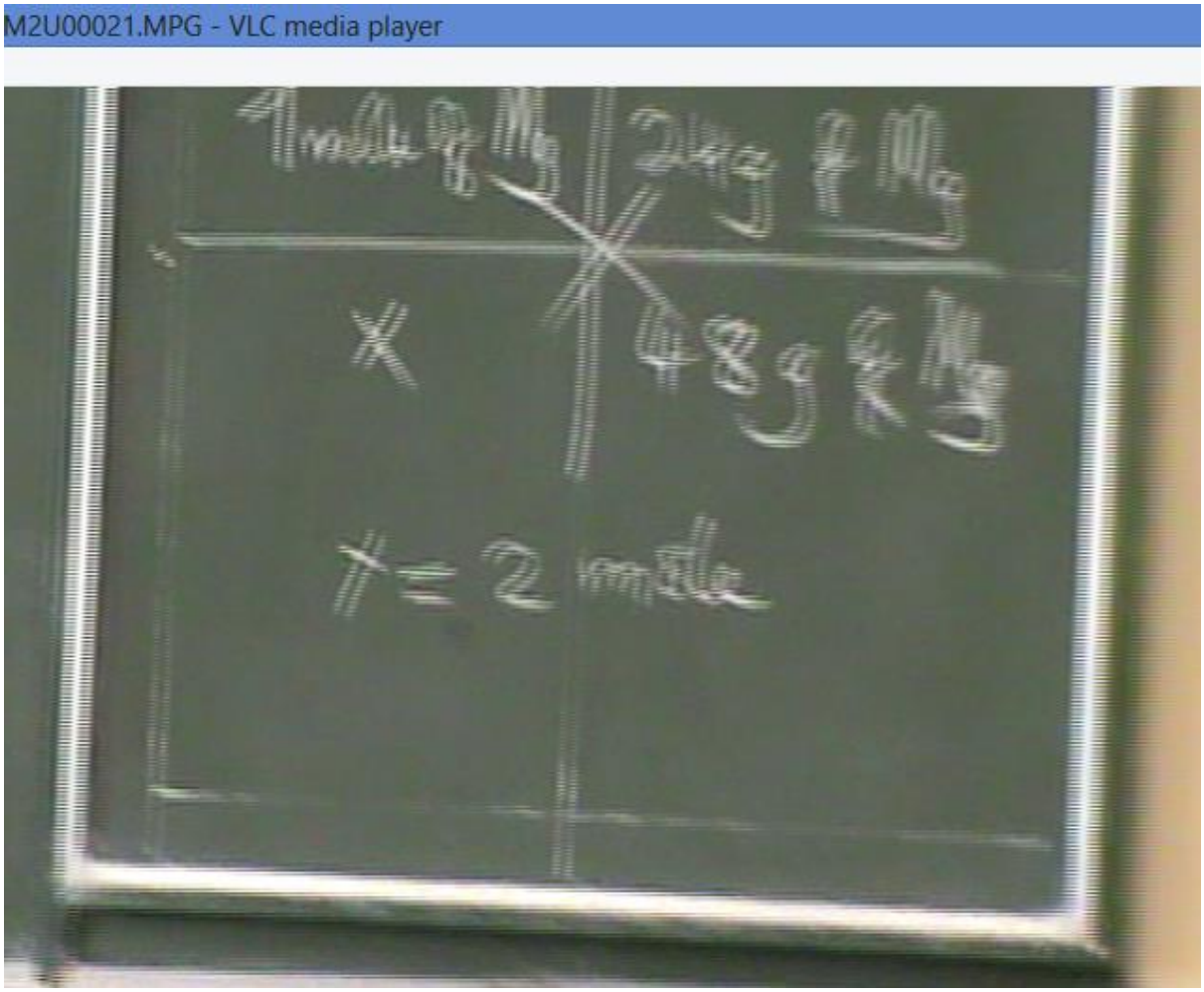
L: Ooo!

LLL: Yes.

T: Then how do we go on? Cross multiply; *x* is going to be….

