Exploring how Grade 11 chemistry teachers make use of the periodic table of elements when mediating learning of writing and balancing chemical equations

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By

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Declaration

I, Reginald Ndeshipanda Kambeyo (19K2069) hereby declare that this thesis is my own original work and has not been previously submitted in any form for assessment or for a degree in any other higher education institution. All ideas, quotations and other materials used in this study derived from the work of other people have been acknowledged using complete references according to Rhodes University Education Department Guidelines.

Signature Date: 19 September 2021

Dedication

This piece of work is dedicated to my precious daughters Nelago Tuyambeka and Kaunapawa Tuhafifa and to my husband Linus Kambeyo for their immense support through this journey.

Acknowledgments

I would first like to extend my special thanks to my supervisor Professor Kenneth Mlungisi Ngcoza. Equally, I want to express my sincere gratitude to my co-supervisor Dr Zukiswa Nhase. Your motivation, guidance, enthusiasm and most of all your immense knowledge helped me to make this piece of work a success. You did not only make my master's journey so wonderful but you also helped me grow professionally as an educator.

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Most importantly, this study could not have happened without my beloved husband, Dr Linus Kambeyo and our lovely daughters Nelago and Kauna. I have neglected you when you most needed my presence. All I can offer now is a sincere thank you for allowing me to complete this study.

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Abstract

The periodic table of elements is central to the study of chemistry and other disciplines of science, yet Namibian learners do not perform satisfactorily in topics which require its use in answering questions. The purpose of this study, therefore, was to explore how Grade 11 chemistry teachers make use of the periodic table of elements to mediate the learning of writing and balancing chemical equations.

The study was carried out with two chemistry teachers in two rural schools in the northern part of Namibia. It was underpinned by an interpretive paradigm, within which a qualitative case study approach was employed. Data were collected through in-depth interviews (semi-structured and stimulated recall interviews), observations, and participants' group reflections. The latter afforded the participants and myself room to reflect and share ideas at the end of the data gathering process. I used Shulman's Pedagogical Content Knowledge as my theoretical framework in this study and the data sets were analysed using the five Topic-Specific Pedagogical Content Knowledge (TSPCK) components adapted from Mavhunga and Rollnick.

The findings revealed that teachers demonstrated positive attitudes towards the use of the periodic table of elements when teaching the writing and balancing of chemical equations. However, challenges regarding inadequate materials that hindered the teaching and learning process were observed. Another finding of this study was that teachers used a variety of mediation tools such as prior knowledge and appropriate representations to enhance learning. However, during lesson observations, the findings revealed that there was an imbalance in the knowledge of using easily accessible resources as opposed to what teachers had indicated during the semi-structured interviews. Nonetheless, teachers' group reflections influenced them to analyse and improve their lessons. The study thus recommends that there is a need for continuing professional development for chemistry teachers so that teachers can be afforded opportunities and spaces to share subject matter knowledge, pedagogical content knowledge as well as easily accessible resources that they can use to enhance teaching of chemistry in their classrooms.

Keywords: Chemistry; periodic table of elements; balancing of chemical equations; pedagogical content knowledge; topic specific pedagogical content knowledge

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List of Abbreviations and/or Acronyms

ACE:	Advanced Certificate in Education
CK:	Curricular Knowledge
CPD:	Continuing Professional Development
LCA:	Learner Centred Approach
MoE:	Ministry of Education
NCBE:	National Curriculum for Basic Education
PCK:	Pedagogical Content Knowledge
PK:	Pedagogical Knowledge
PT:	Periodic Table
PTE:	Periodic Table of Elements
TSPCK:	Topic-Specific Pedagogical Content Knowledge
UNAM:	University of Namibia
UNICEF:	United Nations International Children's Emergency Fund
UNESCO:	United Nations Educational Scientific and Cultural Organisation

CHAPTER ONE: SITUATING THE STUDY

1.1 Introduction

The main aim of this study was to explore how Grade 11 chemistry teachers make use of the periodic table of elements to mediate learning of writing and balancing chemical equations. The study was triggered and motivated by the fact that the periodic table of elements is the cornerstone of learning and understanding chemistry. Similarly, whether it is learning science at school or studying science-related courses at college or tertiary level, chemistry as a subject plays a pivotal role. It was prudent, therefore, for me to understand teachers' instructional practices when mediating learning of chemistry.

In this chapter, I thus describe the background of the study based on the National Curriculum for Basic Education (NCBE) in Namibia. This is followed by my personal experiences, the statement of the problem, and the significance of this study. The research goal, research questions, and summary of the theoretical and analytical frameworks of the study are highlighted. Lastly, the key concepts used in the study are defined and the thesis outline is provided. I end with a chapter summary.

1.2 Background of the Study

After Namibia gained her independence in 1990, the Namibian constitution demanded that every person has the right to basic education from Grades 1-12. Based on this, the NCBE was introduced which is a document that gives direction to planning, organising, and implementation of teaching and learning (National Institute for Educational Development [NIED], 2016). Further to this, Vision 2030 was launched in the year 2004 (Republic of Namibia, 2004), which stipulates Namibia's dream to become a prosperous and industrialised nation developed by her human resources, enjoying peace and harmony and political stability by the year 2030.

Notably, in an attempt to respond to the challenges and demands of education and to those of the Vision 2030 document, the Namibian curriculum has gone through several reforms. Unsurprisingly, this curriculum reform in Namibia is similar to that of South Africa's outcome-based curriculum (OBE) which was introduced in the year 2005 and henceforth called Curriculum 2005 (C2005). However, this curriculum transformation came with changes in the teaching methods. That is, it advocated a change from teacher-centred education (TCE) approaches to more learner-centred education (LCE) approaches, in which learners are required to play an active role in their own learning (Nyambe, 2008). In other words, learner-centred education places emphasis on the interaction between the learners and the curriculum content, and teachers are regarded as facilitators. This basically translates into the need to consider teachers' subject matter knowledge (SMK) and as well as their pedagogical content knowledge (PCK) (Shulman, 1986).

Like in any other country globally, the NCBE recognises natural sciences as one of the key learning areas. It acknowledges the immense importance of the inclusion of natural sciences in the curriculum as these subjects help learners learn how to manipulate and relate to the natural environment. Also, natural sciences play an important role in any society in any country and offer a value-framework of the sustainable use of matter, energy, and processes in living and non-living things (Namibia. MoE, 2010; 2016). The aim of natural sciences in the senior secondary phase is further stipulated in the extract from the NCBE below:

Table 1.1: Extract from the NCBE

Natural sciences	Learners use methods and skills to develop simple scientific models on the basis of existing and new information, and communicate their investigations, analyses and conclusions using scientific and mathematical language, theories, laws and principles. They apply and generalise scientific knowledge to everyday situations, understand the value and vulnerability of the natural environment, as well as actions that affect the environment negatively, and know how these can be countered.

Source: NIED, 2016, p. 27

From this excerpt, it is clear that the national curriculum is very explicit on the expectations of the teaching and learning of natural sciences. In order to achieve these aims and expectations, the curriculum highlights the key subjects as biology, physics, chemistry, agricultural science, geography, and computer science. This study focused on chemistry. According to Uchebu,

Oguoma, Elenwoke, and Ogbuangu (2016, p. 1), "Chemistry is one of the science subjects where students are taught in secondary schools to prepare them for Science based courses at the tertiary levels and if not properly handled may affect their performance at higher levels". In addition, these authors further emphasise the significance of chemistry, in that it plays a role in unifying other science subjects. Moreover, it is also argued that in other countries such as Gambia and Nigeria, chemistry topics are important because they contribute to the improvement of scientific reasoning (Adu-Gyamfi & Ampiah, 2019).

In Namibia, physical science is a compulsory subject taught from Junior Secondary (JS) level, that is, in grades 8 and 9. It covers aspects of chemistry and physics. After completing the JS level, learners proceed to the senior secondary phase in order to obtain a Namibian Senior Secondary Certificate at Ordinary level (NSSCO). According to the revised Curriculum for Basic Education, at the NSSCO level, physical science is split into two components, namely chemistry and physics and these are taught as separate subjects (Namibia. Ministry of Education, Arts and Culture [MEAC], 2018). This suggests that teachers may choose to teach either physics or chemistry depending on what their strengths are in terms of SMK (Shulman, 1986). It seems that this is indeed a relief to most teachers, as the challenges of teaching a complex physical science subject (combination of physics and chemistry) has been reduced. This study therefore focused on chemistry at the senior secondary phase, that is, Grade 11.

Furthermore, the chemistry curriculum (Namibia. MEAC, 2018) outlines some of the aims as to:

- "Provide, through well designed studies of theoretical and practical science, a worthwhile educational experience for all learners, whether or not they go to study science beyond this level and, in particular, to enable them to acquire sufficient understanding and knowledge;
- Develop abilities and skills that are relevant to the study and practice of Chemistry and useful in everyday life;
- Develop attitudes relevant to Chemistry such as: concern for accuracy and precision; objectivity, integrity, enquiry, initiative and inventiveness;
- Stimulate interest in, and care for, the environment; and
- Promote an awareness that scientific theories and methods have developed, and continue to do so, as a result of the co-operative activities of groups and science transcends national boundaries and that the language of science, correctly and rigorously applied, is universal" (pp. 2-3).

From the aims above, it is clear that chemistry as a subject, places a strong emphasis on the learners' understanding of the physical and biological world around them at the local, regional, and international levels. In particular, it aims for learners to acquire sufficient understanding and knowledge to become confident citizens in a technological world (Namibia. MoEAC, 2018). This makes chemistry a prerequisite subject for most science-oriented courses in tertiary institutions and this calls for the need to teach it effectively (Adesoji & Olatunbosun, 2008).

Furthermore, the teaching of *content* in the Namibian curriculum is arranged in such a way that learners move from the simple to complex and more complex concepts. For instance, the content is divided into themes followed by topics arranged according to their level of complexity. The topic of writing and balancing equations is covered under theme two "Matter" which comes soon after the learners are introduced to theme one, "Scientific processes". Topic 2.3 focuses on the periodic table of elements followed by topic 2.4, Bonding and structure of matter. Writing and balancing equations is topic 2.4.6, and it is the last to be covered in this theme. The extract below shows the objectives that should be met under the topic of writing and balancing equations.

Table 1.2: Extract from the Namibian Chemistry Curriculum

TOPIC	**GENERAL OBJECTIVES** *Learners will:*	**SPECIFIC OBJECTIVES** *Learners should be able to:*
2.4.6 Writing and balancing equations	• know how to write word equations and balance simple equations	• use the symbols of the elements to write the formulae of simple compounds • deduce the formula 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 • deduce the formula of simple compounds from a model • construct word equations and simple balanced chemical equations (including simple ionic equations) • deduce the formulae of compounds, molecules and compound ions – see hydroxides, phosphates, nitrate, (hydrogen) carbonate and sulfate as oxyanions that bond in the same ratios as anions of elements in Groups V, VI and VII – see the ammonium ion as a compound cation bonding in the same ratio as cations of metals in Group I

Based on the extract above, learners will not be able to understand writing and balancing chemical equations without having a good understanding of the periodic table of elements. To be able to use the symbols of the elements to construct formulae and equations, one needs a thorough understanding of the group properties and how elements bond to form molecules and

compounds, respectively. In is recognised, however, that in order to achieve the aims and objectives of the chemistry curriculum, the teachers' PCK plays an important role, as reiterated by scholars such Shulman (1986) and Mavhunga and Rollnick (2013) to mention a few.

1.3 My Personal Experience as a Teacher

Reflecting on my teaching experience of 12 years as a physical science teacher, I observed that the learners' performance in the two components of physical science differ, whereby learners perform better in physics compared to chemistry. Also, being a national marker for the Junior Secondary Certificate (JSC) for physical science, I noticed that learners do not perform well, specifically in the questions related to the periodic table of elements such as periodicity, chemical bonding, writing and balancing chemical formulae and equations, just to mention a few. For instance, a typical examination question could be as follows:

The reaction between calcium carbonate and hydrochloric acid is a neutralisation reaction.

a) *Write a word equation for the reaction.*

   Hydrochloric acid + **calcium carbonate** → **calcium chloride** + **carbon dioxide** + **water**

Based on my observation, writing word equations does not seem to be a problem for the learners since the information needed is always provided within the question.

b) *Write a balanced chemical equation.*

$$\mathbf{HCl_{(aq)} + CaCO_{3(s)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}}$$

To write and balance the above chemical equation, learners are basically required to refer to the periodic table of elements and recall the basic properties of elements in terms of gaining and losing electrons during chemical bonding. This will enable them to write the correct chemical formulae of the compounds involved in the reaction, for instance, hydrochloric acid and calcium carbonate as presented in the word equation. Failing to write the correct chemical formulae will result in an incorrect chemical equation and being able to balance it. This has been a common problem over my teaching years and my assumption is that it is the main cause of many learners scoring low marks and eventually failing the examinations.

Furthermore, my observation was backed up by the NSSCO examiners' reports for physical science for the years 2014, 2015, 2016, 2018 and 2019. These reports revealed that learners do much better in physics topics compared to the chemistry topics. The examiners' reports further indicate that learners' performance in the topics related to the periodic table of elements was not satisfactory. For instance, the examiner's report for 2018 highlighted the following;

> The majority of learners failed to write the chemical formula for Chlorine and Aluminium thereby losing marks for balancing the equation. Most learners wrote chemical equations rather than word equations and teachers should place more emphasis on inclusion of transition elements. (Namibia. Ministry of Education [MoE], 2018, p. 435)

Based on the aforementioned background, my assumption was that the poor performance in the chemistry section might be influenced by the understanding and the use of the periodic table of elements by the teachers. I observed that no study has been conducted in Namibia to date which looks at the periodic table of elements and how it is used by chemistry teachers in their teaching. I therefore developed an interest to explore how Grade 11 chemistry teachers make use of the periodic table of elements when mediating learning of writing and balancing chemical equations in particular.

Notably, there are a number of studies that have been conducted in Namibia on how teachers mediate learning of chemistry topics. For example, Hoepfner (2014) conducted a study on atoms and molecules, Chani's (2014) study focused on chemical equilibrium, and Kanime's (2015) and Denuga's (2019) studies were on stoichiometry. These scholars revealed that teachers were trying their level best to mediate learning in order for learners to make sense of abstract concepts, but it was evident that they were constrained by limited PCK (Shulman, 1986). From these findings, it could be deduced that chemistry teachers seem to fail to select appropriate teaching strategies during teaching and learning. Having looked at the work done by these scholars, I observed that they did not address the understanding and the use of the periodic table of elements in these chemistry topics. Yet, the periodic table of elements as alluded to earlier is a cornerstone for chemistry. Thus, my study sought to close that gap by exploring how Grade 11 chemistry teachers make use of the periodic table of elements in their classrooms, focusing in particular on the writing and balancing of chemical equations.

1.4 Statement of the Problem

The periodic table of elements is central to the study of chemistry and other disciplines of science, yet the Namibian learners seem to struggle on how to use it as a resource. As a result, they perform poorly in chemistry. Literature has shown that one of the reasons for this poor performance is in part due to the fact that some teachers possess limited knowledge of the teaching approaches and methodologies (Chani, 2014; Denuga, 2019; Hoepfner, 2014; Kanime, 2015). It is against this background that this study sought to explore how the Grade 11 chemistry teachers make use of the periodic table of elements when mediating learning of writing and balancing chemical equations.

1.5 Purpose and Significance of the Study

Since the periodic table of elements is an important scientific concept across various disciplines of science, it is thus important to understand the teachers' perspectives, experiences, and pedagogical insights on the use of the periodic table of elements in chemistry topics. Identifying the understanding possessed by the chemistry teachers and how they use the periodic table of elements to mediate learning of writing and balancing chemical equations might not only benefit me as a researcher, but might inform our practice as chemistry teachers and enable us to help learners develop an interest in the subject we teach. The outcome of this study might also be beneficial to other practicing science teachers, subject advisors, curriculum developers, and textbook writers.

1.6 Research Goal and Research Questions

My intention to observe some chemistry teachers in two secondary schools in the Ohangwena region was to pursue the following goal, guided by the research questions mentioned hereunder.

1.6.1 Research goal

The main goal of this study was to explore how Grade 11 chemistry teachers make use of the periodic table of elements to mediate learning of writing and balancing chemical equations.

To achieve this goal, the following research questions were addressed.

1.6.2 Research questions

1. What are Grade 11 chemistry teachers' perspectives, experiences, and pedagogical insights on the use of the periodic table of elements in their chemistry lessons?

2. How do Grade 11 chemistry teachers make use of the periodic table of elements when mediating learning of writing and balancing chemical equations?

3. How do stimulated recall interviews and group reflections influence Grade 11 chemistry teachers' understanding of and the use of the periodic table of elements when mediating learning of writing and balancing chemical equations?

1.7 Theoretical Framework

This study is underpinned by PCK (Shulman, 1986). The PCK is a teaching theory focusing on pedagogical knowledge which teachers draw on to teach learners. It is a way of thinking about the transformation of knowledge into a format which makes it easier for leaners to understand. Within the field of PCK, I drew on the seminal work of Mavhunga and Rollnick (2013), and focused on the five-topic specific pedagogical content knowledge (TSPCK) components as my analytical framework.

1.8 Data Gathering Techniques

- Semi-structured interviews;
- Lesson observations;
- Stimulated recall interviews; and
- Participants' group reflections.

1.9 Definitions of Key Concepts

Chemistry: The branch of science concerned with the substances of which matter is composed, the investigation of their properties and reactions, and the use of such reactions to form new substances.

Chemical equations: A symbolic representation of a reaction in the form of symbols and formulae.

Periodic Table of Elements: A tabular display of the chemical elements which are arranged by their chemical properties.

Pedagogical content knowledge: The representation and transformation of subject matter knowledge to make it comprehensible to others (Shulman, 1986).

Prior (everyday) knowledge: Experiences which learners brings into the classrooms which originate from home, cultures, communities, and/or from previous grades.

Subject Matter Knowledge (SMK): Encompasses an understanding of the various ways of how a discipline is organised or understood as well as of the ways by which a discipline evaluates and accepts new knowledge.

1.10 Thesis Outline

The thesis consists of six chapters and an overview of these chapters follows.

Chapter One

In the first chapter, I explained the background of this study. The Namibian Chemistry Curriculum was also discussed as well as my personal experiences as a teacher. It also provided reasons as to why this study was carried out. This included the purpose, the statement of the problem, significance of the study, research goal, and questions. Theoretical and analytical frameworks were introduced. The data gathering techniques were described and the key concepts defined.

Chapter Two

In this chapter, I review the literature relevant to the study. I look at the concepts relevant to the teaching of 'Writing and Balancing Chemical Equations' such as professional development and teachers' perspectives as conceptual framework. The theoretical and analytical frameworks used in the study are described in this chapter.

Chapter Three

This chapter presents the research methodologies adopted in the study. The strategies used to generate data including how the data was generated are also discussed. Examples of data gathering techniques are semi-structured interviews, lesson observations, stimulate-recall interviews, and group reflections. Analysis of data and issues regarding ethics and validity are discussed in this chapter.

Chapter Four

In this chapter, I present, analyse and discuss data from semi-structured interviews and lesson observations. That is, emerging themes and findings from these data gathering tools are discussed. The chapter provides detailed discussions in relation to theory and relevant literature.

Chapter Five

This chapter presents the data generated from stimulated recall interviews and participants' group reflections. The empirical research findings are interpreted using the relevant literature and the theoretical framework of the study.

Chapter Six

This chapter sums up the main findings of the study. It also presents some recommendations and suggestions from the study. Limitations of the study and areas for further research are discussed in this chapter. The chapter ends with a summary of my personal reflections and some conclusions.

1.11 Chapter Summary

In this chapter, I presented the background of the study. I also outlined the research goal and research questions. In addition, the key concepts were defined, and the thesis outline was highlighted with the intention to help readers to navigate the study.

In the next chapter, I present the relevant literature informing this study and the theoretical framework underpinning the study.

CHAPTER TWO: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

This study focused on an exploration of how Grade 11 Chemistry teachers make use of the periodic table of elements when mediating the learning of writing and balancing chemical equations in two selected schools in Namibia. According to Matlin, Melik, Hopf, and Krief (2019), the periodic table of elements is central to the field of chemistry.

In this chapter, I therefore present the literature relevant to my study, in particular, the periodic table of elements and writing and balancing chemical equations. I first discuss the literature on the periodic table of elements and its centrality to chemistry. Secondly, I discuss tenets of chemical equations, focusing on its learning and teaching challenges as well as some methods of teaching suggested by several authors. I also discuss the aspects of professional development for chemistry teachers. I conclude the chapter by discussing the theoretical and analytical framework informing this study, that is, the PCK and TSPCK, respectively.

2.2 The Periodic Table of Elements

The periodic table was created by a Russian chemist Dimitri Mendeleev in the 1860s. Mendeleev's fundamental insight as a classification framework remains intact, although new interactives in the presentations have emerged. Mendeleev's work on the periodic table led to the development of the periodic law (Mendeleev's law) which states that similar properties recur periodically when elements are arranged according to increasing atomic numbers (Mokiwa 2016). In other words, Mendeleev's law implies that when elements are arranged in order of their increasing atomic number, there is a periodic repetition of their chemical and physical properties. This law is followed as the elements are arranged in the modern periodic table.

Elements are substances like hydrogen, oxygen, mercury, gold, and uranium from which all compounds and consequently all substances are made (Scerri, 2012). The periodic table then represents and organises all known chemical elements on the basis of their properties (Mokiwa, 2016; Scerri 2012; Ross, 2018). According to these authors, the modern periodic table is made up of squares each representing an element, where the letters and numbers indicate each element's abbreviated symbol and atomic number, respectively, as shown in Figure 2.1 below.

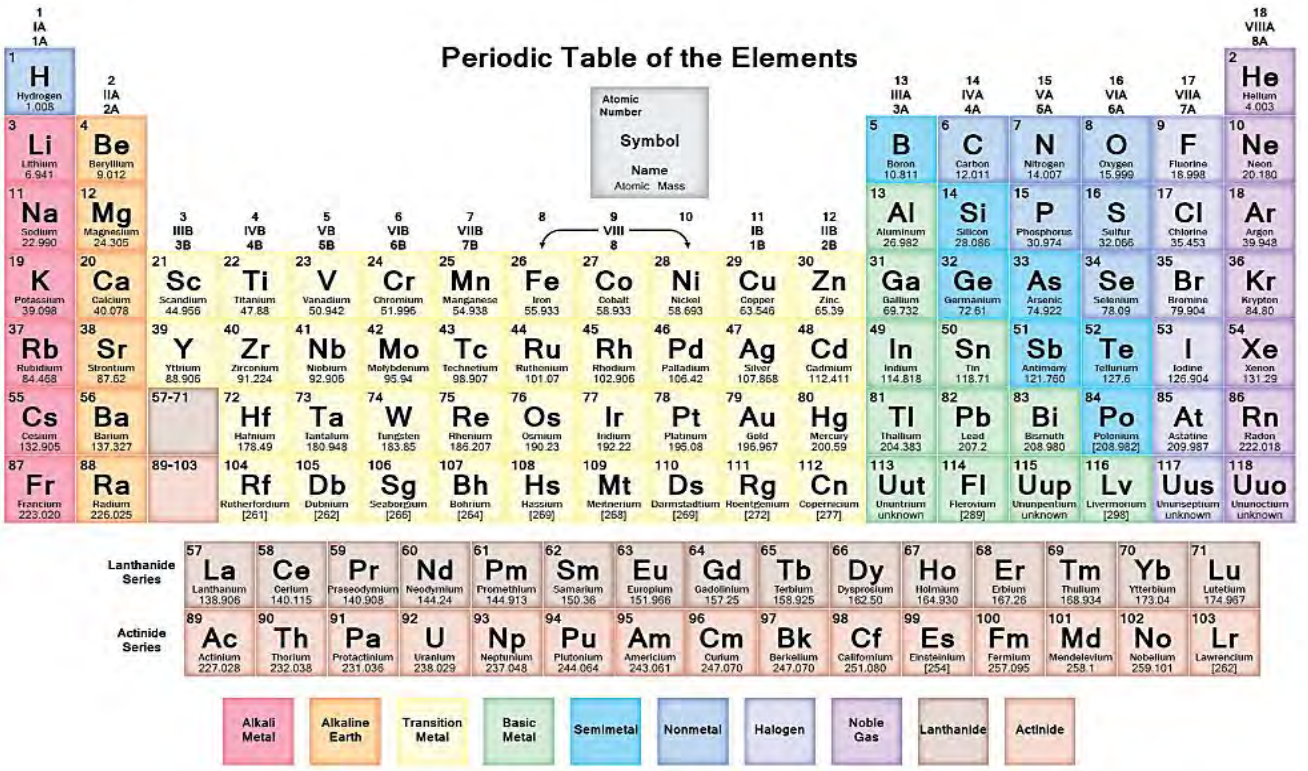


Figure 2.1: The periodic table of elements

In addition, there are other important key features that should be noted when trying to understand the periodic table of elements and these features provide all the information needed to balance chemical equations. There are horizontal rows called *periods* and vertical columns called *groups.* All of the elements in a period have the same number of atomic orbitals. Similarly, elements in the same group share similar properties such as the same number of valence electrons.

Furthermore, the vast majority of the known stable elements are of central importance to people, biologically, technologically, and/or economically (Matlin et al., 2019). To elaborate more, let us for example look at water (H_2O) which is crucial to life. To stay alive, all living

organisms take in this important material for making energy, while getting rid of the toxic substances such as waste products – this process requires water. Looking at the example above, learners seem not to know the chemistry behind the formation of water. It is a teacher's responsibility, therefore, to make the learners understand that water is formed through the chemical combination of an oxygen (O) atom and two hydrogen (H) atoms which are gaseous elements found in the periodic table of elements.

Apart from the above-mentioned example, the importance of the periodic table of elements is further explained based on its impressive role it plays in other life processes of human biology. According to Al-fartusie and Mohssan (2017) and Konikowska and Mandecka (2017), the periodic table lists essential trace elements such as iron (Fe), zinc (Zn), fluorine (Fe), and iodine (I) just to mention a few. The trace elements are important for the functioning of cells in a variety of processes necessary for life such as regulating homeostasis and can also be important in preventing deficiencies. This then indicates that life would not be possible without these elements.

Adding to the importance of elements in the periodic table, their technological and economical significance cannot be underestimated as many modern devices use a wide range of elements and compounds derived from them (Matlin et al., 2019). For example, the computers and smartphones that we use today rely on the existence of elements found in the periodic table, namely lithium and cobalt which are used to manufacture batteries and silicon to make the electronic chips.

Furthermore, understanding the periodic table is crucial as it serves as the foundation for a sound understanding of chemistry. That is, the periodic table of elements is one of the threshold concepts in chemistry (Park, 2015). Threshold concepts are those key ideas in a discipline that offer the learner a gateway to new ways of thinking (Meyer & Land, 2003). Put differently, the periodic table of elements is a fundamental concept in the field of chemistry and has a historical significance in science because of its transformative and integrated nature (Park, 2015). This is in agreement with Matlin et al. (2019) who state that the periodic table of elements is central to the field of chemistry as it also carries a message of broad societal significance. Hence, it is important that teachers understand the significance of the periodic table of elements, how it is linked to other concepts in chemistry and ensure that learners understand it. This in turn may help learners to develop higher order thinking skills (Park, 2015).

Several studies done in Namibia indicate that topics such as stoichiometry (Denuga, 2019; Kanime, 2015), rates of reactions (Nikodemus, 2017), and chemical equilibrium (Chani, 2014) become difficult concepts for students to learn because they are inherently linked to learners' prior knowledge of the periodic table of elements as stated by Aydeniz and Dogan (2016). This therefore necessitated looking at the periodic table of elements before getting into the details of writing and balancing chemical equations.

2.3 Balanced Chemical Equations

Under this section, I discuss what chemical equations are and their significance to the study of chemistry and to other science disciplines. I also discuss other aspects relevant to teaching and learning of writing and balancing chemical equations.

2.3.1 The significance of balanced chemical equations

Several studies have highlighted the importance of balanced chemical equations. For instance, Anthony (2009) suggests that the understanding of chemical equations is a pre-requisite to the meaningful learning of other chemistry topics such as chemical equilibrium, electrochemistry, and organic chemistry. Other scholars also posit that equations are the language chemistry and fluency in writing these chemical equations is critical for any student studying or intending to study chemistry (Chamundeswari & Bai, 2014). Further to this, chemical equations also play a major role in the theoretical as well as industrial chemistry (Hiremath, 2015). On the other hand, it is argued that the difficulties in the learning of chemistry can be precipitated by a lack of chemistry language skills (De, 2018).

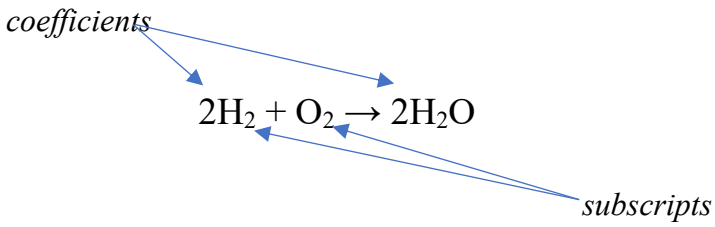
What is a chemical equation? A chemical equation can be defined as "a language of chemistry, one that chemists and chemical educators use constantly" (Yitbarek & Ababa, 2011, p. 11). Concurring, Hiremath (2015). It explains that the language (chemical equation) used to describe a chemical reaction, and every chemical equation is a story of some chemical reaction Similarly, De (2018, p. 52) defines a chemical equation as "symbolic and quantitative representations of the changes that occur in the process of chemical reactions, based on the principle that matter".

Chemical equations are constructed using chemical formulae which are derived from the chemical symbols of the reacting elements. These chemical equations have coefficients and

subscripts in them. “The coefficients in a balanced chemical equation can be interpreted both as the relative number of molecules, moles or formula units involved in the reaction, while subscripts on the other hand indicate the relative number of atoms in a chemical formula” (Yitbarek & Ababa, 2011, p. 11). A plus sign connects the initial substances (and final substances, if there are more than one), and an arrow (→) represents the chemical change. Let us look at this example for the formation of water, whereby hydrogen reacts with oxygen to form a water molecule. So, the equation is:

$$H_2 + O_2 \rightarrow H_2O$$

To balance the chemical equation, the law of conservation of matter should be observed (Yitbarek & Ababa, 2011). These scholars explain that the law of conservation of matter says that in chemical reactions, the total mass of the products must be equal to the total mass of the reactants. Hence, a balanced chemical equation must have an equal number of the same types of atoms on each side of the arrow. This is because in a chemical reaction, atoms are neither formed nor destroyed (ibid.). There are two types of numbers that appear in chemical equations. There are subscripts, which are part of the chemical formulas of the reactants and products; and there are coefficients that are placed in front of the formulas to indicate how many molecules of that substance are used or produced. Balanced chemical equations are those whose coefficients result in equal numbers of atoms for each element in the reactants and products. The balanced equation for the formation of water would then be:



This is an abstract concept more especially when there are some more complex equations to be involved.

2.3.2 Challenges in teaching the writing and balancing of chemical equations

Several studies document the inadequacy in learners’ understanding and interpretations of balancing chemical equations. For instance, Huddle and Pillay (1996) conducted a study in South Africa which revealed that learners have difficulty in solving stoichiometric problems

because they lack basic concepts related to stoichiometric calculations. Unsurprisingly, these findings are not different from those of Kanime (2015) and Denuga (2019) whose studies were conducted in Namibia. The basic concepts referred to earlier include balancing chemical equations as well as ratio and proportions. Studies conducted in Nigeria gathered similar evidence, and reported that many learners in Nigeria are unable to write and balance chemical equations and thus perform poorly in stoichiometry (Agunbiade, 2020; Upahi & Olorundare, 2012).

Additionally, these findings also resonate with those from a recent study conducted by De (2018) at a teachers' college in Ethiopia. De (2018) assessed the general understanding of the second-year students on chemical symbols, chemical formulae, and chemical equations. According to him, students have serious problems when writing chemical equations and cannot subsequently solve or analyse them. Based on De's findings, one can conclude that balancing chemical equations is not only problematic to high school learners but to students at tertiary level as well.

Furthermore, Chiu (2005, p. 1) states that the difficulty of chemistry topics arises 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". Based on that, it is recommended that the teachers' role is to find ways to try make learners understand the basic chemistry topics to prepare them.

In light of the above, De (2018) accentuates that the understanding of chemical equations is influenced by the knowledge on chemical bonding. This begins with the number of electrons an atom has on the outer shell (valency), and the existence of polyatomic ions and molecules which basically lead to production of the correct chemical formulae (ibid.). De's study therefore made the following recommendations to the teachers:

- Students should be maximally exposed to chemical language and terminologies;
- A glossary of symbols of different elements and formulas of different compounds should be provided to students;
- There should be clear rules and steps that students should strictly follow; and

- Using video clips on how to write chemical formulae (the rules) and balancing to enhance student's understanding and to take them to a different mode of teaching.

In addition, several scholars suggest different ways of balancing chemical equations. For instance, Chamundeswari and Bai (2014) carried out an experimental study on the method of writing chemical equations through simple teaching methods. Based on their findings, the main problems are that the learners are mostly engage in rote learning and this makes it difficult to automatically apply knowledge across topics. It is therefore suggested that there is a constant need to update the skills of teachers engaged in teaching chemistry (Denuga, 2019).

In this regard, Hiremath (2015) suggests the use of a mathematical method. He states that "balancing chemical reaction is not chemistry, but it is just algebra" (p. 132). To him, the problem of balancing chemical equations is nothing but finding the coefficient numbers for both reactants and products. He therefore suggests a system of writing chemical equations using linear equations and solving them following the Gauss elimination method. Gaussian elimination is a method of solving linear system $A\mathbf{x} = \mathbf{b}$ (consisting of m equations in n unknowns) by bringing the augmented matrix to an upper triangular form.

Another method of teaching the balancing of chemical equations is to use coloured blocks as was suggested by Ridzuan and Iksan (2017). These scholars did an exploratory study in which they had two groups of form four learners in Malaysia. One group (the control group), was taught using the conventional method and the other group (treatment group) was taught using the coloured blocks to balance chemical equations. Both groups were given two tests, a pre-test before the teaching and a post-test after the teaching using the two different methods. From this study, it was concluded that the method of using coloured blocks has the potential to improve students' concept of balancing chemical equations since the treatment group students showed a significant improvement in terms of their post-test results compared to the control group students who were taught using the conventional method.

Having talked about some methods of teaching balanced chemical equations, it should be noted, however, that learning can only be meaningful if it builds on the learners' prior knowledge.

2.4 Prior Knowledge

Prior knowledge is described as the experiences that learners acquire from their everyday lives and that they bring from previous grades which help them make meaningful connections to the new learning content (Kuhlane, 2011; Okanlawn, 2012; Roschelle, 1995). According to these authors, it is not possible for learners to learn without having prior knowledge. In support of this, Cetin-Dindar and Geban (2017) reiterate that engaging learners in real-life examples embedded in learning process activities enriched with real-world contexts and learners' active involvement in learning processes increases their conceptual understanding. In light of this, the NCBE emphasises that learners must build on their own learning experiences and cultural backgrounds in order be able to work effectively and independently. Chemistry teachers should therefore understand what prior knowledge learners have before planning their lessons.

In a study conducted in South Africa, Mokiwa (2016) found that teachers were struggling to link the periodic table of elements with learners' everyday life, even though there were many activities to refer to such as mining activities in the region. According to Mokiwa, learners were forced to learn by rote or memorisation and by carrying out meaningless tasks for the sake of passing tests and examinations. Yet, teaching that ignores learners' everyday knowledge and value systems may diminish the learners' enthusiasm and motivation towards the subject (Kibirige & Van Rooyen, 2006).

On the other hand, however, taking the learners' prior everyday knowledge into consideration should be done with caution. For instance, according to Taylor (1999), not all the experiences are suitable for the classroom; some contexts may be misleading and may also have the opposite of the desired effect. This suggests that prior knowledge is only effective when learners have the correct experiences. It is therefore the role of the teacher to determine what prior knowledge best fits the specific topic to be taught in the classroom. Having talked about the learners 'everyday experiences, it is also equally important for the teacher to be aware of the language they use in their everyday classroom discussions.

2.5 Language in Science

Vygotsky (1978) views language as the most important tool with which knowledge can be constructed. Gibbons (2003) also posits that language is a very important tool in the learning

process and it is the key to the development of scientific ideas and communication in science. For my second research question, the aspect of language is central in looking at how teachers mediate the learning of writing and balancing chemical equations. Oyoo (2015) points out that effective teaching and learning requires language, whether it is written in books or shared orally during classroom discussions. This made it relevant for me to look at how the teachers use language in their classroom interactions, in using scientific terminology, how they simplify abstract terms, and the general communication.

The NCBE dictates that the medium of instruction for leaners from Grade 4 to Grade 12 should be English. This suggests that the teaching of chemistry like all other subjects should be done in English. Hoepfner (2014) states that poor English proficiency among the Namibian learners has a significant impact on their education and may lead to poor academic achievement. This is compounded in part by the fact that science is a language on its own (Wellington & Osborne, 2001). In light of this, these authors suggest that the most significant action that educators can take to improve the quality of science education is to pay more attention to science language. It is, however, recognised that scientific language may pose a threat to science learners because it sounds foreign and uncomfortable to them (Nikodemus, 2017). Hence, some teachers find themselves deviating from the language policy, using everyday language in their classrooms. Yet, the use of everyday language in classrooms may change the meanings of some scientific explanations which can lead to learners' misconceptions (Gudyanga & Madambi, 2014).

Apart from using everyday language in the science classrooms, some teachers try to incorporate local languages in their lessons – a practice referred to as code-switching. This is defined as the movement by a speaker from one language to another or the use of more than one language in order to contextualise communication (Msimanga & Lelliott, 2014). This practice can also be referred to as "smuggling the vernacular into the classroom" (Probyn, 2009, p. 123).

Literature describes the use of local languages in the classroom in different ways. Msimanga and Lelliott (2014), for instance, allude that some learners may not be confident in using English, hence, they should be allowed to use their home language to engage with difficult concepts. Concurring, Ashofor, Ekele, and Milcah (2016) and Mavuru and Ramnarain (2019) echo that the incorporation of home language helps to boost the indigenous learners' self-esteem which ultimately increases their engagement in the classroom. In addition, code-switching can also be used as an effective classroom management tool as well as for attracting

the learners' attention during questioning (Probyn, 2009). In the context of this study, all learners spoke the same home language, Oshiwambo, which made it easier for the teacher to code switch.

In contrast, the incorporation of the local language may be challenging, especially in multilingual classrooms because teachers may not know which home language to use in facilitating learner understanding (Mavuru & Ramnarain, 2019). This may, however, not be a matter of concern in this study as I alluded to already. Added to this, the study by Mavuru and Ramnarain (2019) further states that "learners who were accustomed to learning science through code switching experienced difficulty in answering test or examination questions in English" (p. 8). This implies that since all the examinations are written in English, the use of the local language makes it difficult for the learners to understand the questions, causing them to fail the examinations. Further to the use of language in chemistry lessons, teachers should take into consideration what other learning and teaching materials can be used when discussing a specific topic.

2.6 The Use of Representations in Science

Shulman (1986) defines representations as "including analogies, illustrations, examples, explanations, and demonstrations in a word, the ways of representing and formulating the subject that make it comprehensible to others" (p. 9). Parnafes and Disessa (2004) point out that "when the students use several representations, they develop a more flexible understanding of the concept" (p. 251). Since my second research question sought to establish how teachers mediate learning of writing and balancing chemical equations, it is important to look at how they make use of representations, including powerful examples and analogies, which is one of the five components of Mavhunga and Rollnick's (2013) TSPCK model.

Furthermore, the Namibian curriculum recommends that teachers have wall displays in their classrooms. "Wall displays are pictures, wall charts and/or artefacts displayed on the walls of the classroom that make learning interesting" (Namibia. MBEC, 2010, p. 7). The wall displays may serve as representations and they can be used in multiple ways during the problem-solving process. Solving a problem means finding a way out of a difficulty, a way around an obstacle, or attaining an aim that was not immediately attainable (Doorman, Drijvers, Dekker, Van den Heuvel-Panhuizen, De Lange & Wijers, 2007). In this study, the problems that were solved are

those of writing the word equations from a chemical reaction, using chemical symbols of elements to construct chemical equations and using several methods to balance the equations.

Moreover, one of the common challenges in the teaching and learning processes in Namibian schools is inadequate learning and teaching support materials (LTSMs). To address this, teachers can make use of easily accessible resources to make models to make science more understandable to the learners as echoed by Asheela (2017), Ndevahoma (2019), and Asheela et al. (2021). In support of this, Denuga's (2019) reported that teachers used representations in the form of models, some of which were made by the learners, and that this can be applicable to any school regardless of the availability of models in the school laboratory.

Moreover, Shulman (1986) posits that the use of visual representation is part of the teacher's PCK. By implication, it is the responsibility of the teacher to choose the appropriate representations for a specific content. This is because representations, for example analogies, can lead to misconceptions if they are not well-chosen (Harrison & Treagust, 2006). Hence, when planning and preparing representations, teachers should not just copy what they see in textbooks but should also think about the correctness of the content to be presented (Josef, 2017). However, the use of the correct representations depends on the teacher's experiences and pedagogical insights.

2.7 Experience and Pedagogical Insights

The teaching experience that a teacher gains over many years of teaching seems to matter in classroom instruction. There is actually a difference in the classroom practices of a novice teacher and those who have been teaching in classrooms for a longer period of time. A teacher who has considerable teaching experience is likely to have a better understanding of how students learn which is a key aspect of good teaching. In this regard, the teacher's knowledge about learners helps in understanding different kinds of learners.

According to Park (2015), teachers gain knowledge about learners (their understanding, difficulty in learning science and so forth) and instructional strategies after teaching experience. Effective teaching requires teachers to communicate efficiently and this cannot be done without knowing the characteristics of students and their problems as well as by using the appropriate methods.

Furthermore, a study conducted by Park (2015) revealed that there is a relationship between the teachers' teaching experience and development of their PCK. In Park's study, one of the participants admitted to having an attitude change towards science through experience. The participants also cited that participation in higher education or degree programmes gives opportunities to enrich their experiences of overcoming knowledge blocks. Park's study further recommends that teachers be given professional development programmes such as workshops, seminars, conferences, and teachers' social activities.

2.8 Professional Development

Teachers are undoubtedly the most important agents of change in the education system. That is, they play a leading role in the training of new generations, in the development of countries, and in the socialisation of individuals who make up society. Like any other professionals, teachers too need to go through some sort of professional development. This is due to the fact that the pre-service training for teachers cannot be expected to prepare teachers for all the challenges they will face throughout their careers, no matter how good it is (Organisation for Economic Co-operation and Development [OECD], 2009).

To continue with the discussion, it is important to look at how some scholars have tried to describe the concept 'professional development'. Villegas-Reimers (2003) defines professional development as the development of a person in their professional role. Concurring, Kennedy (2016) states that teacher development is the professional growth a teacher achieves as a result of increased experience and examining their teaching practices.

Moreover, professional development has an ongoing nature, hence some scholars prefer calling it continuing professional development (CPD) (Ngcoza & Southwood, 2019). CPD plays a major role in changing teachers' teaching by moving beyond "comprehension of the surface features of a new idea and innovation, to a deeper understanding of a topic" (Rout & Behera, 2014, p. 9). Tekkumru-Kisa and Stein (2017) point out that the transformation that needs to occur for improving instructional quality in science and mathematics classrooms, demands a sustained focus on professional development of science and mathematics teachers.

Furthermore, professional development is essential for teachers as it inculcates curiosity, motivation, and new ways of thinking (Rout & Behera, 2014). It is also noted that professional

development can lead to improvements in instructional practices and student learning (Borko, 2004; Eun, 2008).

Loucks-Horsley and Matsumoto (1999) studied professional development and noticed a connection between teacher perceptions and beliefs about their own teaching and learning, and instructional practice. Denuga (2019) also emphasises the need for continuing development activities in the field of education as they create opportunities for teachers to learn from one another which enhances their classroom effectiveness. Chemistry teachers should therefore be no exception to adopting the stance of lifelong learning and being willing to collaborate and share their expertise with other education and science professionals. These teachers must then be provided with opportunities to draw upon their own ideas about the content they teach and about student learning and appropriate pedagogy.

Furthermore, there is need for education systems to provide teachers with opportunities for in-service professional development in order to maintain a high standard of teaching and to retain a high-quality teacher workforce (OECD, 2009). Over the past years, the Namibian government came up with some initiatives such as the Mathematics and Science Teachers Extension Programme (MASTEP), focusing on mathematics and science teachers. This programme had a great impact on the improvement of science and mathematics teachers' knowledge of content and improved their classroom instructional methods. Nevertheless, MASTEP ended in the year 2014 which has indeed left a significant gap in professional development for science and mathematics teachers.

As I mentioned in Chapter One, the Namibian Curriculum has gone through some changes recently. Chemistry was a subject on its own separate from physics, some teaching content was moved from the higher-level syllabus to the ordinary level syllabus and some new topics were added (MEAC, 2018). These changes may not have been easily adopted by all the teachers who had been teaching Physical Science in the past. In this case, it was important for these teachers to be provided with professional development platforms such as workshops. In this study, the participants' group reflections afforded the teachers an opportunity to share their content and pedagogical strategies. It is therefore hoped that the teachers improved their content knowledge and practices which would ultimately contribute to learner achievement in the national examination (Buczynski & Hansen, 2010; Nazair & Ledbetter, 2011).