LLL: 2mole, 2mole

157 *Teacher work on the chalkboard*

158 

159 **T:** Some people seem to be left out here? Den dede den! Are you okay?

160 **L:** Ummh.

161 **T:** Now I will see with the compound. Let's look at the compound, the compound that you
162 like most. Which one is that? 14:46

163 **L:** Carbon dioxide.

164 **T:** which compounds do you like most; Carbon three?

165 **L:** What is that?

166 **LL:** Yes.

167 **T:** Okay let's look at calcium carbonate.

168 **LLL:** Okay.

169 **T:** Are you sure is a compound?

170 **L:** Ummh.

T: There we talk about aaa…., with the compound we are talking about Mr ne; Relative Molecule mass. It can be relative molecule mass or relative formula mass depends on or you say formula mass M_r. I say is not mean that the grade; mind the way you write you r ne. (not Mr but M_r) Because sometimes you see people write Mr; there is that different. Okay now, this is still mass of one mole of a compound; mass of one mole of a compound M_r. Then, meaning that 1mole of calcium carbonate is how many grams? How many grams is one of calcium carbonate?

L: 6.point…

T: Is a 100grams.

L: Yes

T: Because the M_r for, for calcium carbonate is 100

LLL: Ooo!

T: Okay! Good, now this contains; it contains the particles of; it contains that; we are dealing with chemistry now.

LL: Oooo ….

T: Eeeeh. Because I said any mole of any substance ne; be an atom, a molecule, an element a compound we are talking about same amount of particles or atoms per 1mole. Now there I can still ask you, but this one I will give it to you as exercise. that eee how many particles are there; this particles of are; of calcium carbonate are there in a 50grams of calcium carbonate. Alright

(the teacher gave the learners some times to solve the question in their books)

T: (clapping hands together and moving towards leaners) may I check the first five. 18:55

LLL: Oh, the first five?

T: The first five. And some people they never seen my red pen at all.

LLL: (laughing)

T: (moving to his cell phone ringing and go out to answer it) you see now; who is this one calling me?

L: (laughing to the teacher when he is going out)

L: (busy doing the exercise given by the teacher but making a bit noise)

T: (coming back from outside) the first five. I can see one, two, three there, done at the newspaper; or who's newspaper, this one is KFC. Oh! KFC newspaper?

LLL: Yes.

LLL: (those who are done put up their hands and calling the teacher) sir, heir, sir, heir, sir

T: (teacher moving around marking learners works) you should write like…. I said you should be able to emulate from me.

T: (with another learner) you should learn to compare things. How many particles?

L: (boy laughing while the teacher marking his works)

LLL: sir… sir..sir

T: (With another learner) the question is, how many particles not how many chickens

After some times

T: Opuwo, it is over

LLL: (*those not marked complaining*) Aaye.. you are mot fair

T: You are not fair also. Eee; you are saying I'm not fair, Wilbart, what is your problem? Some people are attention seeker. They seek attention very good.

L: (girls laughing)

T: Okay! Okay!

LLL: (Calling again the teacher) sir, sir… here

T: aah! Aah aaha, I even extended for more than five.

T: (*on the chalkboard*) how many grams where given? We know; ei, what we know is that a 100g of this from these contains 6.025×10^{23} particles.

LLL: Yes.

T: Newspaper! Newspaper you know this. That is the first thing you will know. One mole, of calcium carbonate contains 100grames. 100grams contains that same amount of particles. Now! When you have that; thus are people seek for red pen. Now 50g of calcium carbonate will contain *x*. 24:27

LLL: Ummh.

T: will contain X. X will be equals to; X will be equals to

LL: (some learners mumbling, showing confusion)

T: (*writing the answer on the chalkboard without saying it*) x = 3.011 x 10^{23} particles

LL: Ooo, hamba sir osho ha ningi ngeyi (*so this is how he do it?)*

LLL: *start making noise*

T: What is the problem there? Oh! Yes. Or you just want the red pen. Now that I say some people will have their books….. okay!

235 **L:** (asking a question) Yes!

236 **T:** Ummh! (Giving a learners a chance to ask)

237 **L:** now you said, is the same question when if it say find the moles, is the same with molar
238 mass?