Another recent term for professional development is a professional learning community (PLC) (Brodie, 2013; Chauraya & Brodie, 2018). According to these authors, learning is central to professional learning communities. In the context of this study, learning entailed the use of the periodic table of elements when balancing chemical equations. However, PLCs are criticised due to their nature which requires facilitators who are also teachers in this case and who might not have enough time to prepare (Brodie, 2013).

Notwithstanding, PLCs are relevant in my study, albeit not extensively since they talk to my third research question. For instance, similar to Nhase's (2019) study, the participants' group reflections afforded them an opportunity to come together and share ideas which hopefully had a positive influence on their PCK.

2.9 Conceptual Framework: Teachers' Perspectives

Perspectives include one's conceptions and dispositions. Herein, I discuss how the teachers' conceptions and dispositions influence and affect classroom instructions.

2.9.1 Conceptions

Generally, conceptions are ideas of what something or someone is like, or a basic understanding of a situation or a principle. These may include the beliefs, concepts, meaning, rules, and mental images concerning the discipline of chemistry. Thompson (1992) refers to conceptions as mental structures that encompass beliefs, concepts, meaning, proposition, mental images and others. According to Atallah, Bryant, and Dada (2010), conceptions have two components, knowledge and beliefs. These conceptions or beliefs affect the teaching approach as well as the teachers' professional development (Mokiwa, 2014) who Mokiwa (2014) states that teachers' conceptions are worth investigating because the educational environment is not static.

Furthermore, past studies indicate that conceptions predict the practices that occur in the classrooms (Mafunganyika & Nkambule, 2018; Panadero & Brown, 2017; Tavakoli & Baniasad-Azad, 2017). According to these authors, there are teachers who believe that teaching should be done using a variety of methods to ensure that learners are able to apply knowledge outside the classroom context. However, some teachers' conceptions are examination-oriented focusing only on giving learners activities similar to those in the examination so that they pass

and proceed to the next grade. It was, therefore, the intention in this study to explore the teachers' beliefs about teaching chemistry and find out how these conceptions influence their teaching.

2.9.2 Dispositions

Several scholars have come up with different definitions in an attempt to understand the term 'disposition', Dewey (1992) defines disposition as the readiness to act overtly in a specific fashion when it is the right time to do so. Similarly, dispositions can also be defined as regular and deliberate habits of thinking about something and doing things (Da Ros-Voseles & Fowler-Haughey, 2007). Ritchart (2002) posits that dispositions are acquired patterns of behaviours which are dynamic and can manifest themselves in a specific context. As Thomas and Brown (2007) note, dispositions involve attitudes towards the world, generated through a set of practices which can be seen to be interconnected in a general way. Similarly, Graven (2011) perceives dispositions as the habitual tendency to act in a particular way when an opportunity presents itself. These scholars all view disposition as a learnable human quality that is not static and develops through interactions within the environment.

Furthermore, Diez (2007) mentions that for dispositions to develop, there should be optimal interaction with the environment. Putting it in the context of my study, dispositions are viewed as the attitudes of the chemistry teachers towards the subject they teach, their classroom habits and how they interact with learners every day. These dispositions are seen in the way the teachers feel about chemistry, how they act towards/how they take part in/whether they tend to like and enjoy or hate teaching chemistry as noted by Thomas and Brown (2007).

Teachers' attitudes and motivation play a pivotal role in the teaching and learning process (Ogembo, 2012). Concurring, Agunbiade, Ngcoza, Jawahar, and Sewry (2017) posit that a disposition towards science is considered as one of the most important affective concepts in science education. Denuga (2019) also laments that dispositions greatly affect teaching and learning capabilities. It is therefore important that chemistry teachers demonstrate good values, actions, attitudes, and beliefs as they interact with learners, so that they can facilitate meaningful learning and convey a positive image of the subject they teach – these values depend on their teaching experiences.

Seminal work from Shulman (1986; 1987) articulates a unique form of teacher knowledge called pedagogical content knowledge, Pedagogical Content Knowledge. Many scholars have recognised the importance of PCK and its existence in the continued professional development of the teachers. Therefore, I now discuss Pedagogical Content Knowledge and Topic-Specific pedagogical content knowledge, TSPCK.

2.10 Theoretical and Analytical Framework

This study is underpinned by PCK (Shulman, 1986). The PCK is a theory focusing on the knowledge of thinking about the transformation of knowledge into a format which makes it easier for leaners to understand. Within the field of PCK, I drew on the seminal work of Mavhunga and Rollnick (2013) and focused on the five TSPCK components as my analytical framework. I discuss each of these below.

2.10.1 Theoretical framework: Pedagogical content knowledge

The study is informed by Shulman's (1986) PCK which he defined as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests of learners, and presented for instruction" (1986, p. 8). Shulman suggests that teachers should possess the knowledge to recognise and address the misconceptions learners may have about a topic. This should, however, come with the best strategies and methods of how the teacher makes a topic more meaningful to the learners.

Besides PCK, Shulman further proposes two other categories of content knowledge for teachers: subject-matter knowledge (SMK) and curricular knowledge (CK). SMK deals with the teacher's knowledge of the discipline of content and organisation. This includes knowledge of discipline conceptual schemes and specific knowledge of particular topics of which each individual teacher possesses a different unique level of content knowledge. Chani, Chikunda, Ngcoza, and Sewry (2018) noted that limited SMK has a negative effect on the PCK of teachers which consequently affects the way they prepare lessons. CK talks to the use of the syllabus, scheme of work, textbooks, laboratory demonstrations, and other mediating tools used in the classroom in an attempt to make learning meaningful to the learners.

Furthermore, teachers should be able to use different methods and strategies to mediate teaching and learning, for example, the use of the periodic table of elements to teach writing and balancing chemical equations in the context of this study. Additionally, the teaching of the periodic table of elements needs to be transformed into a form which is more meaningful to the learners, hence, the importance of the teachers' PCK. This is also echoed by Fernandez (2015) whose study points out that there is evidence that the PCK is a fruitful model that contributes to the understanding of the professional knowledge of teachers, systematising empirical data and enabling the documentation and exchange of ideas on relevant knowledge to teaching practice.

Loughran and Mulhall (2006) state that the teachers' PCK is related to their experience and it entails transforming knowledge so that it makes sense to the learners. It is should be noted, however, that the two participant teachers in my study did not have the same experience in teaching at a senior secondary level; one teacher had nine years' experience whereas the other one was relatively new to teaching chemistry at the senior secondary level. I therefore acknowledge that these teachers' personal PCK were unique to themselves (Carlson & Daehler, 2019). Notwithstanding, the different experiences of these two teachers enriched the insights on the issue under study.

Shulman (1987) further explains PCK as the knowledge that includes "an understanding of what makes learning of a specific topic easy or difficult" (p. 9). This suggests that the teacher should know the teaching strategies and the support materials needed to teach a specific topic, in this case, exploring the teaching strategies being used by the chemistry teachers to mediate learning of writing and balancing chemical equations. Kind (2009) posits that the PCK in science education has not received enough attention, although it is a useful concept in understanding the teachers' professional practices. My study thus adds to several studies that have investigated science teachers' PCK.

Furthermore, Kind (2009) argues that understanding how science teachers' pedagogical practices develop, knowing how to measure and represent these, and establishing what constitutes effective pedagogy for teaching science, might contribute to our overall understanding of what high quality science teaching looks like. Kind's (2009) critique however is that, "although there is wide agreement that PCK is a useful construct, finding out exactly what it comprises and using this knowledge to devise good practice in teacher education is not

easy" (p. 3). Moreover, Bromme and Tillema (1995) lament that defining PCK as an instructional strategy gives the impression that the influences of other mediating factors such as presentation on teaching and learning are not acknowledged. Sharing the same sentiments, Kind (2009) however posits that PCK is not yet backed up by theoretical evidence to support its existence and it is not yet an explicit tool used by teachers. It should be noted that the method to be used on how to balance chemical equations depends on the PCK of the teacher.

In an effort to extend the understanding of PCK, a summit was held (Colorado Springs, USA, October 2012). At that summit, a group of scholars from different countries agreed on a consensus model of PCK that is referred to as a teacher professional development model (see Figure. 2.2 – the PCK consensus model – Gess-Newsome, 2015, p. 31).

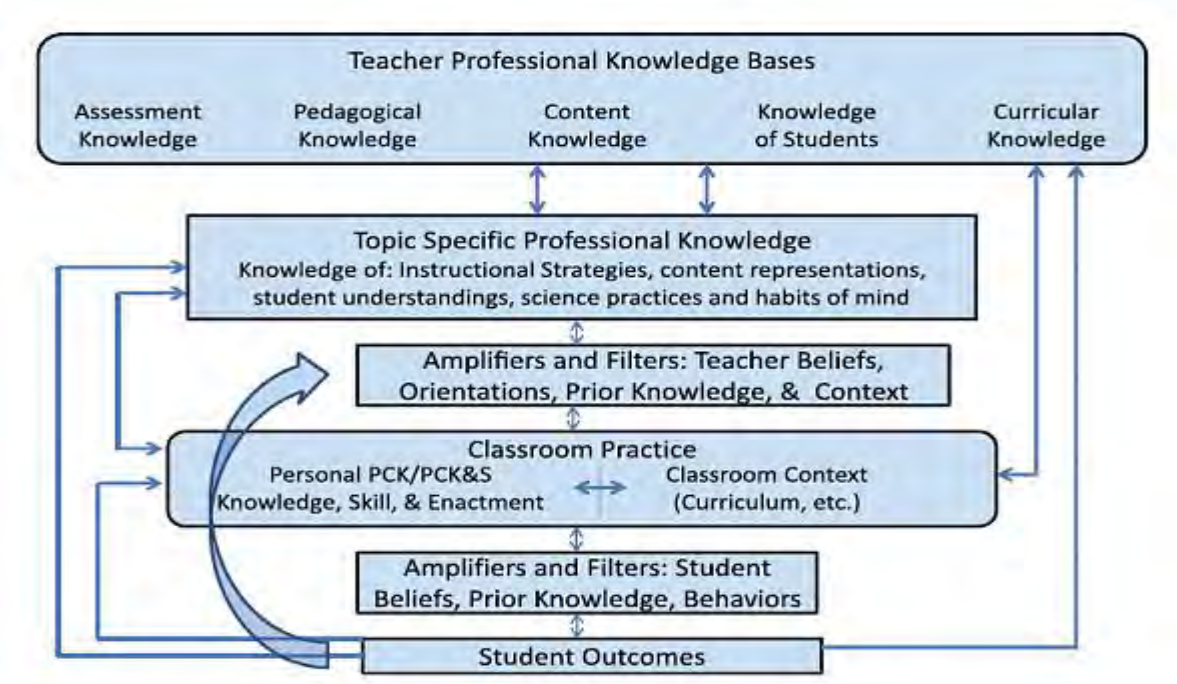


Figure 2.2: The PCK consensus model (Gess-Newsome, 2015, p. 31)

In the model above, PCK was defined as a combination of a knowledge base that is used in planning for and the delivery of a topic in a specific classroom context, and as a skill used when involved in the act of teaching Gess-Newsome (2015). However, the use of this model has been criticised for having minimal details about PCK. This model was therefore refined at a second PCK summit to cater for the multi-dimensional nature of PCK (Carlson & Daehler, 2019), as shown in Figure 2.3 below.

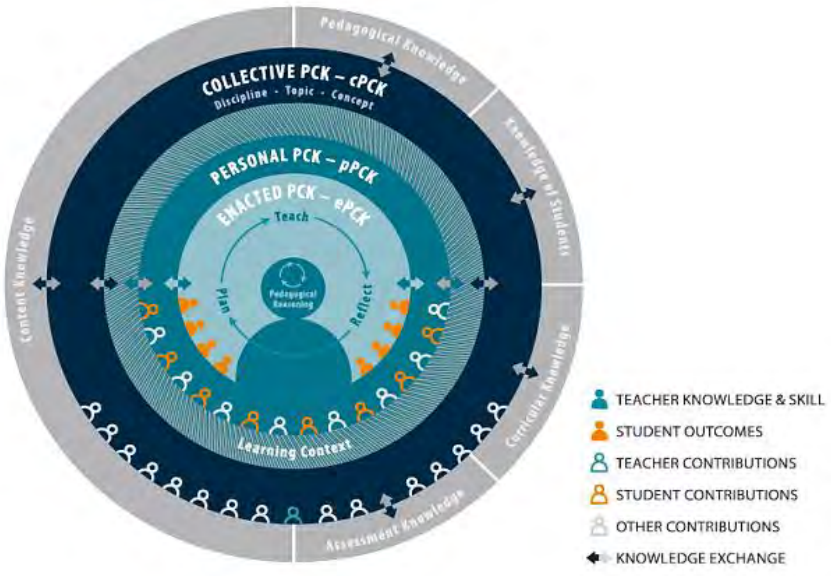


Figure 2.3: Representation of the refined consensus model (RCM) of PCK (Carlson & Daehler, 2019, p. 83)

From this figure, the new refined consensus model of PCK introduces the three realms of PCK, viz., collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK). According to Carlson and Daehler (2019), the first realm is the collective PCK which has to do with a specialised knowledge held and shared by multiple educators in a specific field. In this case, this refers to the knowledge possessed and shared by the chemistry teachers in this study which they have acquired from university. In the context of this study, this realm was observed through the lesson observations as teachers taught the writing and balancing of chemical equations.

The second realm is personal PCK which entails the unique knowledge an individual educator develops through experience. This is then followed by the third realm, enacted PCK. Mazibe, Coetzee, and Gaigher (2020) described enacted PCK as the knowledge that the teachers reveal during teaching. This knowledge is developed and shaped through reflections on their own lessons, their planning and pedagogical reasoning. The participant group reflections held in this study afforded the teachers an opportunity to interact and share pedagogical practices which might improve their PCK. However, the results from this study were interpreted using Mavhunga and Rollnick TSPCK model.

2.10.2 Analytical framework: Topic-specific Pedagogical Content Knowledge

Over the years, the examination reports from the Directorate Namibia Examination Assessment (DNEA) for the Namibia Senior Secondary Certificate Ordinary level (NSSCO) have shown that learner performance in the questions related to writing and balancing chemical equations has been a concern (Namibia. MoE, 2014; 2015; 2016; 2018; 2019). Looking at what these reports point out, one can then relate it to the position of the teachers' TSPCK. TSPCK considers how teachers use their PCK to transform difficult concepts of specific science topics into forms that are best understood by the learners (Mavhunga & Rollnick, 2013). This means, the teachers understanding of the content they teach and how they interpret it to the learners plays a very important role in this regard.

These scholars developed the five knowledge components from which transformation emerges, namely; "learners' prior knowledge, curricular saliency, what is difficult to teach, representations including analogies and conceptual teaching strategies'' (Mavhunga & Rollnick, 2013, p. 115) (see Figure 2.4).

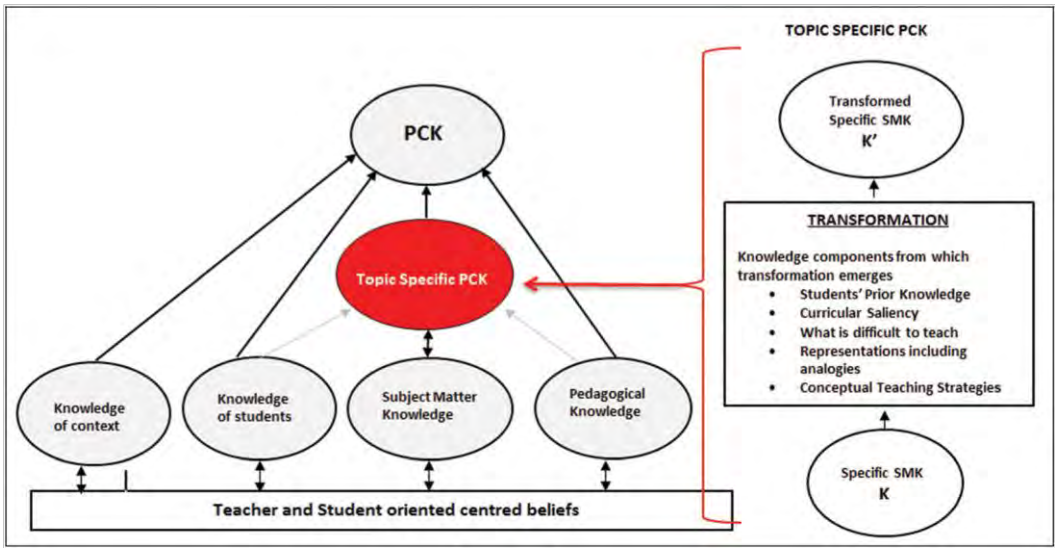


Figure 2.4: Showing the five components of TSPCK (Adapted from Mavhunga & Rollnick, 2013, p. 115)

According to Mavhunga and Rollnick (2013), the first component, learners' prior knowledge (LP) entails the elicitation of learners' prior knowledge. This component also includes the teacher's skills in dealing with misconceptions learners have in a particular topic. The second component, curricular saliency (CS) refers to the sequencing of the specific topic and puts emphasis on the identification of the most important concepts in that particular topic. The third

component, what is difficult to teach (WDT), pertains to concepts that students find difficult to learn. Representations (REP), including analogies, are used to support and scaffold explanations of a difficult concept. The last component, conceptual teaching strategies (CTS) focuses on teaching strategies that teachers employ to help learners to acquire conceptual understanding.

Their study sought to improve the quality of PCK in pre-service teachers in a specified topic in science, based on the premise that teachers should not be using the same teaching methods for different topics within a certain subject. They further state that topic specific components of PCK should be considered when a specific topic is taught.

Having said that, the data obtained from this study was then analysed using the five TSPCK components developed by Mavhunga and Rollnick (2013) as an extension of Geddis and Wood's (1997) seminal work. Mavhunga and Rollnick (2013) argue that PCK has a topic-specific nature. I chose to use the theoretical framework of TSPCK as the five components led me to a better understanding of how teachers elicited the learners' prior knowledge, how they organised and presented the ideas to the learners, how they made the abstract concepts meaningful to the learners, and the teaching materials and strategies they used to teach this specific topic.

2.11 Chapter Summary

In this chapter, I discussed literature relevant in this study. I focused on the significance of the periodic table of elements to the teaching of science as well as the importance of writing and balancing chemical equations in chemistry. Some aspects of studies on teachers' perspectives toward teaching chemistry were discussed. The conceptions and dispositions regarding the use of the periodic table of elements and teaching of balancing chemical equations were discussed as was some literature on professional development in the teaching profession in Namibia. I also outlined Shulman's PCK as the main theory underpinning this study and TSPCK (Mavhunga & Rollnick, 2013) as the analytical tool used in this study.

In the next chapter, I discuss the research design and methodology employed in this study.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

The goal of this study was to understand how teachers make use of the Periodic Table of Elements to mediate the learning of writing and balancing chemical equations. As alluded to earlier, the study was triggered by my personal experiences as a chemistry teacher, having noticed that many learners often struggle to write and balance chemical equations. I was therefore interested to know and learn how other chemistry teachers taught this topic in their classrooms.

In this chapter, I discuss the research methodology adopted in this study, that is, the paradigm informing this study as well as the research design employed. I also give a clear description of the participants, data gathering procedures, and the data analysis process. Lastly, I discuss the validity and ethical issues considered in this study.

3.2 Research Paradigm

A research paradigm is a lens through which a researcher perceives or experiences the world (Creswell, 2014; Maree, 2016). This study is underpinned by an interpretive paradigm. Cohen, Manion, and Morrison (2018) posit that the interpretive paradigm views the social world as an emergent social process, which is created by the individuals concerned through their experiences. Moreover, the interpretivists purport to understand the meaning which informs human behaviour and to make "interpretations with the purpose of understanding human agency, behaviour, attitudes, beliefs and perceptions" (Bertram & Christiansen, 2015, p. 26).

Hence, in this study, the interpretive paradigm was appropriate since the purpose of the study was to gain insight on perspectives and experiences on how teachers make use of the periodic table of elements to mediate learning of writing and balancing chemical equations. Thus, the interviews and lesson observations which were adopted in this study enabled me to make some

interpretations in the natural contexts of the participants (Cohen, Manion, & Morrison, 2011; 2018).

Despite the above-mentioned strengths of the interpretive paradigm, I am mindful of criticisms about the interpretive paradigm. In the first place, Cohen et al. (2011) proffer that the interpretivists aim to gain a deeper understanding and knowledge of phenomena within the complexity of the context rather than generalise these results to other people and other contexts. Secondly, it is argued that the interpretive paradigm is more subjective than objective (Thanh, Thi, & Thanh, 2015). Another criticism is that it focuses on descriptions rather than explanations and places more emphasis on the characteristics of an individual – that is one's own moods, attitudes, and opinions. In this study, I tried to build trust between the participants, treated every situation without any bias or preconceptions about their inferences. A qualitative case study research design was employed within the interpretive paradigm.

3.3 Research Design

According to Bertram and Christiansen (2015), when designing a research study, researchers should systemically plan how to gather data and how this data are to be analysed in order to answer the research questions. Concurring, Cohen et al. (2018) posit that "the research design identifies the evidence needed to address the research purposes, objectives and questions, i.e. the logic that underpins the connections between purposes, objectives, questions, data and conclusions drawn" (p. 175). As noted earlier, in this study I employed a case study research design.

3.3.1 Case study

In an attempt to describe a case study, Maree (2016) emphasises that a case study is a method of research which looks at the holistic understanding of how participants relate and interact with each other and the researcher in a specific situation to make meaning of phenomenon under study. Additionally, a case study is a type of qualitative research where in-depth data are gathered with reference to a problem statement to learn more about an unknown or poorly understood situation (Leedy & Ormrod, 2014). Concurring, Bertram and Christiansen (2015, p. 42) define a case study as a "systematic and in-depth study of one particular case in its context".

A case study was thus deemed appropriate in this study since I intended to gain deeper insights on the teachers' perspectives, experiences, and pedagogical insights on the use of the periodic table of elements to make writing and balancing chemical equations meaningful to the learners. A case study was advantageous as it helped in answering 'how' and 'why' questions as I engaged with the participants (Yin, 2009). In other words, the in-depth case study analysis helped me to obtain more data from this study (Cohen et al., 2011). Thus, the results from this case study were analysed based on how the participants presented themselves. Another important concept about case studies is that they are conducted in a bounded system. This means that a case study always has boundaries in the topic of research whether it is bounded by a limited number of participants or limited amount of time for observations.

However, case study research has been subjected to criticism on the grounds of no representivity and a lack of statistical generalisability. Additionally, the richness and complexity of the data collected means that the data is often open to different interpretations, and potential 'researcher bias (Cornford & Smithson, 1996).

The case in this study was thus the Grade 11 chemistry teachers from two rural secondary schools in the Ohangwena region. The unit of analysis was how they made use of the periodic table of elements when mediating learning of writing and balancing chemical equations.

3.3.2 Research goal and research questions

The main goal of this study was to explore how Grade 11 chemistry teachers make use of the periodic table of elements to mediate learning of writing and balancing chemical equations.

To achieve this goal, the following research questions were addressed:

Research questions

1. What are Grade 11 chemistry teachers' perspectives, experiences, and pedagogical insights on the use of the periodic table of elements in their chemistry lessons?

2. How do Grade 11 chemistry teachers make use of the periodic table of elements when mediating learning of writing and balancing chemical equations?

3. How do stimulated recall interviews and group reflections influence Grade 11 chemistry teachers' understanding of and the use of the periodic table of elements when mediating learning of writing and balancing chemical equations?

3.3.3 Research site, participants and sampling

I conducted the study with two teachers from two different schools. In the next sections, I describe the research site, research participants, and sampling procedure in more detail. I begin this section with the research site.

3.3.3.1 Research site

This study was conducted in two conveniently selected schools in the Ohangwena region, which is in the far north of Namibia. The schools are located in a radius of about 80 km from a small town called Eenhana and they are about 1 km away from each other. These schools are both senior secondary schools which comprise of learners from Grade 8 to Grade 12. I chose the two schools because they were close to me and gaining access to them was quite easy.

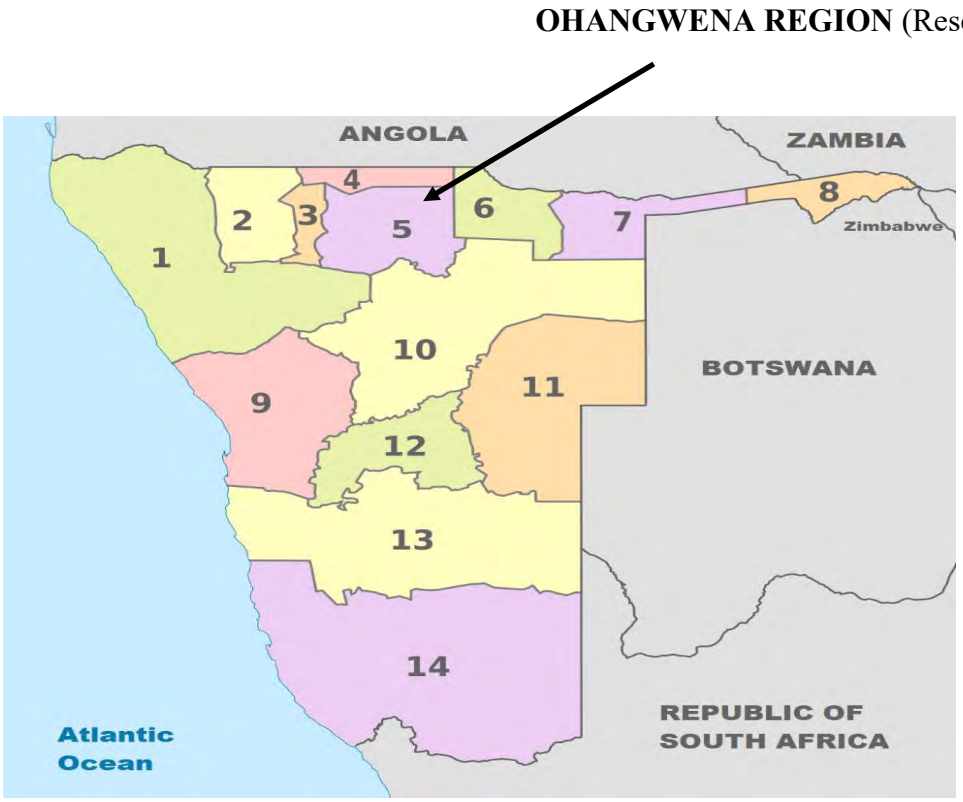


Figure 3.1: Map of Namibian regions

3.3.3.2 Research participants and sampling

"The quality of a piece of research stands or falls by the appropriateness of its methodology and instrumentation and by the suitability of the sampling strategy that has been adopted" (Cohen et al., 2018, p. 202). Sampling involves making decisions about which people, settings, events, or behaviours a researcher is to include in a study (Bertram & Christiansen, 2015). Sampling in this study was purposive and convenient.

According to Cohen et al. (2018), in purposive sampling the sample is assembled based on the possession of particular characteristics to meet specific needs. Thus, two Grade 11 chemistry teachers were involved in this study. These two teachers were purposively chosen because they have good experience in teaching the writing and balancing of chemical equations which is covered in this particular grade. Notably, at the time of this study one teacher had 11 years teaching experience while the other one had nine years of teaching experience.

To protect the participants' identity, I asked the two teachers to give themselves pseudonyms. One teacher named herself Ms Iyaloo which is an Oshiwambo name which means 'thank you'. She explained that she was thankful because she was chosen among her colleagues to be my research participant. The other teacher named himself Mr Imagine. According to him, he has ambitions to study further and he has imaginations for himself carrying out a research study one day. I will therefore use these pseudonyms throughout this thesis. The biographical information of the teachers is shown in Table. 3.1 below.

Table 3.1: The biographical information of the teachers

Biographical information	**Participant 1**	**Participant 2**
Age	30-35	30-35
Gender	Female	Male
Home language	Oshiwambo	Oshiwambo
Qualification	Diploma in Education	Diploma in Education, ACE
Teaching Experience	11 years	9 years
Participants' codes	Ms. Iyaloo	Mr. Imagine

Apart from the teaching experience of these teachers as a selection criterion, I also looked at the location and accessibility of the schools where they teach. These two schools are not very far from one another, which then made it easy for the researcher to access the participants within a reasonable time and it made the research process convenient as noted by Creswell (2012). As a researcher, my role in the research process was that of an observer and facilitator. Such a role was intended to create a conducive and respectful environment, as well as to ensure that the research process continued so that the objectives were met. For instance, in arranging for participants' group reflections, I did not take any position in deciding when to meet with the participants, but rather remained neutral and negotiated with the participants based on their own convenience and availability. I also asked permission from all the participants, building rapport with them and involving them to interact fully in the research study. The data was videotaped, transcribed, and analysed, which I then interpreted and will present in different ways.

3.3.4 Positionality

I am a chemistry and physics chemistry teacher and I have been in the teaching profession for 11 years. Over the years, I gained more expertise in the sciences which gave me an opportunity to head a Natural Science Department at my school. In conducting this study, my interest was to develop and improve my academic understanding on the challenging concepts in the chemistry syllabus, particularly writing and balancing chemical equations.

Being a master's student at Rhodes University and a head of a department at my school, I was mindful about the influence of power dynamics this might have during the research process. To overcome this, I had some informal discussions with my participants to establish rapport and build a relationship with them. I shared my research interest and explained that I would like to work with them in my project. Amazingly, these teachers were excited to be part of my study because they felt it was an opportunity for them to learn something new. For instance, Mr Imagine indicated that it was the first time that he would be a participant researcher and he looked forward to the start of the project.

My role as the researcher was to communicate with the participants to organise suitable times to meet and collect data, while following the data collection procedures explained previously. I ensured that the participants in this study were not forced or obliged to participate in it. I therefore conducted my study without being biased in any way and treated my participants

equally and fairly. As a result, transparency in relation to positionality and my intentions as a researcher were central to my research efforts.

3.3.5 Data gathering techniques and research process

According to Leedy and Ormrod (2010), data gathering involves the use of different techniques or tools that include observation, interviews, objects, written documents, audio-visual materials, electronic documents and anything else that can help to answer a research question. Looking at the scope and context of this research, I chose semi-structured interviews, observations (videotaped lessons), stimulated-recall interviews, and group reflections as data gathering methods**.** The reason for choosing to use different data gathering methods was intended to enhance validity and trustworthiness of the data gathered. This process is known as triangulation (Cohen et al., 2018). I now discuss each of these below, with respect to their phases in the research process.

Semi-structured interviews

Maree (2016, p. 92) defines an interview as a "two-way discussion whereby the interviewer asks the participants questions with the aim of collecting data and to learn about the ideas, beliefs, views, opinions and behaviours of the participants". Based on this definition, I engaged in semi-structured interviews with my participants because I believed that they would help me gain some insights on their perspectives, experiences, and pedagogical insights in teaching chemistry. The interview method was therefore used because qualitative studies are strongly connected with thoughts, feelings, and intentions that cannot be directly observed (Patton, 2015).

Furthermore, I used an interview guide with open-ended questions (see Appendix F). An interview guide is a schedule of questions which the interviewer intends to ask (Leedy & Ormrod, 2014). In this study, the semi-structured interviews gave me the freedom to change the order and emphasis of questions depending on the answers given. It also enabled me to ask follow-up questions as stated in Cohen et al. (2018). This then enabled me to probe with more questions for clarity and ensure that all the questions were answered in full. I used an interview schedule which I adapted from Cetin-Dindar and Geban (2017).

In addition, with the consent of the participants, the interviews were recorded in two ways. The first way was the use of a video recorder. The advantage of videos is that "they allow for

repeated viewing and checking, though this takes time to watch, re-watch and analyse" (Cohen et al., 2018, p. 633). On top of that, video material catches the non-verbal data that audio recordings cannot, which may be particularly useful, for example, in detailed case study data collection (ibid.) Hence, a video recorder allowed me to be flexible in the process of transcribing and I was actually able to see the gestures and the body language when the respondents were trying to emphasise some points. To back up the video recorded data, an audio recorder was used which meant that if anything happened to the video recorder, I would still have the audio data.

The interview with Ms Iyaloo took about 15 minutes. This was a little shorter than the interview with Mr Imagine which took about 19 minutes. Mr Imagine gave some detailed explanations when answering questions while Ms Iyaloo gave short direct answers. However, both teachers were able to share their experiences and pedagogical insights on the integration of the Periodic Table of Elements in teaching the writing and balancing of chemical equations which helped me to answer my first research question.

However, there were times when I asked questions and the teachers struggled to answer them as I anticipated. This could perhaps have resulted from a lack of clarity on some questions, or the teachers needed a bit more time to think about them first.

Table 3.2: Semi-structured interview questions and their purpose in this study

Question	**Purpose**
Could you please describe what you think is the purpose of teaching the periodic table of elements in chemistry?	To find out their thoughts about the nature of chemistry and why they believe it is required to learn it.
Could you please tell me how you elicit your learners' prior knowledge?	To see how teachers elicit their learners' prior everyday knowledge when teaching writing and balancing chemical equations.
May you share with me the examples of teaching and learning materials you use to support the learners understand the periodic table of elements?	To find out which representations including analogies, demonstrations, and any other materials used apart from notes.
May you please share with me the fascinating moments and challenges you experienced when	To find out what makes the topic easy or difficult to understand.

teaching concepts involving the periodic table of elements?	
After teaching the periodic table of elements how do you find out that the learners have understood it and they can use it in other chemistry topics?	To describe the evidence that they successfully taught the content and the learning has become meaningful to the learners.

Observations *(videotaped lessons)*

Observation is a technique that allows the researcher to gain live data in a social situation or context (Bertram & Christiansen, 2015; Cohen et al., 2011). Bertram and Christiansen (2015) add that observation involves the researcher going to the site where the phenomenon is happening and observing what is actually happening there. Observations afforded me an opportunity to observe directly at what was taking place rather than relying on second-hand information (Cohen et al., 2018).

In this study, I observed two chemistry lessons per participant in order to answer my second research question. These observations were done after the semi-structured interviews. I had initially planned to observe three lessons per participant, however, due to the circumstances imposed by the Covid-19 pandemic I could only observe two lessons per participant as schools were closed for quite a long time which then availed little time to teach, hence, teachers rushed to complete the curriculum before the mid-year examinations. Teachers had to make arrangements to have extra lessons in an attempt to compensate for the time lost.

Based on this, the lessons for Ms Iyaloo were observed during the afternoons and those of Mr Imagine were conducted during the evening studies since all these learners resided in the school hostel. During the observations, I used an observation schedule as a guide that I had adapted from Nikodemus (2017) (see Appendix F). This observation schedule helped me to focus on the key concepts of the lessons. I was thus able to document how teachers mediated learning of writing and balancing chemical equations. Additionally, I also paid special attention to the use of teaching and learning aids, the learners' activities prepared for the lessons as well as to the language of instruction that was used during the lessons.

Furthermore, the lessons were video recorded with a help of a critical friend and with the permission of the participants. I chose to video tape the observations because I believe video data has the capacity for completeness of analysis and comprehensiveness of material reducing

the dependence on prior interpretations by the researcher and enabling the researcher to scrutinise data (Cohen et al., 2018).

After the observations, I watched the video recordings and wrote narratives from all the lessons that I observed followed by verbatim transcriptions of each videotaped lesson. These transcriptions and video recordings then served as the main source of information that enabled me to administer the third data gathering tool in my research process which was the stimulated recall interview.

Stimulated recall interviews

A stimulated recall interview is a collaborative inquiry between research participants and the researcher, with the dialogue focused on the practice through video or audio recall (Nguyane, McFadden, Tangen, & Beutel, 2013). Moreover, stimulated recall interviews are known to have the potential strength as a clear professional development tool, whereby teachers can critically reflect to understand their own teaching practice (Reitano, 2005).

After the lesson observations, I watched the video recordings for each teacher on my own and transcribed them into written format. These transcripts afforded me an opportunity to develop the stimulated recall interview questions. For convenience's sake, these interviews were conducted on different days and at different venues that suited each participant. The interview with Ms Iyaloo was conducted in a community library due to the fact that their school was temporarily closed down due to Covid-19. This venue was convenient to her because it was close to her house. These stimulated recall interviews lasted for almost 25-30 minutes.

All the Covid-19 protocols were followed when meeting with the participants. During the interviews, I watched the video recordings with each teacher. Teachers were delighted to see themselves teaching and Ms Iyaloo asked me to share her video with her so she could keep watching herself. As I played the videos, I paused it at intervals so that I could ask questions for clarity and to obtain further information on how teachers mediated their lessons. The stimulated recall interviews therefore afforded me an opportunity to ask the teachers for clarity and for further explanations on things that may have not been clear during the lesson observations, with the purpose of validating the data gathered.

Participants' group reflections

As a token of respect towards my participants, I requested that we come together and have a discussion based on what transpired during the data gathering process. This is similar to Nhase (2019), whose participants deemed it necessary to be given some space for reflections as a group. These reflections took place at school 2 because Mr Imagine volunteered to prepare a venue for us. Because the participants welcomed my request wholeheartedly, they freely shared their experiences and reflected on the entire research process. The discussion took one and half hours.

As a starting point and with permission from the participants, the participants agreed to watch the videos of each other's lessons. This enabled us to share ideas with the purpose of exploring ways to improve the quality of future student learning, with particular reference to design of the lesson, the materials used, and the mode of delivery (Chikamori, Ono, & Rogan, 2013).

Further, these reflections aimed at providing answers to my third research question which was to understand the participants' thoughts and actions towards the research process. This phase provided a platform for us (myself and the participants) to come together and share experiences and elicit stories that might have gone untold during the research process. According to Nhase (2019), reflections avail the participants an opportunity to strengthen each other's understanding. It is therefore in light of this statement that I arranged and facilitated this to happen. Also, this availed me an opportunity to learn new teaching skills from the participants as fellow chemistry teachers.

Table 3.3: Summary of research questions and data instruments

	Research Questions	**Data Collection Instruments**
1	What are the Grade 11 chemistry teachers' perspectives, experiences, and pedagogical insights on the use of the periodic table of elements in their chemistry lessons?	Semi-structured interviews
2	How do Grade 11 chemistry teachers make use of the periodic table of elements when mediating learning of writing and balancing chemical equations?	Lesson observations & stimulated-recall interviews

3	How do stimulated recall interviews and group reflections influence Grade 11 chemistry teachers' understanding of and the use of the periodic table of elements when mediating learning of writing and balancing chemical equations?	Discussions & group reflections

Table 3.4: Shows a summary of the data gathering techniques used in this study

Methods	**Reason for using this method**
Semi-structured interviews	Help me to solicit the participants' understanding on how and why they use the periodic table of elements in teaching the writing and balancing of chemical equations.
Lesson observations	Helped to understand how teachers interacted with the periodic table of elements in real-time teaching of balancing chemical equations.
Stimulated recall interviews	To clarify why the participants used the methods they used when teaching. To find out their intentions and aims per lesson taught.
Participants' group reflections.	They helped to understand the participants' thoughts of and actions towards the process of this research which resulted in the second phase of lesson observations.

3.3.6 Data analysis

According to Leedy and Ormrod (2014), when analysing data in qualitative research, the researcher begins with a larger body of information and must, through inductive reasoning, sort and categorise it and gradually bring it to down to small set of abstract, underlying themes. Concurring, Cohen et al., 2018, p. 645) state:

> Qualitative data analysis includes, among other matters, organizing, describing, understanding, accounting for, and explaining data, making sense of data in terms of the participants' definitions of the situation (of which the researcher is one), noting patterns, themes, categories and regularities, all of which are the task of the qualitative. Concepts, theories, explanations, understandings, summaries, models etc. which fairly and comprehensively explain the data or phenomenon.

That is, during this process, emerging patterns were noted and recorded as noted in the excerpt above. I then used a thematic approach to analyse the data in order to identify categories, patterns, and themes because of this approach is flexible with respect to identifying themes

(Braun & Clarke, 2006). The themes emerged from the data were coded. Coding refers to "segmenting and labelling data" (Creswell, 2012, p. 243). The figure below indicates how data was analysed to arrive at themes.

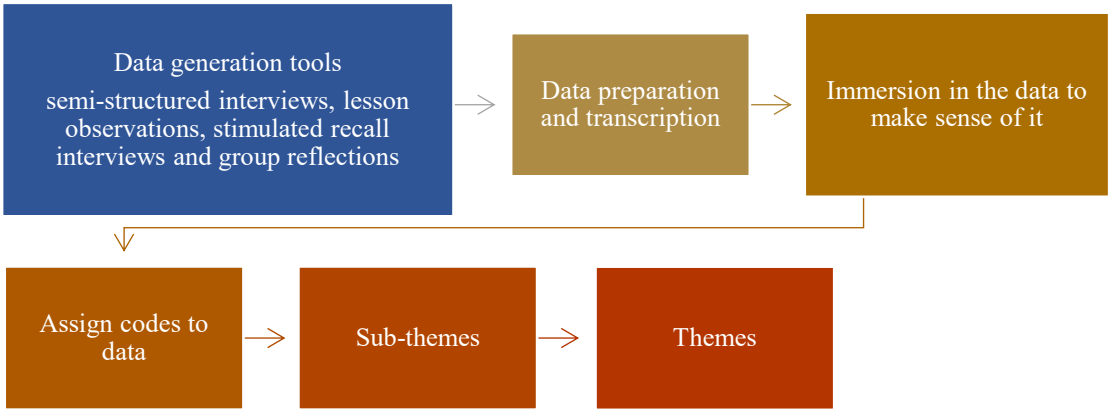


Figure 3.2: Scheme showing the data gathering process

As alluded to in Section 3.3.5, the semi-structured interviews, lesson observations, and reflections were video recorded. I then transcribed the videos which helped me to develop themes and sub-themes. I then used the theoretical framework (discussed in Chapter Two) to help to interpret the data and to answer my research questions. For research question one, I adapted Atallah, Bryant, and Dada's (2010) indicators of conceptions and dispositions (see Appendix G). This analytical tool was deemed to be valid and relevant to my study since it has been used before and proven to be useful.

Further, triangulation from different data sources was used to build a coherent justification for the themes. Thus, to interpret the research question two, I used the TSPCK that I adapted from Mavhunga and Rollnick (2013) (see Appendix M). This TSPCK contains five components, namely, learners' prior knowledge, curricular saliency, what is difficult to teach, representations, and conceptual teaching strategies. Unlike Mavhunga and Rollnick (2013), however, who referred to this table as a rubric which they use to score the teachers' PCK, I borrowed Maton and Chen's (2016) concept of a translation device since my intention was not to score the teachers' PCK as such, but to understand how they mediated learning in their classrooms. This translation device enabled me to analyse the data as I looked at episodes where the five components of the TSPCK were manifested by teachers' knowledge and practice.

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

3.3.7 Validity and trustworthiness

Validity is the key issue in the debate over the legitimacy of qualitative research (Maxwell, 2008). Concurring, Cohen et al. (2018, p. 245) stress that "validity is an important key to effective research". These scholars further add that if a piece of research is invalid then it is worthless. Thus, in this study, the interview schedule was piloted with other MEd (science) students during a contact session. This enabled me to refine the interview questions in order to be able to gather a rich set of data from my research participants. The study further employed the method of triangulation to ensure and enhance validity and reliability of data. Triangulation involves using more than one method to gather data and it is powerful way of demonstrating concurrent validity (ibid.). In addition, the data gathered through semi-structured interview and observations were video recorded. This allowed for easy transcription, and for the participants to review and reflect on their lessons which validated the data. I also used the stimulated recall interviews while watching the videos with my participants and I believe that this technique lends itself to being a validation technique.

3.3.8 Ethical considerations

This section highlights various ethical aspects taken into consideration in this study.

Respect and dignity

The privacy, experiences, and expertise of the participants in this study were respected. Prior to the signing of the consent forms, participants were informed that participation was voluntary and withdrawal at any point would be allowed. Also, I was mindful that the participants' participation in this study was an extra task on top of their daily work schedules, hence, I conducted the research activities at convenient times for the participants'. Additionally, the participants were informed that the lesson observations would be video recorded, and they were asked to give their consent in this regard. I also highlighted that I would not share the information from this study with third parties without their permission.

Transparency and honesty

Before the commencement of the research, permission from the Regional Education Director of the Ohangwena region and from the principals of the two schools was obtained. This was done in writing where the aim of the research was explained clearly (see Appendix B & C). I also explained the aim of the study to the participants as well as the details on the process.

Accountability and responsibility

When considering ethical issues, consideration should be based on protection and security of participants whether they are people or institutions. According to Maree (2016), "an essential ethical aspect is the issue of protecting the participants' identity" (p. 44). To adhere to this in this study I avoided using real names and instead used pseudonyms (School 1 and School 2) for the two schools and for the participants (Ms Iyaloo and Mr Imagine), respectively. In addition, the participants' inputs on providing information were protected, respected, and were not exposed to any third party. The findings and the results in this research were kept anonymous to protect the identities of participants. Moreover, I behaved and demonstrated a high level of professionalism by upholding ethical principles and created a trustworthy relationship with my research participants.

Integrity and academic professionalism

This study is my own product, using my own ideas and where I used others' ideas, I have acknowledged and referenced them according to the referencing guidelines. Data were presented without fabrication.

3.4 Chapter Summary

In this chapter, I described the methodology employed in this study and within that methodology, I discussed the paradigm underpinning the study as well as the research design employed. Further, I outlined the data gathering techniques followed by research goal, research questions, and research process. Thereafter, I discussed how data was analysed. The issues of validity and trustworthiness were discussed to make sure that both myself as a researcher and the participants understood the research process. Ethical considerations were also discussed,

and transparency which was key during the whole process. The data sets gathered in this study are presented in the next chapter.