239 **T:** When we say find the moles, you have to find the relationship involves. If I said how
240 many moles are there in 50grams, if I say; (*writing on the* chalkboard) how many moles
241 of calcium carbonate are there in 50grams of calcium carbonate? Then this one, then this
242 one… one mole of calcium carbonate is how many grams?

243 **LLL:** 100 grams

244 **T:** 100grams of calcium carbonate. Then X mole will have 50grams of calcium carbonate.
245 Then you cross multiply. This it will be?

246 **L:** *(shouting)* 0.5

247 **T:** X will be

248 **LL:** 0.5….

249 **LL:** Half…. One half

250 **T:** Yah! Yes.

251 **L:** 0.5 is it mole or moles?

252 **T:** Ooo! Okay! Aaa. Is a very, is a very good intelligent question.

253 **LLL:** (*some are laughing*)

254 **T:** From tomorrow, Gerelda is asking that; moles and mole, you see some times you find
255 people writing this (mol) some time you find already. Okay one mole, moles. 28:15

256 **LLL:** mole.

257 **T:** plural, singular, which one is which?

258 **L:** Plural

259 **T:** Plural and singular

260 **LLL:** moles, plural

261 **T:** Now do we say 0.5 mole or 0.5 moles?

262 **LLL:** (*shouting*) Mole… Mole

263 **T:** 1 mole

264 **LLL:** (*Shouting*) moles … mole

265 **T:** one moles

266 **LL:** one mole

267 **T:** mole, but 0.5 moles

268 **LL:** Yes.

269 **LL:** (*showing confusion*) No…. why? … No.

270 **T:** it is a technical question, or is a 0.5 mole

271 **LLL:** (*shouting)* Yes… No.

272 **L:** 0, 2 or 3, mole

273 **LL:** 0.5 mole.

274 **T:** Eee! Is it moles or mole?

275 **LLL:** Moles

276 **T:** I think it is moles ne.

277 **LLL:** Yes. Moles,

278 **LL:** No.

279 **T:** Because we only use for one. One is when you say mole.

280 **L:** Yes.

281 **T:** But many

282 **L:** moles

283 **T:** No, if a 0.5 we can still say moles not mole, but when we say one, one mole of a
284 substance, and one moles how do we say; we say mole. There are word that already in
285 plural. You cannot say two peoples.

286 **LL:** (laughing) two peoples, peoples, two persons 29:56

287 **T:** Or two person

288 **L:** (laughing)

289 **T:** Okay we can say 0.5 moles is not a problem. Now let's go to calculating moles. This was
290 just an intro. Okay, now let's go to calculating mole. I would like us to look at three
291 things here. It is three things or four?

292 **L:** Four

293 **T:** Four things….

294 **L:** No, they are seven

T: (*teacher writes the four thing he is referring to on the chalkboard*) Moles of any substance, moles of solution, moles of gases; moles from equations

Now I was talking about quantities of substances. We have to look at moles in those, in those in four parts so that you can understand them very well. We take things like calcium carbonate; this is substance in a solid form included in the first paragraph of the mole. Mole four is from the equation; mole three is for gasses, mole two for solution, and one for any substance. I will tell you why I say any substance because we will come and look at that one. This is included in mole one. When you look at this solution, we talk about mole two there, and when we look at mole of gasses they will put it in different way.

Now mole one, number of mole is abbreviated n, according to what I give you, is mainly mass; let me write in full because clear people to see enough,

(*the teacher writes the equation for the number of moles on the chalkboard*) number of moles is equals to mass divided by the Ar or Mr whatever you use there. Here you are relative atomic mass or relative formula mass or molecular mass. That is mole one, when you are calculating there, you can use that one. Is not a problem if you use a relationship in a triangle kind of thing that number of moles is equal to mass over Ar or Mr is not a problem. (*The teacher draw the triangle on the chalkboard*)

L: Hmmm.