CHAPTER FOUR: SEMI-STRUCTURED INTERVIEWS AND LESSON OBSERVATIONS

4.1 Introduction

The goal of this study was to explore how Grade 11 chemistry teachers make use of the periodic table of elements when mediating the learning of writing and balancing chemical equations. Since the periodic table of elements is a cornerstone in the teaching of chemistry, it was prudent for me to understand how chemistry teachers use this in their science classrooms.

In this chapter, I present data generated from the semi-structured interviews and lesson observations. The purpose of the semi-structured interviews and the lesson observations was to find answers to my research questions 1 and 2:

1. What are Grade 11 chemistry teachers' perspectives, experiences, and pedagogical insights on the use of the periodic table of elements in their chemistry lessons?

2. How do Grade 11 chemistry teachers make use of the periodic table of elements when mediating learning of writing and balancing chemical equations?

4.2 Data Presentation and Discussions from Semi-Structured Interviews

In the first phase of this study, I interviewed two Grade 11 chemistry teachers who teach at two different schools in the Ohangwena region as explained earlier. The interviews were conducted in the afternoons at the participants' respective schools so that we did not interrupt the normal teaching time. As alluded to in Section 3.3.6, the two teachers participated in this study willingly and gave themselves the pseudonyms, Ms Iyaloo and Mr Imagine. These pseudonyms were used to present data in this chapter and this made it easy for the data handling process. As explained earlier, the interviews took about 15 and 19 minutes, respectively.

With permission from the participants, the interviews were videotaped backed up by an audio recorder. I then transcribed the interviews verbatim. A deductive approach was then used to determine the themes and subthemes. Table 4.1 below shows the themes and sub-themes that emerged from the semi-structured interviews and the relevant literature.

Table 4.1: Themes and sub-themes that emerged from the semi-structured interviews

Themes	**Sub-Themes**	**Literature/Theory**
Teachers' perspectives on the use of the periodic table of elements in their lessons	Views on the significance of the periodic table of elements to chemistry	Atallah et al. (2010), Matlin (2019), Mokiwa (2016), Ross (2018), Scerri (2012), Park (2015).
	Views on the significance of the periodic table of elements on balancing chemical equations	De (2018), Chamundeswari and Bai (2014), Hiremath (2015) Matlin et al. (2019),
	Attitudes towards teaching the writing and balancing of chemical equations	Anthony (2009), Chani et al. (2018), Denuga (2019), Kanime (2015) Nicodemus (2017), Upahi and Olorunde (2012),
Teachers' experiences and pedagogical insights on the use of the periodic table of elements in their chemistry lessons	The use of prior knowledge	Asheela (2017),
	The use of representations including analogies	Asheela et al. (2021), Denuga (2019), Hiremath (2015),
	Challenges encountered when mediating writing and balancing of chemical equations	Ndevahoma (2019),

I now discuss each theme below.

4.2.1 Teachers' perspectives on the use of the periodic table of elements in their chemistry lessons

From the semi-structured interviews, it emerged that the two chemistry teachers seemed to see value in the use of the periodic table of elements during chemistry lessons. For instance, they commented that:

> *All right, so it's very important because a periodic table is a method of classifying elements and it determines or predicts the characteristics of elements for you to know to which group or period an element belongs to you have to go through the periodic table (Ms Iyaloo).*

> *Ok, the purpose of teaching the Periodic Table in chemistry is for learners to, to know the group numbers because group numbers indicate the number of charges for instance the elements in group two (2) they have charge number two (2). So, when they react with an element in group seven (7), that means they exchange (swap) charges. So, now teaching Periodic Table will help learners to know that if you react for instance magnesium with chlorine, that two (2) that is found from chlorine came from magnesium because it is in group two (2) that is why the basis of that should be a periodic table first (Mr Imagine)*

From these excerpts, it could be argued that the teachers seem to understand the purpose of the periodic table of elements. For instance, Mr Imagine's description of the periodic table is in line with Scerri (2012), Mokiwa (2016), and Ross (2018) who posit that the periodic table of elements presents and organises chemical elements on the basis of their properties. Also, Mr Imagine indicated that the periodic table of elements is important in the sense that it helps learners to make connections in the group numbers in relation to the charges and reactivity of the elements.

Further to that, both teachers believed that the periodic table of elements is important in any topic in chemistry. For instance, Mr Imagine views are shown below:

> *Oh yes, the Periodic Table is important. It has so many important things when it comes to Chemistry not only in balancing chemical equation. We can also use Periodic Table in teaching salts when the salts are formed when for instance a metal is reacting with an acid, you can be able to formulate the formula using the knowledge of the Periodic Table. For instance, you can have hydrochloric acid reacting with sodium. You know that sodium is in group one and chlorine is in group seven so the charges will already tell you the group number can also be used in that regard.*

This excerpt seems to highlight a strong point that the periodic table of elements is the steppingstone to chemistry and it should be understood in order to understand chemistry. This perception is supported by Park (2015) who calls the periodic table a threshold concept. That

is, it is a gateway for the learners to new ways of thinking. This view is in agreement with Matlin et al. (2019) who make it clear that the periodic table of elements is central to the field of chemistry and that it is important that teachers understand its significance, including how it is linked to other concepts in chemistry. This also corresponds with the findings of some studies carried out by different scholars in topics such as chemical equilibrium (Chani, 2014), rates of reactions (Nikodemus, 2017), and stoichiometry (Agunbiade, 2020; Denuga, 2019) which concluded that these topics are inherently linked to the periodic table of elements.

Furthermore, it emerged from the semi-structured interviews that the two chemistry teachers seemed to have positive attitudes toward teaching the writing and balancing of chemical equations. For example, they said that:

> *When you are presenting a certain topic and write an equation, if it is not balanced then you hear a learner saying* ***"that equation is not balanced Ms. Let us balance it first"****. So that means that they have picked up something when you were teaching them the topic of balancing equation as a basic (Ms Iyaloo).*
>
> *Yeah, what I have enjoyed on this topic most is that learners do not know that for one to know how to balance this you need to know the Periodic Table. And, it sounds very funny that some of them think that they are separate topics that are not related. For instance, you ask them to come up with a compound they fail because they are neglecting the Periodic Table, and when they realise, they say "Aa, aa, no, this is very simple". Yeah, and then they get excited when they realise that they are linked (Mr Imagine).*

Based on the excerpts above, it was evident that teachers have the belief that chemical equations are linked to other topics and learners need to be familiar with them in order to understand other topics. For instance, the fact that Ms Iyaloo indicated that she enjoys moments where the learners link balancing equations to other topics highlights her sense of being positive towards the topic. That is of course similar to Mr Imagine whose comment seemed to highlight a sense of being happy when his learners realised the link between the periodic table of elements and balancing chemical equations. According to him, that makes it easy for his learners to understand what balancing equation is. This is in line with the ideas of Anthony (2009) and Chamudeswari and Bai (2014) who stress that chemical equations are a pre-requisite to the meaning of chemistry. Other studies also confirm that learners always have difficulty in solving stoichiometric problems if they are unable to write and balance chemical equations (Denuga, 2019; Kanime, 2015; Upahi & Olorundare, 2012).

4.2.2 Teachers' experiences and pedagogical insights on the use of the periodic table of elements in their chemistry lessons

From the semi-structured interviews, it also emerged that the two chemistry teachers' experiences in teaching the writing and balancing of chemical equations seemed to be more or less the same. For instance, the experiences shared were on teaching and learning materials as well as on the challenges encountered when teaching this topic. The responses from these teachers indicated that there are various materials that the teachers use in order to help learners to understand writing and balancing chemical equations and they commented that:

> *Okay, we have some models in the lab that we can use that represent elements (Mr Imagine).*
>
> *You can carry out a practical where you can react for example, magnesium with perhaps oxygen then once you react that then you deduce the equation from there then you can ask them to balance it … I have taught at different schools, so, I did that at my former school (Ms Iyaloo).*

Mr Imagine indicated that their school laboratory is equipped with some materials that can be used to make balancing chemical equations meaningful to the learners. It was however a missed opportunity when I did not ask him a follow-up question to get more details on the type of materials. On the same question, Ms Iyaloo also indicated that she has some experience on carrying out some hands-on practical activities with learners which she then uses to write equations and balance them thereafter. The use of hands-on practical activities concurred with Asheela et al. (2021), who stresses that 'hands on 'and 'minds on' practical activities lead to effectiveness and skills development. However, part of Ms Iyaloo's response could be interpreted to mean that there are no teaching and learning materials in their school laboratory. The fact that she referred to her previous school suggested that her current school does not have or perhaps has limited materials.

Furthermore, the two teachers shared that they do not only rely on the resources available in the school laboratories. They commented that:

> *All right, so, I actually use many materials, for example you can use stones, then you can count them and you can put some amount or certain number of stones on one side and then you put a number of stones on the other side and then you try to make them equal on both sides, that is now on balancing the equation (Ms Iyaloo).*
>
> *Yeah, I can use eenyandi I do not know (laughs) that in English. You can use eenyandi and those eenyandi can easily come up with molecule depends on what type of*

molecules. Or, you can use aa palm, not palm but marula fruits. You can also be used and then you can also use, what is this any fruit that is available that can assist apart from those that I just mentioned (Mr Imagine).

From these excerpts, it could be deduced that these teachers seem to make use of easily accessible resources such as models in order to make science more understandable to the learners as echoed by Asheela (2017), Ndevahoma (2019), and Asheela et al. (2021). These authors shared the same sentiment that teachers should try to consider using easily accessible materials which should be included when planning lessons and during teaching and learning.

Interestingly, both Mr Imagine and Ms Iyaloo indicated that they make use of locally available and easily accessible materials such as fruits and stones when teaching this topic. For instance, Mr Imagine stated that he uses marula fruits and *eenyandi* (jackal berries) and sticks and connects them together in order to represent the bonds that hold the atoms together. This demonstrated that some teachers do make use of easily accessible resources to make models in order to make science more understandable to the learner as noted by Asheela (2017) and Ndevahoma (2019). This is also in line with Denuga's (2019) study which reports that teachers used representations including models of which some were made by learners.

However, both teachers pointed out some challenges that they encounter and most are experienced by the learners.

Table 4.2: Challenges encountered by teachers when teaching balanced chemical equations

Ms Iyaloo	Mr Imagine
• Writing chemical formulae of compounds. • Counting the number of atoms on both sides of the equation. • Confusion about polyatomic ions which require the use of brackets.	• Teaching and learning materials are very rare or difficult to get. • Learners misunderstand the numbers to be counted during balancing equations. • Confusion about polyatomic ions which require the use of brackets.

To remedy some of the challenges mentioned in Table 4.2, the two chemistry teachers in this study indicated that they try to link balancing chemical equations to other subjects. For instance, Ms Iyaloo commented that: *"I normally ask them to recall from mathematical point of view because they use to do that in Mathematics".*

As indicated in the extract above, Ms Iyaloo indicated that she always tries to refer learners to what they have learnt in mathematics. These findings corroborate what Hiremath (2015) did with his students. According to him, balancing equations is purely algebra, hence, he preferred his students to solve chemical equation problems by writing them as linear equations. The use of brackets when dealing with polyatomic ions is mostly emphasised in algebra in mathematics, which is a compulsory subject for all learners in the senior secondary phase. In elementary algebra, parentheses are used to specify the order of operations whereby the terms which are inside the brackets are worked out first. As a result, learners may find it easier as they simply make connections between the two subjects, mathematics and chemistry.

Further, Mr Imagine indicated that the challenges are eliminated by giving the learners more work to practice, because practice makes perfect. This demonstrated that these teachers try to make some effort to help their learners to do work. However, none of these teachers indicated that they give remedial lessons to the learners.

4.3 Data Presentation and Discussions from Lesson Observations

As explained in Section 3.8, observations accorded me a first-hand opportunity to look directly at what took place in the classrooms. That is, the observations enabled me to experience how teachers actually mediate learning of writing and balancing chemical equations as opposed to what they said they do. As the Covid-19 regulations dictated, I observed that the two teachers that participated in this study also took responsibility in making sure that these regulations were observed. For instance, I observed how they kept on reminding the learners to observe social distancing, wash their hands regularly as well as wearing their face masks properly.

During the observations, I was able to witness the interactions between the teachers and the learners, the interactions between the teachers and the subject content, and the use of representations as highlighted by Mavhunga and Rollnick (2013).

A total of four lessons were observed, two presented by each teacher. All lessons were video recorded with the permission of the teachers. Similar to Nhase's (2019) study conducted in South Africa, I wrote narratives based on all the lessons that I observed followed by verbatim transcriptions of each videotaped lesson. As highlighted by Sedlacek and Sedova (2017), the narratives afforded me an opportunity to identify episodes from the video whereas transcriptions helped me with identifying excerpts from the lessons. Also, during the observations, I took some field notes on any aspects that I found to be interesting.

As indicated in Section 2.10, this study is informed by Shulman's (1986) PCK and the analytical tool was the five components of the TSPCK as narrated by Mavhunga and Rollnick (2013). The data herein is therefore presented using the themes developed from the TSPCK components that is learners' prior knowledge (LPK), curricular saliency (CS), what is difficult to understand (WDU), representations including analogies (REP), and conceptual teaching strategies (CTS) (Mavhunga & Rollnick, 2013). The description of these five components and how they relate to the findings from the lesson observations are presented in Table 4.3 (see Appendix M).

I now give a detailed account of each component and begin with the learners' prior knowledge.

4.3.1 Learners' prior knowledge

From the observations, it was evident that the two chemistry teachers in this study seemed to teach by drawing from the learners' prior knowledge. For instance, Ms Iyaloo asked the learners as follows: *"Now, who can tell us what an element is? What is an element? I want you to use the knowledge that you got from grade 8 and 9 physical science*".

Also, she had a display of the periodic table of elements pasted on the chalkboard which to my understanding is aimed at helping learners to recall the elements.

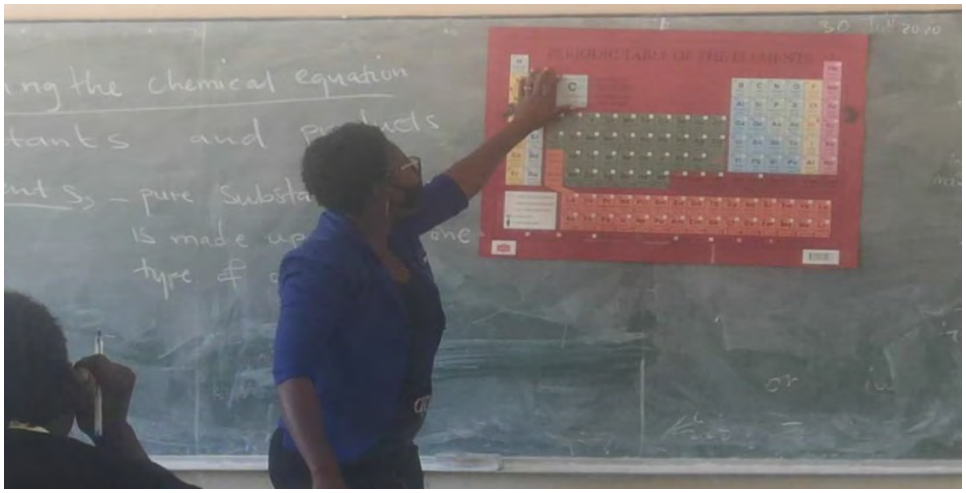


Figure 4.1: Ms Iyaloo pasting a periodic table of elements on the chalkboard

From her questions above, it could be surmised that the teacher kept in mind that it is important to consider what learners acquired from the previous grades as noted by Kuhlane (2011) and Okanlawn (2012).

Similarly, at the beginning of his lesson, I observed that Mr Imagine introduced the topic in the same manner as Ms Iyaloo. However, he did not have a poster like Ms Iyaloo had, instead he had copies of the periodic table of elements that he distributed to the learners.

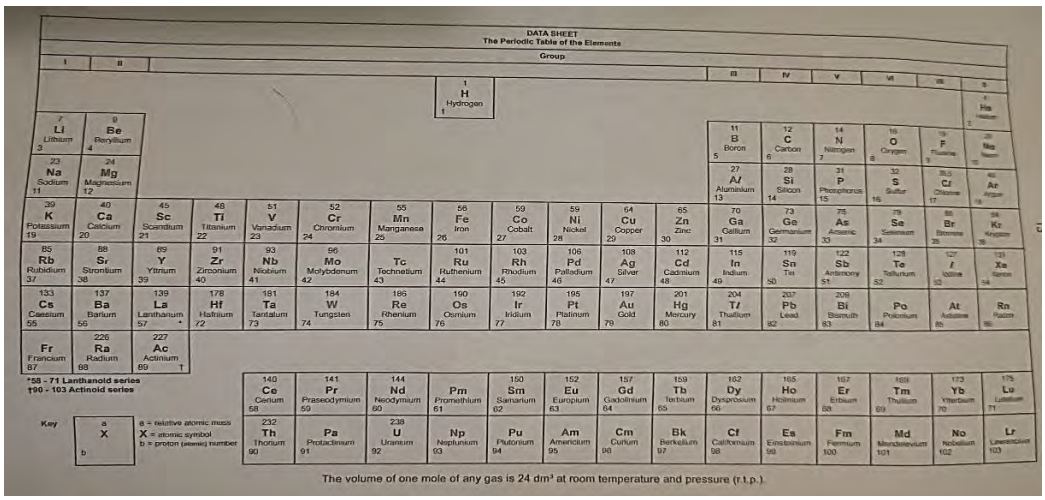


Figure 4.2: A copy of periodic table of elements that Mr Imagine distributed to learners

After the distribution of the copies, Mr Imagine asked the learners some questions as indicated in the vignette below.

T:	*I want someone to tell me, why did I give you periodic tables when we want to learn balancing equations? Why do we need it?*
L:	*Because we are going to work with elements.*
T:	*Yes, when we balance chemical equations, we use elements and those elements are in the periodic table. What else?*
L:	*We need to know the mass number and atomic number of the elements that we are going to work with.*

Based on this vignette, it seems that the teacher wanted to establish whether or not the learners could recall what a periodic table of elements is and why learning about it is important in other topics in chemistry (Matlin et al., 2019; Park, 2015). Hence, building on the learners' prior knowledge makes it easier for them to understand new concepts in a gradual manner and this enables the teachers to identify any areas that make the topic difficult to understand.

4.3.2 What is difficult to understand (WDU)

From my observations, it seemed that Mr Imagine and Ms Iyaloo have some insights on what makes the writing and balancing of chemical equations difficult to understand as noted by Mavhunga and Rollnick (2013) and Mavhunga et al. (2016). For instance, the fact that both teachers' introductory part of the lesson was on the periodic table of elements is a very strong point in this regard. This goes hand in hand with what the teachers indicated during the interviews, that it is impossible to teach chemical equations without understanding the periodic table of elements. They emphasised that learners need to understand the chemical symbols of elements in order to be able to write correct chemical formulae of compounds which makes it easy to formulate chemical equations and balance them.

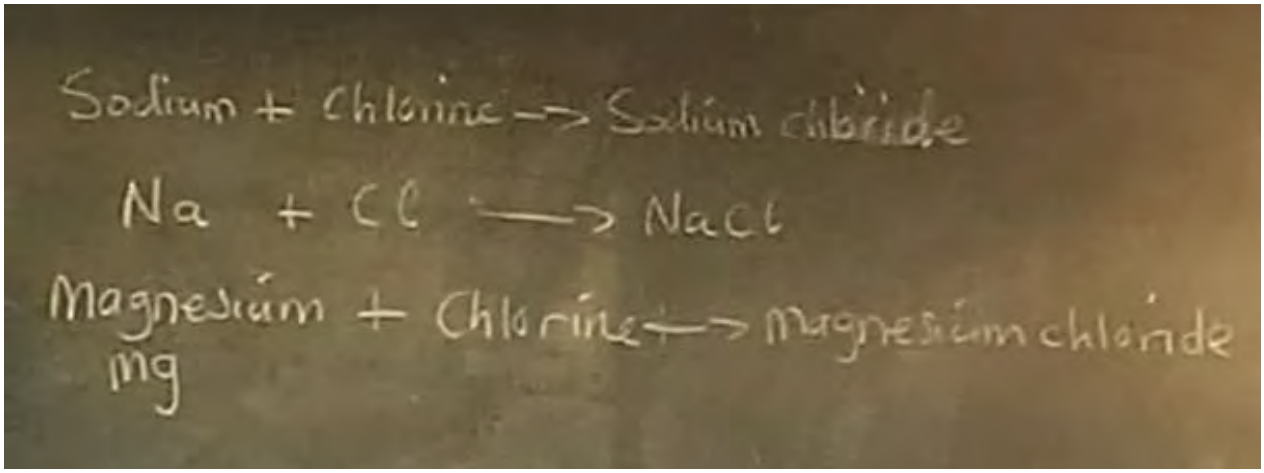


Figure 4.3: An example showing Mr Imagine use of a word and a chemical equation

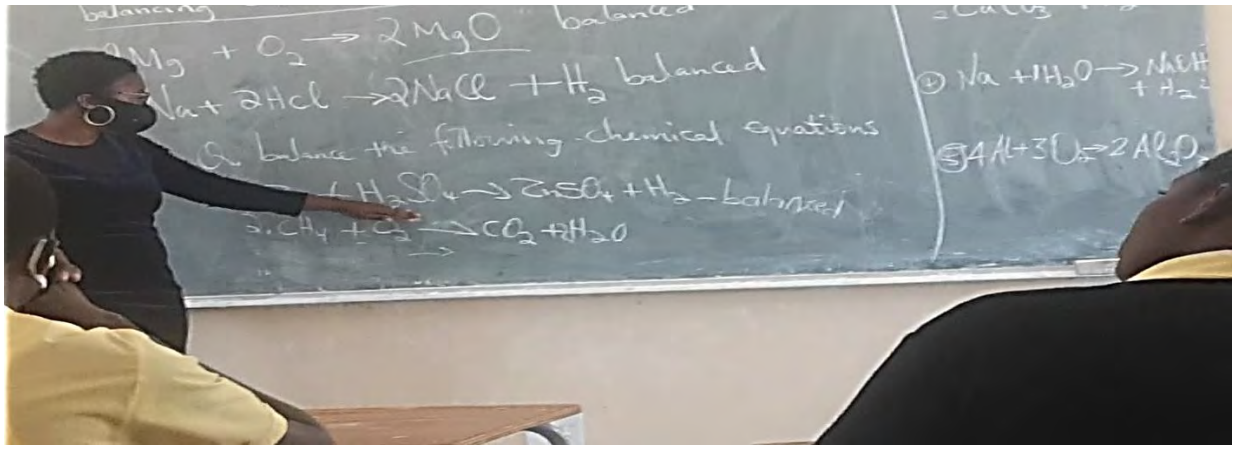


Figure 4.4: Examples showing chemical equations written by Ms Iyaloo

From Figures 4.3 and Figure 4.4, it was revealed that the two teachers use various examples when explaining how to balance chemical equations. Furthermore, the use of different examples and explanations by the teachers and mostly the demonstrations used by Mr Imagine, revealed that they have an understanding on how to make the topic more fun and enjoyable for the learners. This therefore makes a connection to the next component, curriculum saliency.

4.3.3 Curriculum saliency (CS)

Geddis and Wood (1997) define curriculum saliency as the teachers' understanding of the place of the topic in the curriculum and the purpose of teaching it. From the observations it was revealed that teachers know what is required to make the writing and balancing chemical

equations understandable for the learners. That was evidenced by the manner in which they started the discussions and the sequencing of concepts, that is, starting with the elements, followed by the explanations on the formation of ions through losing or gaining electrons. in this regard. This is echoed by De (2018) who posits that the understanding of chemical equations is influenced by the understanding of chemical bonding that includes the valency electrons and correctness of chemical formulae used.

Furthermore, the examples used led to the revelation that teachers were able to make connections between balanced equations and other topics in chemistry. For instance:

T1, L2, T; We are going to have an example of sodium + hydrochloric acid, what will be the products when you react sodium with hydrochloric acid?

	LL:	*Sodium chloride*
	T:	*Sodium chloride. Is it only sodium chloride?*
	L:	*No*

T2, L2:	*T:*	*Ok, so what I am going to do now, I am going to write two chemical equations and I will have two people to come and balance them for me and we will see.* $Mg + HCl \longrightarrow MgCl_2 + H_2$
	L:	$Mg + 2HCl \longrightarrow MgCl_2 + H_2$

From the vignettes above, the examples used are those of acids reacting with metals to form salt and hydrogen gas. Based on this it could be argued that teachers understood the connections between writing and balancing chemical equations and other topics in chemistry.

Furthermore, it was evident from the observations that Mr Imagine has strong SMK (Shulman, 1986). For instance, the explanations he gave shed more light on polyatomic ions (see Figure 4.5), their charges, and how they are demonstrated using the beads which added more value in this regard.

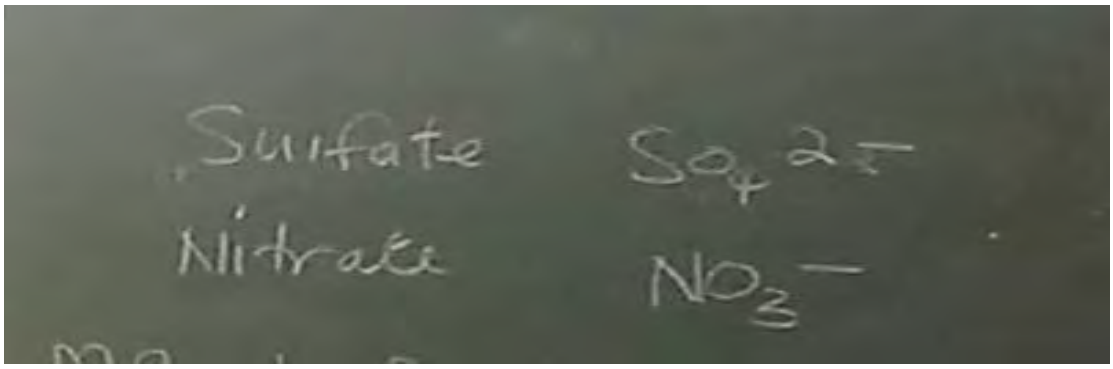


Figure 4.5: A snapshot of the polyatomic ion examples used by Mr Imagine

4.3.4 Representations (RP)

Representations include illustrations, examples, diagrams, models, texts, and any other tool that help learners to grasp abstract concepts. In this study, I observed that these teachers seem to have a strong understanding about the use of representations as evidenced by the use of a variety of tools. For instance, in the first lesson, Ms Iyaloo made use of a poster of the periodic table of elements (see Figure 4.6).

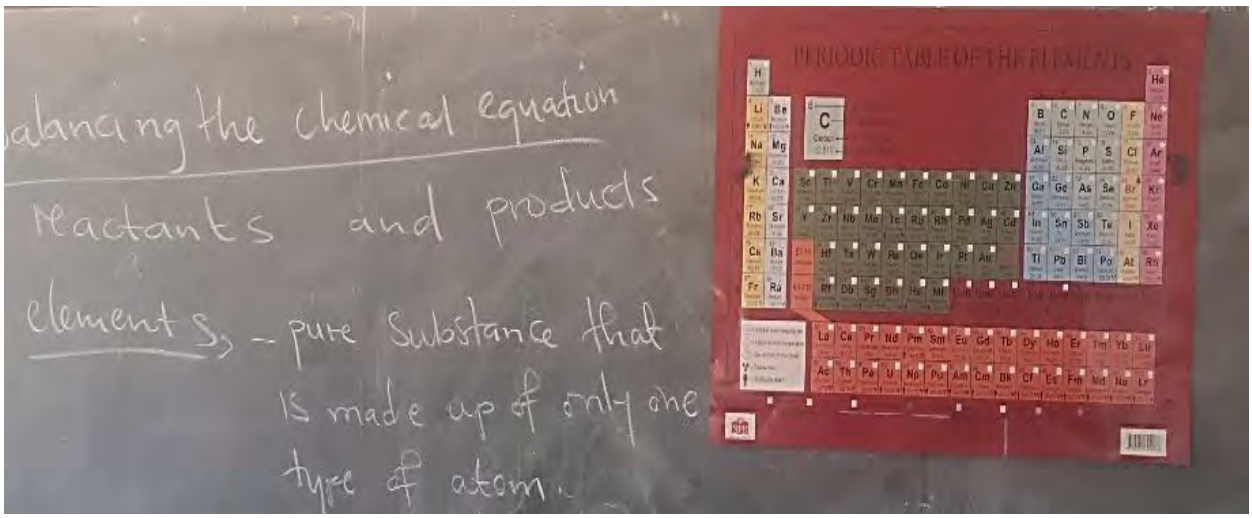


Figure 4.6: A Periodic Table of Elements pasted on the chalk board by Ms Iyaloo

Similarly, Mr Imagine also used and distributed copies of the periodic table of elements to the learners. Another interesting support material for learning and teaching was the beads used by Mr Imagine to represent atoms of different elements. These are shown in Figure 4.7 and 4.8, respectively.

Figure 4.7: Beads and connectors used by Mr Imagine

Figure 4.8: Beads used by Mr Imagine to represent a hydrogen molecule

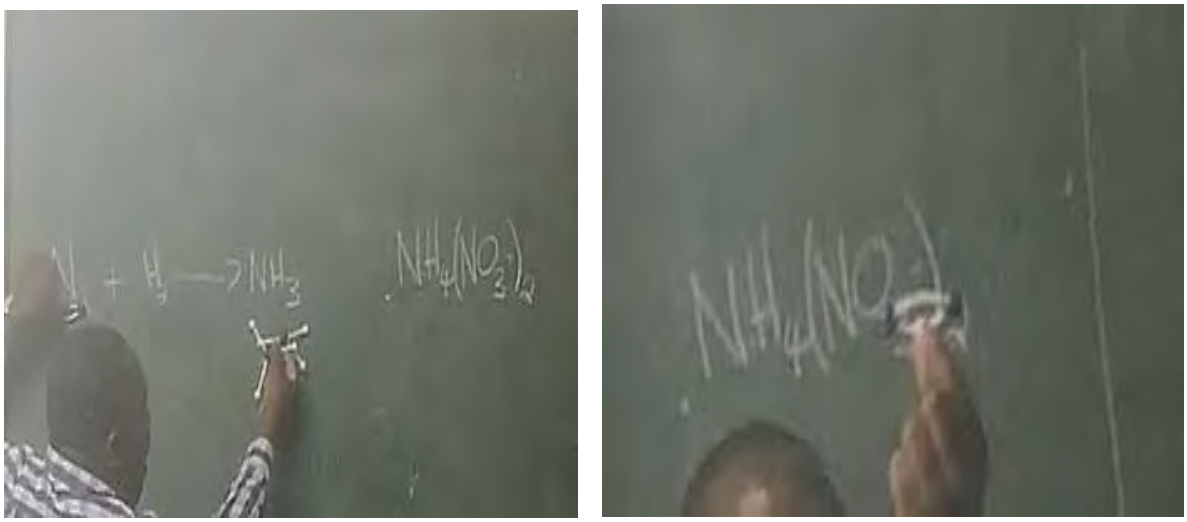


Figure 4.9: Mr Imagine demonstrating how atoms bond and can be balanced using beads

On reflection, from the semi-structured interviews the two teachers stated that:

> *I actually use many materials, for example you can use stones (Ms Iyaloo).*
>
> *Or, you can use palm, not palm but marula fruits ... and then you can also use what is this, any fruit that is available that can assist apart from those that I just mentioned (Mr Imagine).*

Although these two teachers indicated that they do make use of locally available materials, however, I observed that none of them tried to include some of the materials they mentioned. Yet, the use of locally available resources allows learners to understand science better and this is highly advocated for by scholars such Asheela et al. (2021), Ndevahoma (2019), and Asheela (2017).

4.3.5 Conceptual Teaching Strategies (CTS)

According to Mavhunga and Rollnick (2013) and Mavhunga, Ibrahim, Qhobela, and Rollnick (2016), conceptual teaching strategies refer to the teaching strategies derived from the considerations made from other components and excludes general teaching strategies.

From my observation, I witnessed both teachers using different strategies in order to enhance conceptual understanding on the topic. This included the notes that Ms Iyaloo prepared and gave to the learners as handouts. To strengthen the content, Ms Iyloo further planned some written activities that learners had to write individually on the work sheets, as well as some examples that learners had to solve on the chalkboard (see Figure 4.10).

Figure 4.10: Learners solving some equations on the chalkboard during Ms Iyaloo's lesson

Although she used the methods mentioned above, it was however evident that her lesson presentations were predominantly lectures. During the lessons, the teacher provided explanations and there was little opportunity for the learners to talk and express themselves. Further, lecturing does not give learners an opportunity to fully grasp the information provided to them by the teacher as espoused by Schuh (2004). Thus, learners cannot construct their own knowledge.

On the other hand, lessons presented by Mr Imagine had a fair teacher-learner interaction and the teacher ensured this by posing a lot of questions to the learners. When he did the demonstration using the beads to construct compounds and equations, I observed how learners became excited and they were all curious to see what was going to happen next. The teacher's demonstration also allowed for maximum learner engagement as every learner had to do the construction of equations using the beads individually. This is consistent with McRobbie and Tobin (1997) who call for creativity in teachers if they want learners to become actively involved. Using the beads also talks to the integration of learners' prior knowledge which is part of the TSPCK of Mavhunga and Rollnick (2013) and Mavhunga et al. (2016).

Since Mr Imagine's lessons had more learner engagement compared to Ms Iyaloo, his instructional strategies could be referred to as learner centred as advocated for by Nyambe (2008). It could be concluded, therefore, that teachers' PCK is unique to individual teachers as pointed out by Carlson and Daeler (2019).

4.4 Chapter Summary

This chapter presented the data generated from the semi-structured interviews and the lesson observations. Findings revealed that the two chemistry teachers have similar perspectives towards the use of the periodic table of elements when mediating the writing and balancing of chemical equations in particular. It was also revealed that teachers make use of the learners' prior knowledge, make good use of representations.

In the next section, I present, analyse, and discuss data from the stimulated-recall interviews and participants' group reflections.

CHAPTER FIVE: STIMULATED RECALL INTERVIEWS AND GROUP REFLECTIONS

5.1 Introduction

In this study, I sought an in-depth understanding of how two chemistry teachers mediate learning of writing and balancing chemical equations through using the periodic table of elements as an enabling cultural tool. As explained earlier, the study was prompted by the need to understand chemistry teachers' instructional practices when mediating learning of writing and balancing chemical equations.

In this chapter, I present the data generated from stimulated recall interviews and participants' group reflections. These were aimed at addressing my research question three:

> How do stimulated recall interviews and group reflections influence Grade 11 chemistry teachers' understanding of and the use of the periodic table of elements when mediating learning of writing and balancing chemical equations?

I begin with the presentation of stimulated recall interviews.

5.2 Stimulated Recall Interviews

As alluded to in Section 3.8, the stimulated recall interviews were aimed at looking for clarity on the teachers' instructional strategies and actions during the lesson observations. Prior to the stimulated recall interviews, however, I had watched the videos on my own and transcribed them. That allowed me to draw up the stimulated recall interview questions. For convenience, these interviews were conducted on different days and at different venues that suited each participant.

We began by watching the video clips for the lessons observed with each teacher. The videos afforded these teachers an opportunity to remember the events as they happened during the

lessons as well as to give justifications on their decision-making processes for their teaching behaviours as noted by Nguyen et al. (2013).

Similar to the semi-structured interviews discussed in Section 4.2, the stimulated recall interviews were also audio recorded and later on transcribed verbatim (Cohen et al., 2018). The data presented here, therefore, is based on the audio transcriptions.

5.2.1 Stimulated recall interviews with Ms Iyaloo

Unlike all other activities with Ms Iyaloo that took place at her school, the interview took place in the conference room at a community library. This was because her school had been closed due to Covid-19 and the library was the only place that was convenient to both of us. As explained earlier, at the start of the interview we watched some video clips of the lessons that were recorded during the observation phase. Ms. Iyaloo was indeed excited to have seen herself teaching and commented that:

> *Wow! I did not see myself in a video before. Can I get this video also? I want to keep watching myself.*

The first question I asked her was what made her refer to the previous grade's work and what made her mention something about elements in particular when the task was to introduce the writing and balancing chemical equations. Ms Iyaloo explained that:

> *Of course, they did elements in the previous grades and it is very important for me to refer them back so that they can remember what they were taught previously.*

She further elaborated that:

> *I did so because I believe that they know the one (elements) that I used especially in the reactions because they know substances that react, and once they react then they use the products. So, now, for them to know what are they going to use they should at least remember what elements are.*

From the excerpts above, it can be deduced that this teacher has a good understanding of why prior knowledge is important to the learners. This resonates with Roschelle (1995) who states that learning should proceed from prior knowledge.

In another lesson, Ms Iyaloo started teaching chemical equations, and I felt she should have started with the word equations like Mr Imagine did. In this regard, she explained that: "*Leaners are already familiar with word equations. I feel we just go-ahead to chemical*

equations". Further, I asked Ms Iyaloo's about her intention to use the test tube stoppers as teaching aids. She commented that:

> *So, I use them to represent the number of atoms present. Ya, the number of atoms like oxygen as we have two atoms of oxygen and magnesium. I represent with one stopper so that they can see.*

As I look at this response, it seems this teacher did not properly prepare to use these stoppers. In her response, she did not go into detail about how the learners would be able to differentiate different atoms and elements. Based on this, one can argue that this teacher simply picked this representation to use without thinking of its correctness which can lead to misconceptions (Harrison & Treagust, 2006).

During the lesson, Ms Iyaloo gave learners some notes to follow. When enquiring why the learners did not do the summary for themselves, she commented that learners might miss out a lot of important points because they do not want to be independent and responsible for their own studies. In another lesson, Ms Iyaloo taught by providing the learners with examples of the equations to be used. On this, she commented that the teaching time was very limited and learners waste more time if they are given the time to come up with examples to be used in the lesson. Looking at Ms Iyaloo's responses, she seemed not to give learners enough time to think and this contradicts social constructivism theory which views education as learner centred and learners are to construct knowledge themselves.

5.2.2 Stimulated recall interview with Mr Imagine

The interview took place at Mr Imagine's school in the afternoon, a week after the last lessons were conducted. This was due to the fact that Mr. Imagine had been in and out of the school to attend to other important school related matters. As was done with Ms. Iyaloo, we began the interview by watching some video clips of the lessons he taught. He too was excited to see himself teaching and kept smiling throughout the interview.

The first question I asked Mr. Imagine was to explain why he introduced the topic balancing chemical equations starting with the periodic table of elements. On this, he explained that:

> *Yaa, the reason why I asked learners is just to find out whether they know anything that they can help them to balance chemical equation easier … and what I expected from them was a usage of periodic table that is what I wanted, if they know it.*

Looking at this response, it was clear that these two teachers have a common understanding that the periodic table of elements plays an important role and it should be well understood so that balancing chemical equations can be easier for the learners.

On assessment, Mr Imagine commented that he prefers to assess his learners through group work because that gives the learners a chance to help one another through the discussions. It was, however, not possible for him to give work to the learners to do in groups due to Covid-19 measures that were to be observed, which included social distancing.

Further, reflecting on his lessons, Mr. Imagine revealed that the beads he used as teaching aids did not belong to his school. He borrows them every year when teaching balancing chemical equations from a university campus that is 50 km away from his school. This action revealed that Mr Imagine always tries his level best to go the extra mile as far as preparing for his lessons is concerned.

5.3 Group Reflections

While trying and struggling to organise a convenient venue, Mr. Imagine volunteered to organise an office for us at his school. At the start, I explained the expectations of the discussion with the aim of creating a rapport and putting the participants at ease. Secondly, with the permission of the participants, the discussions were video recorded and similar to Nhase (2019) I wrote a narrative thereafter. The data presented here is therefore based on that narrative.

As in Nhase's (2019) study, my role as a researcher was to facilitate the discussions. I had prepared some questions that helped to give direction to the discussion. Further, the discussions commenced with the participants watching each other's lessons that were recorded during the observation phase. These videos served as the stimulus for the discussions. In order to give clear guidance to the participants, I posed some questions which helped to direct the discussion.

5.3.1 Teachers' views on the research process

Mr Imagine started with a comment that he felt so honoured to be part of this research and indeed enjoyed every part of the process. He mentioned that the research had opened his mind and triggered his curiosity to do research on the subjects he teaches especially on the teaching methodologies and teaching and learning support materials. This resonates with other studies whose findings support the use of easily accessible materials because they allow learners to

enjoy learning as they make connections with the content (Asheela et al., 2021; Ndevahoma, 2019; Shifafure, 2014; Shinana, 2019).

Similarly, Ms. Iyaloo also shared that she was happy to be a research participant, something she had never done before. Further, she explained how she had a difficult time fitting the lesson observations into her tight schedule because her school had been in session on and off due to Covid-19. She also shared that despite the fact that learners had agreed to attend the lesson, they complained that they were scared of meeting the visitor who was travelling from far which might put them at risk of infection. This led to only a few learners attending the lesson.

5.3.2 Influence on teachers' views regarding the teaching of balanced chemical equations

Mr Imagine commented that being a participant in this study offered him an opportunity to look at the chemistry curriculum and to understand that the topics are placed in a certain order purposefully which talks to curricular saliency Mavhunga and Rollnick (2013). For instance, the periodic table of elements came before other topics due to its importance in relation to these topics. He further mentioned that he would start telling his learners to pay more attention to the periodic table of elements. Based on this, it can be further argued that Mr Imagine has a good level of curricular saliency as stated in Section 4.3.3.

Regarding Ms Iyaloo's lessons, Mr Imagine commented that he liked the way she introduced the lesson. He particularly pointed out the display of the periodic table on the chalkboard which was later pasted on the wall inside the classroom. He mentioned that it is a good idea because the learners will keep looking at the periodic table more often and that will help them master it. Also, Mr. Imagine picked up a strong point that was raised by Ms Iyaloo during the observation which is the emphasis on the importance of writing correct chemical formulae of compounds before trying to balance the equations.

As the discussion proceeded, Ms Iyaloo mentioned that she was impressed by Mr Imagine's lessons, particularly by the use of beads in the demonstration of how atoms are bonded and how the learners were fully engaged in the activity which talks to the use of easily accessible resources as espoused by Asheela et al. (2021). Ms Iyaloo however, confessed, that she hardly uses teaching aids in this topic, blaming it on the school laboratory that is under-resourced.

Moreover, Mr. Imagine mentioned that basically, he wished that the research went further and could find out how this topic might relate to any local knowledge that is familiar with the learners. He stated that because this topic is mainly taught focusing on what the textbooks say, it is sometimes not easy for the learners to understand. He was therefore eager to do further research and perhaps find other ways of teaching in this regard.

Generally, it emerged from this study that the participants' group reflections created learning opportunities for the two teachers. For instance, Ms Iyaloo's was interested in the use of the beads and asked for details on where and how to get them. Also, Mr Imagine developed an interest in experimenting with the use of test tube stoppers used by Ms Iyaloo, despite the fact that it appeared confusing to the learners as he had noted. In other words, this was a professional development opportunity (Rout & Behera, 2014; Tekkumru-Kisa & Stein, 2017; Villegas-Reimers, 2003). According to these authors, professional development is essential in the sense that they give an opportunity to the teachers to learn new ideas, gain a deeper understanding of a topic, and new ways of thinking that improve the quality of classroom instructions.

These findings are in agreement with Shabani (2016) who lamented that teachers need to be engaged in in-service training or interventions to boost their pedagogical approaches to teaching and learning. Furthermore, Mr Imagine's feelings also resonate with the notion that professional development has a continuing nature as it is termed continuing professional development (CPD) by Ngcoza and Southwood (2019). On the overall research process, Mr Imagine commented that:

> *I have learnt that when you are a researcher, you have to be an understanding person because sometimes you can make an arrangement with a participant, put all plans in order and when you go there the participant is doing something else. It has to do with patience, passion and love. You must love your research (Mr Imagine).*

I could easily relate to this excerpt, as several times that I travelled to see the participants it was in vain as I was not able to see them.

5.4 Chapter Summary

In this chapter, I presented, analysed, and discussed the data generated from the stimulated recall interviews and group reflections. These data generating methods were employed in order to answer my third research question in this study. I started this chapter with the datasets

generated from the stimulated recall interviews and ended with those generated from the participants' group reflections. In the next chapter, I present a summary of findings, recommendations, and the conclusion.

CHAPTER SIX: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

The goal of this study was to explore how Grade 11 chemistry teachers make use of the periodic table of elements to mediate the learning of writing and balancing chemical equations. The study was a triggered by my own teaching experiences and by the National Examinations reports of Physical Science for both Junior Secondary Certificate (JSC) and Senior Secondary Certificate (NSSC). I gained some useful insights on the teachers' perspectives, experiences, and pedagogical insights and how they mediate learning. Moreover, teachers shared their reflections on writing and balancing chemical equations, which helped me to get a deeper understanding in this regard.

This study was a qualitative case study and PCK (Shulman, 1986) was adopted as the theoretical framework of the study. Data was analysed using a deductive approach and was further discussed using relevant literature. Furthermore, the study used Atallah et al.'s (2010) indicators to identify perspectives and Mavhunga and Rollnick's (2013) components of TSPCK to explore how teachers mediate learning.

6.2 Summary of Findings

The findings from this study are presented per each research questions as follows.

Research question one

> **What are Grade 11 Chemistry teachers' perspectives, experiences, and pedagogical insights on the use of the periodic table of elements in their chemistry lessons?**

In response to the first research question above, it emerged that the teachers in this study possess an adequate understanding on what the purpose of teaching the periodic table of elements is. For instance, they highlighted that the periodic table of elements is key to any topic

in chemistry that should be understood if one is to understand chemistry, which is in line with Agunbiade (2020), Chani (2014), Denuga (2019), Nikodemus (2017) and Park (2015).