T: Moles of solutions, number of moles of solutions; number of moles of solution is equals to volume of the solution like this one I told you is 2.5L, is a 2.5L then there is a volume times it's concentration. we are also given concentration on most of the chemical container. Ee! We are given concentrations on those things. Sometimes they say is a two mole per dm cube or they give you a concentration of two or three depends. Moles of gasses, moles of gasses; number of moles is equals too; we have volume of gas, are we together there?

LL: *(shouting)* No! Yes.

T: No, I'm just giving you equations for now, than we will come later.

Is volume, volume is normally in which units? Eee!

LL: Cubes. 36:10

T: Okay we are going to come there later. n for gas is equals too volume, this volume is normally either in dm cube or but mostly we are going to use it here. dm cube times, times… 24 okay now we are saying that here, one mole of any gas occupy, occupy a volume of 24dm cube. One mole of any gas, if that gas weather carbon dioxide weather oxygen, one mole of every gas occupy a volume of 24dm cube. Now I will leave this one for a while,

LLL: okay

T: Then we will come here. (*giving the units involved*) The unit here is moles eee! dm cube over, dm cube per mole, this one cancels and units. Here number of moles should be

moles, volume should be dm cube, your concentration will be dm cube mole per dm cube. Then this one and this one will cancel each other than the answer will be in moles. Here your mass; mass should be in grams not in kilograms and this one we know already is grams per one mole from the periodic table eee.

L: Ummh.

T: Gram cancel gram the unit here will be still moles.

LLL: Ummm.

T: So, these are the three equations that you will use, these are the three equations you will use in moles. We have volume there, we have number of moles and we have 24 there. Here, we have number of mole, we have volume and concentration.

I will release you to go for the break.

LLL: Ummm. Thanks for the day.

L: Sir, are we coming back?

T: Yeah, because others are not there, and some of these things that are basic are might be in the exam we are coming back.

LL: Ooo we are coming back?

T: just leave your books there. 40:17

Classroom Observation
Teacher 2
Lesson 2 (30. 07. 2014)

Keys:
T1: Teacher 1
L: One learner talking
LLL: Whole class (Chorus)

T: (writing some questions on the chalk board 5 min) Okay! Now listen. I don't know who talking too much; otherwise we will have miss understanding. I want you to start from here first.

LL: From where?

T: (point to the chock board on questions on moles of any substance)

L: Is that six point, is that six?

T: Six point zero.

L: Ooo!

T: Six point zero because is caused from the gram. Eee! What's her problem?

L: Nothing.

T: Nothing and then you are talking. Okay! Now we, we are going to start here first. (Pointing to the chalk board) Then you are given the formula and then you just to start your way out, and the Periodic Table on the board is given.

LLL: Yes.

T: When you finish these two, you tell me before you come to this one….

(*after some minutes*) what is your problem, what is your problem?

L: My book

T: Go and get it. You see the problem I have with this; this front people.

LLL: Eee!

T: Too much of attention

LLL: (sitting in front) Aaye

T: Oshili! The much needed attention always Wilbart, Hileni, Velonica and Kambapila. Those one

LL: Too much attention. Attention seeker.

T: I said firstly, you know, two questions supposed to be 5minuts only. Oshili, you don't keep time and you waist time here. The formula is there you only plug in things.

(*Teacher start moving from one learner to the other*)

T: (*Attending one learner*) Then is not a problem, you know, you are calculating mass of substance. 08:16

T: I will only mark the first people to finish. (Teacher walking around the class checking learner's works) are you done? (Teacher marking learner's book) the people are too slow. Those I marked you can continue to the second part of mole.

L: (busy discussing the works given to then)

T: I was just asking for a simple thing here.

L: (Those that are done calling the teacher to come and check their works)

T: Hints. Here, aaa, $1dm^3$ is equal to $1000cm^3$, because is very difficult. You are not going to; this is dm^3 this is cm^3 you need to change this to dm^3.

L: Ooo.

T: Yes. You see this one is dm^3, that's why when you use this one it will becomes a problem. There is a hint there.

L: (those who are done calling the teacher to come and check their works) Sir, sir, sir.

T: some peoples are too quite. yeee. I don't know if they done it or withdrawn. Tellif; Japheth; what's going on? Aaaa, then here this ……. A a a a a a a ah ah will not …..