Further, it also emerged that the teachers in this study possess positive attitudes towards teaching the writing and balancing of chemical equations. It was evident that teachers have a belief that chemical equations are linked to other topics in chemistry such as stoichiometry (Anthony, 2009; Chamudeswari & Bai, 2014).

Furthermore, it emerged that the two chemistry teachers in the study share common experiences in teaching the writing and balancing of chemical equations. In light of this, the teachers described the use of various materials that they use in order to help learners understand the writing and balancing of chemical equations. They indicated the use of hands-on practical activities and the use of easily accessible materials to make the topic more understandable as highlighted by Asheela (2017), Ndevahoma (2019), and Asheela et al. (2021).

Additionally, teachers revealed that there are some challenges which they normally experience which hinder the understanding of the learners. They indicated limited teaching and learning materials, misconceptions about the numbers of atoms and elements when learners write chemical formulae, and the inclusion of polyatomic ions when writing chemical formulae. Teachers also indicated that they try to link balancing chemical equations to other subjects such as algebra in mathematics which is in line with Hiremath (2015) who suggests a system of solving chemical equations by using linear equations. Also, teachers indicated that they try to give more written work to the learners in an attempt to make the writing and balancing of chemical equations understandable to the learners.

How do Grade 11 chemistry teachers make use of the periodic table of elements when mediating learning of writing and balancing chemical equations?

During the observations, certain issues were revealed. These are based on the components of TSPCK viz., learners' prior knowledge, what is difficult to learn, curricular saliency, representations and lastly, conceptual teaching strategies. These components are discussed as follow.

6.2.1 Learners' prior knowledge

From the observations, it emerged that the two teachers have a practice of drawing from the learners' prior knowledge as they introduce a new topic. This was evident in the manner that

they asked questions about what learners had learnt in the previous grade such as their understanding of the key issues in the periodic table of elements. Establishing what learners already know about the periodic table of elements will help them to understand other topics.

6.2.2 What is difficult to understand?

From the observation of learners in this study, it was evident that teachers in this study understand what makes writing and balancing chemical equations difficult to understand. For instance, they highlighted from the interviews the understanding of the periodic table of elements concept, which was solidified by the way they referred to it during the lessons. These teachers also used examples and explanations which were challenging to the learners in order to provoke their interest in wanting to learn more.

6.2.3 Curricular saliency

The observations revealed that teachers were able to make connections and links between the periodic table of elements and balancing chemical equations. This was evident as they tried to explain concepts from simple to complex. That is, starting with the periodic table of elements, to how atoms bond and form ions and their charges, writing chemical formulae, then lastly chemical equations (De, 2018). The fact that the teachers were able to use examples from other chemistry topics such as acids and bases to construct chemical equations was a strong point in this regard. However, it was observed that the SMK (Shulman, 1986) of the two teachers was different.

6.2.4 Representations

As explained above, teachers made reference to different types of mediation styles. These included questions, different examples, pictures, and charts. It was also observed that one teacher, Mr Imagine, used models of atoms to represent molecules which afforded learners an opportunity for hands-on practical activities as noted by Asheela et al. (2021) who posit that hands-on activities motivate learners to learn science concepts better.

6.2.5 Conceptual learning strategies

Drawing from how other TSPCK components were considered when mediating learning, it was observed that teachers used different strategies, such as using easily accessible materials. Mr Imagine used some beads for learners to understand how atoms are bonded, and how they are balanced on both sided of the equation.

It was observed that teachers used the language that was appropriate to the learners in all their explanations and demonstrations. It was, however, observed that Ms Iyaloo lessons had limited teaching and learning interactions as she ended up directing learners to answers from the questions she asked.

How do stimulated recall interviews and group reflections influence Grade 11 chemistry teachers' understanding of and the use of the periodic table of elements when mediating learning of writing and balancing chemical equations?

The stimulated recall interviews afforded me an opportunity to look for clarity on the teacher's actions during the lesson observations and for teachers to reflect on their own actions. This was done through watching their videotaped lessons. Teachers were excited to see themselves in these videos together with their learners.

Additionally, the group reflections held with the teachers allowed them to share ideas and experiences. This was done through watching each other's video-recorded lessons. I facilitated the discussion and this showed them that I was doing this study with them as fellow chemistry teachers and not merely focussing on them. They expressed that they had developed an interest in each other's instructional strategies, including the teaching and learning materials, and this can be considered as being part of professional development.

Furthermore, teachers were free to share their views on the research process. They expressed how the honoured they felt to be my research participants. However, they also shared how difficult it was to make time for extra lessons that were meant for this research study as they, together with the learners, feared the risk of Covid-19 infection.

6.3 Recommendations

Several recommendations emerged from my research findings and discussions above. These recommendations aim at alleviating some challenges that are encountered when mediating the learning of writing and balancing chemical equations.

- The study recommends that teaching should strongly make use of the periodic table of elements as a cornerstone to learning chemistry.

- I recommend that teachers include the use of easily accessible resources at their disposal in their lesson preparations and that these should be appropriate for the topics to be taught.
- Since the chemistry syllabus is not explicit on the use of easily accessible resources, I recommend that the advisory services identify teachers that are more knowledgeable in order to share their expertise with other teachers. This will help to improve and strengthen teachers' PCK with special consideration of the TSPCK components Mavhunga and Rollnick (2013) and Mavhunga et al. (2016).

6.4 Limitations of the Study

The results of the study were limited to only two secondary schools and two chemistry teachers and therefore they cannot be generalised. However, some insights on how teachers use the periodic table of elements to mediate the learning of writing and balancing chemical equations were obtained from this study. It is recognised, however, that my presence in the classroom and the videotaping during the observations might have changed the normal way in which the teachers and the learners interact and, in a way, this might have affected the results of my study.

6.5 Areas of Future Research

This study opens up some opportunities for further research.

- Learners' views, attitudes, and experiences regarding the writing and balancing of chemical equations;
- The integration of local indigenous practices in the teaching of chemistry and hence the writing and balancing chemical equations emerging from such practices;
- The role of technology during mediation of writing and balancing chemical equations; and
- Formative interventionist studies to support chemistry teachers on the use of the periodic table of elements when mediating the learning of writing and balancing chemical equations.

6.6 Personal Reflections

I am pleased to have walked this journey despite the fact that there were some difficulties that made me pause and look back again. It was not as smooth a journey as I wished as I had to balance my work, my family time as a wife and a mother, and my studies. These challenges were exacerbated by the unprecedented Covid-19 pandemic.

After completing my honours degree at Northwest University, I always wanted to do my next qualification at a reputable institution. I applied to many institutions of higher learning and I was fortunate enough to gain admission at Rhodes University for the 2019-2020 academic year. In the first contact session, we were introduced to certain aspects of doing research and also discussed critical issues in science which helped me in setting the groundwork for my research. In March 2019, we were invited to the research design course at Rhodes University. We witnessed different scholars presenting different aspects on how to write a research proposal, conduct a research study, and explanations on different types of research. This opened my eyes more and I started with writing the research proposal.

Writing a research proposal was not a walk in the park as I anticipated. For instance, my supervisor had to send it back to me several times before I finalised my research topic which was later approved by the Rhodes University High Degree Committee. As required by Rhodes University, one has to be given an ethical clearance. This was the most frustrating point as I had to wait for the response from the ethical clearance committee and I had to re-do several items. It was only then when everything was clear that I was given the green light to proceed to the next step which was the data gathering process.

The data gathering process took place in the second year (2020). This was a very difficult time because of the challenges imposed by the Covid-19 pandemic. When Namibia recorded its first case in March 2020, there was a state of emergency and the country was under lockdown. Schools had to be closed for close to three months and this delayed my data gathering process. With the advice from my supervisors, I divided my thesis into two parts: Part A (the first three chapters) and Part B (the last three chapters). During this lockdown period, I drafted Part A which was not really challenging as most information for this section was already covered in the proposal.

When the schools reopened, it was not easy to get access to the schools for the data gathering. There were fears of infection and visitors were not welcomed at many schools as in the past. At the same time, teachers were overloaded with much work as they had to teach faster in order to complete the curriculum before the end of the year examinations. Nevertheless, I had very understanding participants and we negotiated well on when and where to meet for the interviews and for the lesson observations. There were also some lesson observations that were conducted in the evenings because it was practically not possible to see this teacher during the day.

After the data gathering process, I continued to write Part B which really gave me a tough time. Transcribing the interviews and video recorded lessons was an endless process which gave me many sleepless nights. It was also not easy for me to extract relevant data from the huge volumes of data that I gathered even though I had analytical tools to guide me. Also, I had a difficult time trying to align my chapters so that they talked to each other, as each chapter was initially written separately.

What kept me going was the spirit of Ubuntu that prevailed in our 2019-2020 MEd Science group. Our supervisors, Prof. Kenneth Ngcoza and Dr Zukiswa Nhase, timely responses, supportive comments, and suggestions brought me this far. They always motivated us with the powerful African proverb that they shared during the contact sessions: "*If you want to go fast, go alone, if you want to go far go together"*, which was our pillar of strength.

6.7 Conclusion

The findings from this study concluded that teachers make good reference to the Periodic Table of Elements when teaching the writing and balancing of chemical equations. It was also established that teachers still make use of traditional lecturing methods which rely more on teacher talk resulting in less learner involvement and talk. The study therefore suggests that teachers need continuing professional development platforms or professional learning communities to afford them opportunities to share teaching strategies in order to help learners to make sense of the concept of chemical equations.

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Appendices

Appendix A: Approval letter from ethics committee

RHODES UNIVERSITY
Where leaders learn

Human Ethics subcommittee
Rhodes University Ethical Standards Committee
PO Box 94, Grahamstown, 6140, South Africa
t: +27 (0) 46 603 8055
f: +27 (0) 46 603 8822
e: ethics-committee@ru.ac.za

www.ru.ac.za/research/research/ethics
NHREC Registration no. REC-241114-045

Prof Kenneth Ngcoza

Email: k.ngcoza@ru.ac.za

Review Reference: 2020-1152-3544

Dear Prof Kenneth Ngcoza

Re: Exploring how Grade 10 Chemistry teachers make use of the Periodic Table of Elements when mediating learning of the topic Writing and Balancing Chemical Equations.

Principal Investigator: Prof Kenneth Ngcoza

Collaborators: Mrs. Reginald Ndeshipanda Kambeyo,

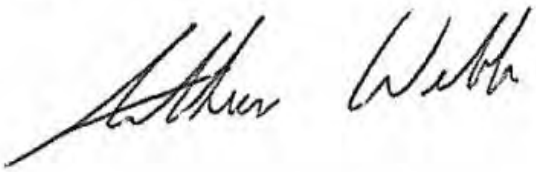
This letter confirms that the above research proposal has been reviewed by the Rhodes University Ethical Standards Committee (RUESC) – Human Ethics (HE) sub-committee and **PROVISIONALLY APPROVED PENDING GATEKEEPER PERMISSION**.

Gatekeeper permission is required from:

a) Department of Education, Namibia

Once the Gatekeeper permission letter/s have been received please forward it to the Ethics Coordinator, (s.manqele@ru.ac.za) in order to finalize your ethics approval.

Sincerely,



Prof Arthur Webb

Chair: Human Ethics Sub-Committee, RUESC- HE

Appendix B: Approval letter from the Regional Director

REPUBLIC OF NAMIBIA
OHANGWENA REGIONAL COUNCIL
DIRECTORATE OF EDUCATION, ARTS AND CULTURE

Section: Office of the Director
Tel: (+264) 65 290200
Fax: (+264) 65 290224
Enquiries: Magano Gaoses
Our Ref : 12/3/10/1

Harelbecke Street, Greenwell Complex Building
Private Bag, 88005
Eenhana

26 June 2020

To: Reginald Ndeshipanda Kambeyo
Private Bag 7129
Oshakati
Email: rndeshinadilu@gmail.com

SUBJECT: REQUEST FOR PERMISSION TO CONDUCT AN EDUCATIONAL RESEARCH WITH TWO GRADE 10 CHEMISTRY TEACHERS AT TWO SCHOOLS IN OHANGWENA REGION

1. Receipt of your letter dated 25 June 2020 is hereby acknowledged.
2. The request has been evaluated and found to have merit.
3. Kindly be informed that permission to collect data from Eengedjo SS and Omungwelume SS for research has been granted under the following conditions and requests.
   - The data to be collected only be used for the completion of your studies.
   - Kindly liaise with the concerned Principals so as to make prior arrangements before the date of the research.
   - No other data should be collected other than the data stated in the request.
   - You may share the final report of your study with the directorate.
4. It is trusted that you will find this arrangement in order while wishing you all the best with your studies.

Yours Sincerely,

26/06/2020

Isak Hamatwi
Director

Ohangwena Regional Council
Directorate Of Education
Office of the Director
26 JUN 2020
Tel: 065-290 200 Fax: 065-290 224
P/Bag 88005 • Eenhana
REPUBLIC OF NAMIBIA

cc: Inspector of Education: Endola circuit
Principals: Eengedjo SS
Omungwelume SS

Appendix C: Letter to School Principals

Private Bag 7129

Oshakati

rndeshinadilu@gmail.com

The Principal

…….. School,

Private Bag

Oshakati

Dear Sir,

Re: Request for permission to conduct an educational research with grade 10 Chemistry teachers.

My I am Reginald Ndeshipanda Kambeyo (Student No. 19K2069), a part-time student at Rhodes University, South Africa. I am studying towards obtaining a master's degree in Science Education. I am writing to request your office permission for me to conduct a research study with one grade 10 Chemistry teacher from your school. I plan to conduct the study for about two to three weeks in term one, 2020 academic year.

My research topic is: ***Exploring how Grade 10 Chemistry teachers make use of the Periodic Table of Elements when mediating learning of the topic Writing and Balancing Chemical Equations.*** The purpose of this research project is to enable teachers to develop a further understanding on how to make use of the Periodic Table of Elements in order to make the Chemistry meaningful to the learners. The study will involve administering classroom observations and conducting interviews with the teachers when teaching the topic Writing and Balancing Chemical Equations.

I will try to ensure that this study does not interrupt the normal teaching and learning process by conducting the research activities after the normal teaching and learning process. I would also like to assure you that the identity of the school and that of the participants will remain confidential and the findings will be strictly used for this study only.

The study is under the supervision of Prof Kenneth Ngcoza (E-mail: K.Ngcoza@ru.ac.az). However, at any stage of this research should you feel uncomfortable or may have concerns, you are welcome to raise your concerns with Rhodes University by contacting Mr Siyanda Manqele at ethics-committee@ru.ac.za.

Looking forward to hearing from you.

Yours faithfully,

Reginald Ndeshipanda Kambeyo

Appendix D: Letter to the participants (Teachers)

Private Bag 7129

Oshakati

rndeshinadilu@gmail.com

Dear Sir/Madam

Re: Participation in research on how to make use of the Periodic Table when mediating learning of Writing and Balancing Chemical Equations.

I am Reginald Ndeshipanda Kambeyo (Student No. 19K2069), a part-time student at Rhodes University, South Africa. I am studying towards obtaining a master's degree in Science Education. I am humbly requesting you to be my research participant. I plan to conduct the research for about two to three weeks in term one, 2020 academic year.

The purpose of this research project is to enable teachers to develop an understanding on how to make use of the Periodic Table of elements in order to make Chemistry meaningful to the learners. The study will involve conducting classroom observations (videotaped) and interviews when teaching the topic Writing and Balancing Chemical Equations.

I will try to ensure that this research does not interrupt the normal teaching and learning process and will not obstruct you from attending to your daily lessons. I would also like to assure you that your identity will remain confidential and the findings will be strictly used for this study only. Participation in the study is voluntary and you can withdraw your consent to participate in the study at any time and this will not have any consequences for your further treatment.

If you later on wish to withdraw your consent or have questions concerning the study, please feel free to contact me at +264813016698, rndeshinadilu@gmail.com or my supervisor Prof. Ngcoza at k.ngcoza@ru.ac.za. Should you feel uncomfortable or may have concerns about this study, you are welcome to raise your concerns with Rhodes University by contacting Mr. Siyanda Manqele at ethics-committee@ru.ac.za.

Your cooperation will be highly appreciated

Yours Sincerely

Reginald Ndeshipanda Kambeyo

CONSENT

I am aware that

- I will be the participant for the above-mentioned topic.
- I am willing to be interviewed and make time for it.
- I am free to withdraw at any time I may wish without negative or undesirable consequences.
- The information provided will be used only in the research project.
- I am also aware that the information provided by me will be strictly confidential and the findings will be reviewed in the research thesis.
- My identity in this study will be protected with the code of ethics stipulated by Rhodes University.

Having taken note of the above information, I freely and volunteer to take part in the research process and acknowledge that I have not been forced to do so.

Declaration

I……. (Full name and surname of participant) hereby confirm that I understand the contents of this letter and the nature of the research project. I consent to participate in the research project.

Signature of participant ……. Date…….

Appendix E: Letter to the parents

Private Bag 7129

Oshakati

rndeshinadilu@gmail.com

Dear parent / Guardian

Re: Request for your child to participate in the educational research.

I am Reginald Ndeshipanda Kambeyo, a part time student at Rhodes University with student number (19k2069). I have written a letter to the principal where your child is attending school to seek for permission to conduct an educational research. The focus of the research is to explore how grade 10 Chemistry teachers make use of the Periodic Table of elements in order to make Chemistry meaningful to the learners. Should I be granted permission, I will be doing some video recordings of lesson presentations in which your child might appear. Therefore, I would like to seek permission from you to know if your child can take part in this educational research.

The research study will be under the supervision of Prof K. Ngcoza (k.ngcoza@ru.ac.za). My contact details are +264813016698 and email (rndeshinadilu@gmail.com). Should you have any concerns feel free to contact me, my supervisors and Mr. Siyanda Manqele the ethics coordinator at (ethics-committee@ru.ac.za) at any time.

I undertake to work with your child ethically and he/she will be free to choose whether to be part of this educational research or not.

Yours faithfully.

Reginald Ndeshipanda Kambeyo

If you would give permission for your child to be part of this research study, please

complete the declaration below.

I..... (Full name of parent/ guardian)

hereby confirm that I understand the content of the letter and give permission for my child to participate in the educational research.

....

Signature of parent Date

....

Signature of learner Date

Appendix F: Interview Schedule (semi-structured interview)

Research Question 1

What are the grade 11 Chemistry teachers' perspectives, experiences and pedagogical insights on the use of the Periodic Table of Elements when mediating learning of writing and balancing of chemical equations in their chemistry lessons?

Question	Purpose
1. Could you please describe what you think is the purpose of teaching the Periodic Table of Elements in Chemistry?	To find out their thoughts about the nature of Chemistry and why they believe it is required to learn it.
2. Could you please tell me how you elicit your learners' prior knowledge before teaching writing and balancing of chemical equations?	To find out how teachers, elicit the learners' prior everyday knowledge when teaching writing and balancing chemical equations.
3. Could you please share with me what teaching and learning materials that you use to: (a) Support your learners understand the Periodic Table of Elements? (b) Support your learners understand writing and balancing of chemical equations?	To find out which representations including analogies, demonstrations and any other materials used apart from their notes.
4. Could you please share with me any success stories that you experienced	

when teaching the topic of writing and balancing of chemical equations?	To find out what makes the topic easy to understand when teaching writing and balancing of chemical equations.
5. Could you please share with me the challenges that you experience when teaching the topic of writing and balancing of chemical equations?	To find out what makes the topic difficult to understand when teaching writing and balancing of chemical equations.
6. How do you find out if learners have understood the topic on writing and balancing of chemical equations??	To describe evidence that they successfully taught the content and the learning has become meaningful to the learners.

Format adapted from: Cetin-Dindar and Geban (2017, p.89)

Appendix G: Indicators of conceptions and dispositions

Concepts	Indicators	Research instrument	Research question
Conception and experience	• *Describing with broader understanding the Periodic Table of Elements* • *Describing the purpose of the Periodic Table of Elements in chemistry* • *Describing what is required to teach the Periodic Table of elements* • *Describing what in-class activities help one to teach the Periodic Table of elements.*	Semi-structured interviews	1
Attitudes	• *Describing one's attitudes towards Chemistry as a subject.* • *Describing one's sentiments/feelings when teaching using the Periodic Table of Elements* • *Describing the perceived value of using the Periodic Table of Elements in chemistry* • *Describing the perceived value or relevance of the topic Periodic Table of Elements to the world views*	Semi-structured interviews	1

Adapted from Attallah, Bryant, and Dada (2010)

Appendix H: Semi-Structured Interview with Ms Iyaloo

Mrs Kambeyo: Ok, Eh, Mrs. Iyaloo good afternoon?

Ms Iyaloo: Good afternoon madam.

Mrs.Kambeyo: I am very well, as I introduce myself already "ah. uhm," I am here for our interview as communicated already. I will be asking you a few questions, please feel free to answer and you are also at the same time free to share with me your, experience to share with me your views. Just feel free this is actually our discussion all right. The first question. Could you please describe what you think is the purpose of "aah," teaching the periodic table of elements in chemistry?

Ms Iyaloo: All right, so it's very important because a Periodic Table is a method of classifying elements and it determines or predicts the characteristics of elements for you to know to which group or period an element belongs to you have to go through the Periodic Table.

Mrs.Kambeyo: All right, so, what is really the purpose around it or in other words; can anybody do chemistry without doing the periodic table?

Ms Iyaloo: "Umh" is not really possible because you need to know where the elements are and on which side should I go if I want to, let me say if I am looking for perhaps potassium. I need to know on which side of the Periodic Table I can find it as simple as such without roaming around, so it's very needed.

Mrs.Kambeyo: All right, thank you, another question **Ms Iyaloo**, could you please tell me how you elicit the learners' prior knowledge; how you integrated the learners' prior knowledge when you teach the topic Writing and balancing chemical equations? How do you integrate learner's prior knowledge?

Ms Iyaloo: All right, so, first of all of course I have to ask them if they know what a Periodic Table is and then I have to ask them the purpose of it. I will give some examples like when you go in a shop you find shelves where things are divided into groups according to their similarities, then by that I will then ask what is maybe the

purpose of that and why can't you find certain things here but the other things are there. So, I have to make or tell them clearly that when you are working with things you have to work with them when they are equal. So, then I will give certain example of where I have balance or give certain example of equations and then show them how to balance the equation.

Mrs.Kambeyo: "Mh" this is very interesting. You talked about an example of going to the shops this is quite an experience I never thought about that as a chemistry teacher. All right, "mh" I will still go ahead with questions. Could you please share with me, what are the teaching and learning materials do you use, the ones that you use to support your learners:

1. To understand the periodic table itself.

2. To understand writing and balancing equations.

What are those teaching materials you use?