T: (shifting to different learners) what's going on here, Is everything too difficult?

L: No!

T: But you are not calculating, or you are already at part B?

L: Yes.

T: Where is the first one?

L: Is this one.

T: The answer for this one? Zero point five, mind, mind your own investigations (Teacher moving to other learners)

T: (Teacher speaking in vernacular language) Meme Paulina, opo ngaa tatu yeni? The first one only, you are too slow, very slow, and you? Peter! This is too slow; this is only mass number of moles the unit. They are, cancel grams than, there only moles. This one is correct…… 15:46

T: (Moving to the next learner) Kefasy! What was the question, how many moles, no! that one was how many grams. You listen to the question and here I don't know, how did you do to get this one. There is a formula, number Ar or Mr, here is it this is mass. Now you are calculating mole number of mole or mass is equals too number of mole times Ar. (speaking in vernacular language) Inwii ningila we otolongo ngiini ano?

T: (moving again to the next learner) what are we going to do here? This one is fine. This one is where did you get 6.0?

L: From the question

T: This one, the relative formula mass of this one is what? What is the Mr of copper sulphate? How do you work about it, 64 copper, 32 that 16 times 4 this, what are you getting? Is the one you are going to use here, and the answers should be in grams.

T: (Moving again to other learners) there is no unity here, is a problem you and is too dangerous you are operate without units

T: (shifting to next learners) Karel what's going on here?

LLL: (those who are done calling the teacher) Sir! Sir! Mr Mbekele, Mr Mbekele, Mr Mbekele!

T: Tegelela manga, (*meaning wait a bit*)

LLL: (laughing and keep on calling the teacher) Mr Mbekele, Sir! Mr Mbekele, Mr Mbekele, Sir!

T: Now everyone, who, who am I going to look at?

LLL: (Shouting loud) me! Here! Me!

T: (moving fast trying to mark everyone's book) ummh! ummh! unnh! This one mass, mass, mass, mass, Mass, Mass, mass

LL: (Discussing after their books were marked) it is the mass not moles, the unit was supposed to be grams

T: Where are we madam?

LL: we are here.

T: Where did you get this one from? No! it is mass we are looking for, the mass of copper sulphate. Then you see is equal too number of mole times Mr.

LLL: (still calling the teacher) Sir! Sir!

T: Ah aa! I'm not coming to you anymore.

L: Oh! Iyaloo (some learners laughing) why?

T: (shifting to learners that are setting at the back of the class) let's keep going, let's keep going, now what to use a formula? Than is mass, mass is has been here mole is in mole. Gapes what is your problem? Calculating numbers of mole, number of moles per unit is moles. 21:26

T: Mass is in grams, mass is in grams and concentration…..

L: (those who are not done still buys discussing, while the buys marking those that are done.)

T: Mass is equal to number of mole times Mr, number of mole you are given in …… Mr of copper sulphate …… here you are shown one dm^3 it is a thousand cm^3 now is what?

L: cross multiply

T: yes, you cross multiply

T: (*Shifting to the next learner*) VL if things are out, what is this? You are calculating Mr or mass? Mr is not you are using this. Mole okay is fine, you don't abbreviate mole. Let us not abbreviate moles. Here, you did not asked for one solve you get it one time it's okay.

T: (moving to the next learners and checking their progressing)

L: (some group of girls asking teacher a question) are we allowed to give answers on fractions

T: (did not here clearly girl's question) Are you allowed to do what?

LL: (girls talking same time repeating the other learner's question) to write your answers in fraction?

T: Aaa, like what?

LL: Like for 0.005

T: aaha, just keep it that way. …. I can only accept a half, 0.5

L: (some boys' discussion on the back ground) did you get 0.5? Ummh.

L: (Girls in front continuer) Ooo! But this one is ….

T: (make it clear to the whole class about girl's question) Zero point whatever just keep it like that

LLL: Oooo!

T: Unless you give it in standard form but I don't like it. But I don't like it a number in fraction. (Teacher moving to one boy's name Namalus and speaking laud) Namalus Gregoli is too quiet!

L: Aye! Aye! Aye!

T: (moving to the chalkboard) Okay, let's go for the first one.

L: (those that are not done) No! Sir.

T: Yess!

L: The last one. 25:17

Giving feedback or answers on the chalkboard together with the learners

T: The first one, almost everybody got it. Number of mole is equals to mass over Mr; the mass is give is 6.0grams over the Mr I said that is a mass per 1mole of a substance carbon is 12grams per 1mole cancel out you get 0.5. (***The teacher uses M_r for an atom***)

LLL: mole

T: I said don't abbreviate mole.

LLL: Yes.

T: Don't abbreviate it. You give things that... Then you come to mass, mass is equals to number of moles times the Mr. Than we know already that here we given 2mole times 160grams per mole. Mole is cancelled, this is going to 360

LLL: 320

T: Ooo! 320grams. That is it. Then I come here, some people don't know how to convert from centimetre to decimetre. From centimetre to decimetre you simply divide with a thousand. Yes, because if you say 1 decimetre is, is going to be a thousand centimetre cube. Then 50 is going to be X you cross multiply like that. Isn't it?

L: Yes.

T: It's is too long then you just takes 50cubic centimetre divided a thousand. Then you get your 0.05dm^3. Now if you get your 0.05dm^3 then you multiply it by two, because here you are going to say, number of mole is volume times concentration. Your volume is 0dm^3, 0.05 times two mole per dm^3. Dm^3 cancel dm^3 your answer will be 0.1mole. I like new things …and I don't like that. In fact here there is no such thing.

T: (continue with giving correct answers to learners) yes then when it's comes to this one (Questions 3 & 4), don't link this two questions are not the same. This one is different. Calculating the concentration of hydrochloric acid in 2mole of this? Now how do you go about that one?

L: (not sure of the correct answer) number of mole ….

T: point of concentration. Concentration is equals to what?

LLL: (answering in a low voice) number of mole …

T: Concentration is number of moles divided by ….

LLL: volume.

T: Volume. Then, how do you go about what the mole, two mole…..

L: (boy's voice) Divided by 0.02

T: zero point?

LLL: Zero point zero two

T: 0 point 0

LLL: 2;

T: 2

T: dm^3 ne? Then the answer is?

LLL: 100. Moles. 29:02

T: Okay. is easy. Those things you should just work out with the formula.

L: (boy's voice) Yes.

T: (knocking at the chalk board) I'm looking for the answer to C now.

L: to C?

T: Yes.

(the teachers move through the class checking learners' works)

L: (a girl rise up her hand)

T: I'm looking the answer to C.

LLL: (pointing their hands up) Sir, sir.

T: (moving toward one learner) what is this? No unit, centimetres, millilitres?

L: (Talking at the background) what is this?

T: (continue to mark learners works) attention to you, unit my friend.

LLL: (calling the teacher) sir! Sir!

T: Unit, unit, unit, unit, unit. What is this? Your answer yes, but it should not like this.

L: where is the pencil?

T: your things should be rounded correctly to the right significant figures.

T: (with another learner) You should just give, your answer you should always give three significant figures or if there is aa….

L: (chatting in front while the teacher still buys helping other learner)

T: Which one? But I don't what to see this. You cannot put the entire calculator ….. You don't ……

T: (moving to the learners at the back) you give your moles in starting …….. (Moving forward and the voice of learners increasing)

LLL: (calling the teacher) Mr Mbekele!

T: (chatting with some boys when marking their works and together starting laughing) Terrif, correct this mole, you see what happen? That is the mistake of the day. 34:19

LLL: (some boys laughing loud) mistake of the day.

T: That is the mistake of the day. (Writing at the chalk board) 000.208; that is the mistake of the day.

LLL: (all laughing loud and some continue calling the teacher) Mr Mbekele!

T: Okay, okay, okay.

LLL: (calling the teacher) Sir! Sir! Sir! Sir!

T: Okay! I know we are almost there, and all most everybody is doing well.

T: (tells learners to minimise their voice) Ei! Ei! Ei! Mind the way you open your mouth. Okay! Aha! Aha! Aha! Okay now what I was saying is dx is, we only avoid some of the mistake like the one I sow here. Aah ,

(giving the answers on the chalkboard) 37:00

T: we are calculating the how many number of moles, number of mole is going… divided by, now are going this $0.05dm^3$ divided by $24dm^3$ per mole. What are you getting here?

LLL: (all answer) 0.00021

T: Not dm but mole ee!

LLL: Mole

T: Okay! Now I thing ….. what you have learned here …easy learners. (Beating at the table) you are not yet experts don't celebrate. What you have learned here there is no difficult. The three types of moles, you must always know, are you dealing with a solution, are you dealing with a substance, are you dealing, and you should know those formulas. Whenever you are given something to calculate you should be able to identify, I'm give mass, I'm given volume, I'm given concentration or I'm given mole. So that from there, you should be able to determine which formula are you going to use. You should be able to determine which formula you are going to use. 38:55

Now I want us to introduce the most challenging, but the easiest of all; moles from the equation. Most challenging, let's take a simple equation. A simple equation can be sodium, sodium let's take…

LLL: Chlorine and sodium.

T: reacting with sulphuric acid will give

LL: Sodium sulphate.

T: Sodium sulphate ee?

LLL: Ummh!

T: Plus?

LLL: Hydrogen

T: a hydrogen gas. That is a simple equation and I like the equation because it contains almost everything in one. Now let's look at the equation, is it balance?

LLL: Nooo! No!

T: Then what can we do?

LLL: add two. Add two at the beginning.

T: add two there!

LLL: now is balance. Now is balance. It's balance.

T: now is balance.

LLL: yes is balanced.

T: okay. Now let, let us express the equation. Let us define what equation means. We are going to look at in term of mole and we are going to look that in term of mass.

LLL: Ohooo!

T: In terms of mole, the equation tells me that, two moles of sodium reacted with one mole of the acid producing one mole of sodium sulphate and one mole of a hydrogen gas. I'm now telling what the equation is telling me about mole. In terms of mole the equation the equation is telling me one mole, two mole of sodium; reacted with two mole of…

L: sulph….

T: the sulphuric acid producing one mole of sodium sulphate and one mole of gas.

LLL: gas.

T: in terms of mass.

L: Ummh!

T: It is telling me that, this is what okay, of sodium

LLL: Yes.

T: reacted with aaa, this one we think what the the mass of …… is it 132, 64 plus 32,

LL: it's120,

T: eh!

LL: 160

T: Aye, is not 160 it does not go to 160. This is 95 I think. 2 plus 32…

T: (teacher writing on the chalk board) Plus 64

L: (boy's voice) 88

T: 88 eee!

LLL: Yes.

T: Is it 2, 32, 64,

LLL: 98, 98, 98

T: To give, how many moles are we talking about here, 23 × 2, 82, 64 what we are having? Umh, un level one.

LLL: 3.142

T: 142 I can just hear anymore 146 this is un level 10

L: 142.

T: 142.

L: Yes.

T: You see, this is an expression that you have people to understand moles from the equation. Sometimes you are given a problem that a certain chemical reaction have taken place. The first thing you are going to be asked is to add that balance. The second one, they will than make reference if you, for example they use 50grams of sodium, then how much? Of this (pointing at the products) will be produced?

LLL: Ummh.

T: Or if 50cm^3 of certain volume of hydrochloric acid completely reacted with sodium how much gas is going to be produced? You listen; this equation makes you to understand that, this products based on how much was reacting. Isn't?

LLL: Ummh.

T: Therefore, I can use information of the product that is to find how much that is reacted, or I can use the, the reactants to find how much is produced. You can only do that if you understand a relationship in terms of moles and in terms of mass. We are not always in stated that. I will give you an example. I'm only give you that you should be able understand this from the equation like, and equation like this, this is two moles of sodium reacting with one mole producing one mole of sodium sulphate one mole of gas. This is a 40… 46, this is 46grams according to the equation now; this is 46grams of sodium that reacted with a 98grams of sulphuric acid producing all from two element in the reaction respectively. Now I will give you an example base on that equation. The equation is already balanced. I will only give you the first question.

If a, if 20grams of sodium completely reacted with the acid, to…, or determined the mass of, okay then I will give you that is one now two, (*if 20 g of Na completely reacted with the acid to produce Na_2SO_4, determine the mass of Na_2SO_4 produced.)* I will ask you to calculate the concentration, (*calculate the concentration of the H_2SO_4 of the volume of H_2SO_4 acid reacted is 50 cm^3)* okay I give you those just few simple ones to give the direction and to see what we are doing when calculating moles from the equation.

I told you, you are given a situation where by you are given a chemical equation, is not the same like you were doing there. There, there were no chemical equation you were only give mass and molar mass. But now in the situation where there is a chemical equation sometimes you have to use a relationship from the equation plus those formulas, plus those formulas. I, I, I will fist punish you if I say calculate let me do the first one. The first one the equation is what is needed, the equation is this one, (writing the equation on the chalkboard) you see the equation is this one. Now they said, determine the mass of sodium sulphate that is going to be produced when 20grams of sodium reactive.

Determine the mass of sodium sulphate that will be produced when 20grams of sodium reactive.

LL: Ooh.

T: That one is simple. I will do it in many ways at least two. The first one I will say, from the equation, I'm having that, what is the mass of this one (2Na) from the equation

LLL: 23grams.

L: 46

T: 46grams.

L: Ummh.

T: of sodium produced, what is the mass of this one (Na_2SO_4)?

L: 142

T: 142grams. That is what I get from the equation. From the equation I am getting that, that produces that. Then I will say given 20grams of sodium produce X. then I will cross multiply. X will be 20grams of sodium times 142 of sodium sulphate divided by 46grams sodium. Grams of sodium cancel grams of sodium, what is the answer here?

LL: (not sure with the answer) 61.04

T: and then I don't trust you calculators. Your calculator sometimes are switch on radius when you are using ….. (Teacher making sure about the answer by as well using a calculator) Okay, this is what we can do, and is the easiest way. There is a longest way also. The longest way is when you say, you are going to convert that mass to moles. Then you say number of moles is equals too, aaa! Mass divided to Mr. Then you say 20grams of sodium divided by 23. Mr of sodium is 23 ne?

L: Ummh.

T: According to the Periodic Table, don't make mistake that you are going to use 46. 46 is not Mr, umh, this is just a mass according to the ratio, Mr is a mass per one mole. Then here you divide you got zero point what? Ee!

L: 0.344

T: Zero point …

LLL: 87

T: 87

LLL: Yes.

T: moles. Eee! Moles ne.

L: Eeeye! (yes)

T: Then from here, with those two your equation, ee! From here you go to your equation, and then say… I told you when I talk on a chalk board you listen and look at me.

Then you say according to your equation, two moles of sodium produces one mole. Two moles of sodium produces one mole of sodium sulphate.

LLL: ummh!

T: Two moles of sodium produces

T: Now that one is from the equation? Then you come here, given 0.87 but remember if that was a formula you leave it like that. But this is counted use your full calculation in these things. Of Na produces X. then you will get like X, X will be equals to 0.4… 43 ne use your calculator. X will be equals to what?

L: (girl's voice) 0.43, 0.43 …..

T: The best way is to press your calculator again. 20 divided by 23. Let's see 20 divided by 23

L: Ummh.

T: Equals to that.

L: Ummh.

T: Divided by 2.

LLL: Ummh. 0.43, 0.43

T: So X, X is equals to 0.4….

LLL: 3… 3.

T: 3. Mole. These moles are for who?

L: (just talking) for me.

T: For sodium sulphate eee!

LLL: Yes.

T: You are not done then.

L: (surprised) Oi…

T: Number of moles is equals to mass divided by Mr. Now you are looking for mass. Then you are saying, mass is numbers of mole times Mr, this is equals to how? That answer don't, don't switch it off now use it like that, mole times the Mr of that one is, the Mr of that one is 142grams

LLL: 61.7, 61.77

T: You are going to get these things, but our problem was, that one is too long.

L: Yes.