Ms Iyaloo: All right, so I actually use many materials. "eh" Example, you can use stones. You can count them and you can put some amount or certain number of stones on one side and then you put a number of stones on the other side. Then you try to make them equal on both sides, that is now on balancing the equation. Then on the Periodic Table you can use things like dominos or balls with different colours and then with those things you can arrange them according to the groups or you can come up with a model using them. You then question learners' example by looking at this 'coz they have shapes or let me say colours for example how many colours on this, how many colours on this? Do you think this those two belong to one group or so, or maybe belong to one period or so and from there they can actually understand what how to balance equations, or what a periodic table is?

Mrs.Kambeyo: All right, now you have mentioned models, how do you come up with these models? Are they are manufactured already? Do you buy them from somewhere or you as a teacher you improvise or do you perhaps ask the learners to do them?

Ms Iyaloo: It will depend on the time. If you know that you have enough time, you can ask learners to come up with some. If you know there is not enough time you can do them yourself and then explain how you come up with them.

Mrs.Kambeyo: This is very interesting, it is actually a learning experience, all right, we still have a few more questions. Could you please share with me any success story that you experienced when teaching the topic Writing and Balancing equations, anything interesting "Ya" just share anything.

Ms Iyaloo: "Uh' actually you hear from learners asking that "Ya" you hear them asking that but why "ah" is it necessary to balance equations? Then, you tell them like is not possible for you to work with unbalanced things. They have to be balance, so that you can make comparisons or you can at least have "uh" let me say, ok any way there are many things and it all depend on the type of the learners you are have, sometimes you might not get something.

Mrs.Kambeyo: "uh" All right "ya, ya" so like your teaching experience now when you teach that topic, how do you feel? Do you feel like your learners achieved something?

Ms Iyaloo: Ok actually you realize that you have delivered something because sometimes even when you are moving around the school and then a learners see something which is not really in a proper way you might hear that learner saying, "*that one is not balanced"!* Or maybe when you are presenting a certain topic and write an equation, if it is not balance then you hear a learner saying *"that equation is not balance Mrs."* Let us balance it first. So that means that they have picked up something when you were teaching them the topic of balancing equation as a basic.

Mrs.Kambeyo; All right "eh" we are closer to the end of our interview I actually have two more questions. Sorry, could you please share with me the challenges that you may have experiencing when teaching this topic writing and balancing chemical equation.

Ms Iyaloo: Ok, so you asked about when they are writing chemical equation.

Mrs.Kambeyo: Whatever challenge you came across and perhaps a bit of how you handled them.

Ms Iyaloo: They actually have a problem on writing a chemical formula of compounds. You have to emphasis more on how did this formula come up by using the valencies or perhaps the Ions. Also, and also, they have a problem on counting the number of atoms on the reactant and the product side. Sometimes you find an equation where the formula has 'mmh" brackets for instance 'aaah" Calcium hydroxide; so, if you happen to look at that two behind the brackets, sometimes those learners never know that anything that is in brackets is or the number out of the brackets is for everything that is out of the blankets. As a result, they end up counting wrong numbers. So, that is actually the problem that I have.

Mrs. Kambeyo: All right, how do you address it to the learners, how do you simplify it to the learners?

Ms Iyaloo: All right, I normally ask them to recall from Mathematical point of view 'coz they use to do that in Mathematics.

Mrs.Kambeyo: Ok

Ms Iyaloo: We were taught calculation where there is an inclusion of numbers outside the brackets. Then once I asked them to recall that, you will hear most of the saying 'Ahhhhaaa, so it's the same' then they learn.

Mrs.Kambeyo: Thank you very much, our last question Ms. IYALOO. How do you find out after you have taught this topic; how do you find out if the learners have understood the topic of Writing and balancing chemical equation or not?

Ms Iyaloo: Actually, if you happen to give them an activity and you look at the way they are answering questions. If they can able to balance the equation you gave them or if they can able to write correct formulas, 'coz for you to balance the equation you have to make sure that the compounds formulae involved in the equation are written correctly. If they are able to do so, then that is a clear point that they have learned something and they know how to balance the equations.

Mrs.Kambeyo: All right, apart from what you have mentioned is there any practical activity that you give and apart from writing maybe is there a certain practical activity where they have to do by touching the materials by assembling them? I am now asking this in connection with the other point that you have mentioned of coming up with models.

Ms Iyaloo: ",ya, mhhhh.." again it depends now, sometimes you can "ahhh " you can make an investigation. You can carry out a practical where you can react for example magnesium with perhaps water then once you react that then you deduce the equation from there then you can ask then to balance it.

Mrs.Kambeyo: "Mhhhh", do you have access to apparatus, does your school have access to some basic chemicals.

Ms Iyaloo: I have taught at different schools, so, I did that at my former school.

Mrs.Kambeyo: Ahhh, all right

Ms Iyaloo: Oh yes, there were chemicals … but here we have a problem

Mrs.Kambeyo; Oh yes

Ms Iyaloo: Thank you very much Ms Iyaloo, it was quite an experience. I have learn quit a lot from you and this marks the end of our session for today, thank you so much.

Appendix I: Semi- Structured Interview with Mr Imagine

Kambeyo: Ok, Mhh, Mr Imagine, good afternoon

Mr Imagine: Good afternoon Ms.

Kambeyo: Thank you very much for making it to this interview, I am so excited. Mmm, like I said before the focus of this research is to investigate how the grade 11 Chemistry teachers integrate the Periodic Table and how they teach the topic of Writing and Balancing Chemical equations. So, Sir feel free. I am going to ask you aah a few questions.

Mr Imagine: Alright

Kambeyo: The first one; could you please describe what you think is the purpose of teaching the Periodic Table in Chemistry?

Mr Imagine: Ok, eehm, the purpose of teaching the Periodic Table in Chemistry is for learners to, to know the group numbers because group numbers indicate the number of, of, of charges. For instance, the elements in group two (2) they have charge number two (2). So, when they react with an element in group seven (7), that means they use exchange charges. So, now teaching Periodic Table will help learners to know that if you react for instance ah magnesium with chlorine, that two (2) that is found from chlorine came from magnesium because it is in group two (2) that is why the bases of that should be a periodic table first.

Kambeyo: Alright, having mentioned that what about the Periodic Table towards other science disciplines?

Mr Imagine: What you mean, sorry can you come again?

Kambeyo: Like…., any relationship between the Periodic Table or let me say and other science disciplines in terms of importance.

Mr Imagine: Oh yes, the Periodic Table is aah important, it has so many, aah important things when it comes to Chemistry. Not only in, in balancing chemical equation we can also use Periodic Table in teaching salts when the salts are formed when

for instance a metal is reacting with an acid, you can be able to formulate the formula using the knowledge of the Periodic Table. For instance, you can have hydrochloric acid reacting with sodium. You know that sodium is in group one and chlorine is in group seven so the charges will already tell you the group number can also be used in that regard.

Kambeyo: Okay thank you Sir, then we move on to our next question. Sir, could you please tell me how you elicit, how you bring in your learners' prior knowledge; everyday knowledge before teaching this topic of balancing, writing and balancing chemical equation? What, what prior knowledge these learners must have and how do you make sure that you include it?

Mr Imagine: Okay, so learners already know, aah, aah, aah, chemical balance equation as refer to everyday situation. For instance, a learner is with a person who is disabled the learner should need to balance, like for instance the learner should not talk bad. I mean, should not talk bad things about disabled people. The learner will be learning about how to balance when, they are with others, balancing the situation. For instance, when, when, they are with parents they know what to say with parents and they know what to say with their best friends so starting from that they can also be able to know the reason why they are being taught that.

Kambeyo: Ooh, so, otherwise based on now the content, mmh, remember this are grade 11 learners; as you teach, is there maybe any knowledge, mmh, that they need to bring along ah before teaching this topic?

Mr Imagine: Oh yes, they, they know already the Periodic Table they know that Periodic Table is made up of group numbers, period numbers and they also learn about electron structures that the, the elements in group one (1) are having one (1) electron on the outer shell that knowledge that they gained from the previous grades can help them to understand better, this topic.

Kambeyo: Uhm, okay, ok, I think I, I understand there from grade 8 and 9 there hopefully and I think that from grade seven (7) people are still learning the periodic table. From there, Sir could you please share with me what teaching learning materials

do you use; number one (1) to support your learners to understand the periodic table now itself.

Mr Imagine: The Periodic Table?

Interviewer: Yes, and then number two (2), to understand now the Balancing of Chemical Equations. Now, in terms of, uhm teaching aids, how do you help these learners since you have mentioned that the Periodic Table is one of the prior knowledges and obviously one has to teach it nicely, one has to make sure that it is well understood. What, what. teaching aids do you use to support these learners to understand what periodic table of elements?

Mr Imagine: Okay, eeh, we have eh some models, eh in the lab that we can use that represent elements. For instance, you can have a model that represents say oxygen then if it is oxygen atoms that you connect to you connect two oxygen atoms together just to show learners that we have two oxygen molecules. And, if elements in group one you can just have one. If it is in group three (3) or if it is having three (3) atoms then you can just show that. Or, maybe you can ask learners to bring fruits. For instance, apples or anything that can be penetrated by perhaps by a stick or anything then uhm you will ask them to come up with a molecule. Then now they can be able to determine that this one it is made out of two atoms. For instance, eehm, oxygen you can have two fruits then you join these two fruits together, so this one represents the bond that joins them together then count and then now you should add another one for instance if it is in group one then you get the results then you can be able to balance by looking at the atoms.

Kambeyo: Uhm, alright, now having said that, eeh, which, we are now trying to include our readily available resources, which local materials do you use in this regard?

Mr Imagine: Yeah, I can use *eenyandi* I do not know (*laughs)* that in English. You can use *eenyandi* and those *eenyandi* can easily come up with molecule depends on what type of molecules. Or, you can use aahm palm, palm ahm not palm but marula fruits, you can also be used and then you can also use aah, what is this aah any fruit that is available that can assist apart from those that I just mentioned.

Kambeyo: Okay

Mr Imagine: Uhmmmm

Interviewer: Okay, thank you alright Sir, we go ahead. Uhm, could you please share with me any success story that you experienced when teaching the topic Writing and Balancing Chemical equations anything that you have enjoyed about this topic?

Mr Imagine: Yeah, ah, what I have enjoyed on this topic most is that learners do not know that for one to know how to balance this you need to, to, to know the Periodic Table. And, it sounds very funny that some of them think that they are separate topics that are not related. For instance, you ask them to, to, to come up with a compound they fail because they are neglecting the Periodic Table, and when they realise, they say "*Aa, aa, no, this is very simple*". Yeah, and then they get excited when they realise that they are linked.

Kambeyo: Ohoo, they actually get so excited nee?

Mr Imagine: Yes, yeah,

Kambeyo: Alright, and another question Sir, having mentioned now your success and enjoyable story about that eeh, what are the challenges that you have experienced in this regard when you are teaching now, this ah Balancing Writing and Balancing Chemical Equations?

Mr Imagine: Yeah, the most challenging is teaching and learning aids. It is very, very difficult to find a teaching and learning aid that will make those learners to understand apart from the ones that are provided labs. So even if you try to improvise, learners will hardly understand really the meaning of Balancing Chemical Equation, it is aa it is a very, very challenging and also some learners do not really know the difference between molecule and then that number of moles that we put there. Sometimes when they are balancing, they refer to that number as (*laughs*) number of moles and it gives a challenge to me as a teacher to make them understand.

Kambeyo: Uhmm, and how about writing the formula?

Mr Imagine: Yeah and also writing the formula it is also a problem, that one is a big problem, eeh, simply because they do not really borrow knowledge from Periodic Table to so that they can implement it in the balancing chemical equations they neglect periodic table that is why they are failing.

Kambeyo: Uhmmm, oh alright, eeh, we are moving towards the end of our interview, eehm one more question or maybe not last but yeah, how do you find out having taught now uh this topic, how do you find out that eehm these learners have actually understood this topic?

Mr Imagine: Yeah, eehm, it is very easy, some learners perform when you give them assessment. For instance, after you teach then you give them assessment and then they perform and even the expectations that you have set, they are always reached. They are also curious to learn, they are asking questions sometimes they follow you up to the staff room, asking a lot of questions, you can see that they are interested and they want to know and understand. Eehm, but what I can say it that the performance will tell you whether they understand or not, if they are failing then they should…. there is need for you to push again.

Kambeyo: Eehm, you have mention assessment, what form of assessment do you usually normally use?

Mr Imagine: Yeah, I usually use, I use a group work. Group work is the most effective assessment method because that is where you are allow learners to interact and share ideas. That will help those that do not understand because among the whole class only 50% of them that do not understand, those that understand can help others, so group work is a most, is a most important assessment.

Kambeyo: Oho oho okay and then otherwise if not group work eeh individually?

Mr Imagine: yeah, individual work comes after group work, group work is first because they should share ideas and then from there you can now be given them individual work or homework.

Kambeyo: Okay, uhmmm, okay ahm, Sir I am very much happy aah for having engaged with you in this aah short eeh interview, I really appreciate your effort, I really appreciate your time, thank you very much.

Mr Imagine: My pleasure.

Appendix J: Transcription of Ms Iyaloo's lesson.

Lesson 1

The lesson was observed conducted during the afternoon study. It took about 40 minutes.

Key: *T- Teacher*
L- One Learner
LLL- More than two learners

T: Good afternoon class

LLL: Good afternoon Ms.

T: Today we are going to look at Balancing Chemical Equations. I know you are not doing it for the first time, you have heard- about it in your previous grades. Before we start, I want to ask, who can tell us, what exactly meant or what do we mean when we are talking about balancing equations.

LLL: (silence no response)

T: I repeat myself, what do we mean when we are talking about balancing equations? Who can tell us? Who can tell us, what exactly is meant when we are talking about balancing equations or balancing chemical equations?

When we talk about balancing equations, we mean that the equation has same numbers of atoms on both sides. What exactly is included in a balanced equation? We are saying the equation has got the reactant as well as the products when you react 2 reactants, they form a product. Let's say, when or more things they actually give you a product. Are we together? Now, what is that is used when reacting things are? Are we together there?

LLL: Mhh

T: Now in the chemistry we are saying that we use what we call elements. Are we together there? We use what we call elements. Now, who can tell us what an element is? What

is an element? I want you to use the knowledge that you got from grade 8 and 9 physical science.

L: It is a mixture one or more chemical substance e.g. compound.

T: (*Did not comment on learner's answer*) Anybody with a different idea? So, when we are talking about an element we mean a pure substance that is made up of only one type of what? One type of atom. Alright, now, because we are saying for the reaction to take place, there must be reactant and product. Now, who can tell us where are the elements found? Where do we find elements?

LLL: In the Periodic Table.

T: One person at a time.

L: In the Periodic Table.

T: In the PT, excellent, elements are found in the PT, Now since you know that they are found in the PT, now to balance the equation you use elements and the element are found in the PT. Now, right away we are going to discuss more about the PT so that if you happen to have that figure or the knowledge on what the PT is, that is when you are going now to work out how to balance the equation using the PT. So, with me, I do have the PT. (*hanging the PT on the chalkboard*). So, this is what we call PT and you can see it is Periodic Table of Elements, that means, that is where we find elements. Now, before we continue, I do have a short summary on what we are going to do, a short summary (distributing the copies to the learners). A short summary that we are going to use in our today lesson. Alright, so we are saying, elements are substances that are reacting together to give products. Now what is a PT by the way? So, when we are talking about a PT, we mean a method of classifying elements and describe them using or describe them to predict their properties. Are we together there? So, it is a method that we use to classify and predict the properties of elements. Now, if you happen to look at the chalkboard and check on the PT that is displayed there, we can see that there are many types, over hundred elements. Are we together there and if you happen to look at them, we are saying that they are classified? Who can tell us, in which way are they classified? In which way are the element classified?

L: They are classified into groups.

T: They are classified into groups so the elements are classified into groups, so that means that we have a total of what, we have a total of 8 groups, from group 1 to group 8. Therefore, we are saying that, the PT also shows several pieces of information. Which information that can be shown by the PT? So, it is showing us that all elements in the PT got symbols and also have what? Mhh? They are having symbols, what else can you see?

L: Atomic number of elements.

T: Atomic number of the element and what else?

L: Mass number.

T: And mass number, so a PT tells us different pieces of information about elements that are found there and these are the chemical symbols, the atomic numbers and even the mass numbers, sometimes it is also referred as the atomic weight are we together there?

LLL: Yes

T: And then we are again saying that it is divided into two parts which is on the left part and on the right side. Now who can tell us, what divides a PT into two parts?

L: Zig – Zag line

T: Yes, it is divided in two parts by a zig – zag line. hen aw are saying that on the left side that is where we found the metals and on the right side here, we are having the non-metals. Now we are saying that, like we say the PT shows us the information on how the elements are grouped, therefore we are saying that there are 8 groups in total as well as seven, seven periods. So, the groups are those in vertical what in a vertical way and the periods are in what?

LLL: Horizontal

T: Horizontal way. Right now, since we know that PT is the one that shows us more about the properties of elements, now, we are saying that it is also arranged in such a way that

it is arranged in the way that you can able to predict their reactivity. You can able to tell that this type of element reacts vigorously or perhaps less or perhaps it cannot react at all. Now, this one brought us to the point of reactions or balancing the chemical equations. Right, now do you have questions? Do we have questions? anyway do we have questions anyway?

LLL: No

T: Alright then that means everything is clear for us. So, maybe to sum up, we are saying that, chemical equations formed when reactant reacts and they give us products. Now, what is that that will react? What will react are elements. Now where do we find the elements? So, we are saying that elements are found in a PT. Now how do a PT look like? what exactly a PT is? We are saying it is a method of classifying and predicting the properties of elements. It's also shows us in which group elements are and which period elements are and we are saying that they react in different ways depending on the position in which they are found in the PT. Are we together there?

LLL: Yes

T: So, that is it. Since we have this idea, in our next lesson, we are going to focus on how these elements react and how to balance the equation. Is it clear there?

LLL: Ok

T: Now before that, I have an activity for you guys to do. I want you to look at these few questions, (distributing the papers to the learners) so, we only have one question there for 3 marks on question,

LLL: (*working individually*) the activity took 10 min.

Appendix K: Transcription of Mr Imagine's lesson.

Lesson 1

The lesson was observed conducted during the evening study. It took about 56 minutes.

T: Good Evening dear learners. Today we will be balancing chemical equations. Ok, so, I know you have learnt this in grade 10 and I hope we are not going to spend a lot of time on this topic.

(*The T distributes copies of PTE to the learners*)

T: How do we call this table?

L: Periodic Table.

T: (*laughs*) I expected you to say it is a timetable, so you know it is a Periodic Table?

LLL: yes

T: I want someone to tell me, why did I give you the Periodic Table when we want to learn balancing equations? Why do we need it?

L: Because we are going to work with elements.

T: Yes, when we balance chemical equations, we use elements and those elements are in the periodic table. What else?

L: We need to know the mass number and atomic number of the elements that we are going to work with.

T: Yes, we need to know the mass numbers and atomic numbers before we start with equations, let us analyse the Periodic Tables.

We know that PT is made up of group No and period No. What does the group number tell? What can we get from the group no.?

L: The number of valence electrons.

T: What are valence electrons?

L: The number of electrons in the outer shell.

T: Who can give me an element: any element from any group.

L: Carbon.

T: How many electrons does Carbon has?

LL: Six (6)

T: Why six?

L: Because that is the atomic number.

T: ok, the atomic number of an element represents the number of electrons in the whole element. And what is the valence of carbon?

LLL: four (4)

T: Yes, so, before we proceed, I want you to know the charges of elements in group 1, group 2 group 3, group 4, group 5, group 6 and group 7. You know what are charges.

LLL: mhm (*some shaking their heads*)

T: O, let us start with group 1, what is the charges of group 1 elements?

LLL: Negative one

T: Group one elements

LLL: Negative one

T; I want one person at the time group 1 elements.

L: Positive one

T: yes, it is positive one, group 2?

LLL: Positive 2

T: Is it positive 2 or two positive ? and why?

LLL; The number comes first.

T: Group 3

L: Positive 3

T: Group 4

LLL: Positive 4

T: Ok, now, what determines the charges of an element?

L: If it gains or loses electrons.

T: Elements in group 1 need how many electrons to make the outer shell full?

LLL: One

T: Group 2, 3

LL: 2, 3

T; Group 4?

LLL: 4

T: Do they lose or gain? Do you know that the electrons in these elements are the same as those that are needed?

LLL: Mhhhh

T: That means these elements in group 4 can give and gain, therefore we call this 4+ or 4- then we come to group 5, what is the charge for group 5?

LLL: Negative 3

T: 6?

LLL: negative 2

T: Group 7?

LL: -1

T; Group 8: Zero. Now then we are forming a compound, two elements must react for instance you want to form sodium chloride: you already know the formula for sodium and chlorine, what charge is sodium?

LLL: +1

T: Chlorine?

LLL: -1

T: Now when sodium reacts with chlorine the compound formed is called ionic compound because it is made up of these ions. During the reaction there is an exchange of charges. So, when they are going to have 1 when they react, Na+ is going to give one C*l* is also going to give one and form NaC*l*. Because they all have one charge, those charges are going to disappear, we are not going to put one here. Let us look at MgC*l* which group is Mg?

LL: Group 2

T: Mg^{2+} , Cl^{+} they cross multiply.

$MgCl_2$

Magnesium appears once and C*l* appears twice. Are you fine with this?

LLL: Yes

T: So now, if you are fine with that, I went us now to construct word equations. We need to know word equation before we move to chemical equations. Ok?

LLL: Yes

T: Who can give me a word equation here? (example on the hand)

LLL: Sodium + Chloride Sodium Chloride

(The teacher wrote sodium chlorine)

LLL: Sir. Sodium Chloride not sodium chlorine

T: Thanks; Chemical equation

LLL: Na + C*l* $\longrightarrow$ NaC*l*

(The teacher wrote on the board)

T: So now, when you want to balance this; how many Na are here?

LLL: One

T: This side?

LLL: One

T: Chlorine?

LL: One

T: This side?

LLL: One

T: Let us look at MgC*l*,

LLL: Magnesium + Chlorine $\longrightarrow$ Magnesium Chloride

(Teacher writes on the board)

T: When you look at these elements, you must already think of the charge because when you are going to write you exams, you will be provided with the PT, but they are not going to show charges here. You must know that if it is Mg, it is in

$\longrightarrow$

group 2 and it has 2 charges. Then we add chlorine, then how many Mg are here? Mg + C*l* $MgCl_2$

LLL: One

T: Is Mg fine?

LLL: Yes

T: C*l?*

LLL: One

T: This side?

LLL: Two

T: Then what are we going to do? We put a 2 here 2C*l*. Now Mg is one here, one on the other side, C*l* are now 2, two on the other side "Ahaa"" (*laughs together with the learners*)

Now, we also have to know some of the cations and anions, sulphates, ammonium, hydroxide, nitrates and carbonates. You need to know those anions and cations. Whenever the salt is formed, that is when the anions and cations come in. So, we have "Mhh" I will start with sulphates. What is the charge of sulfates?

LLL: $SO4^{2-}$

T; Nitrate?

LLL: NO^{3-}

T: Let us try to react Mg and a sulphate (Mg + SO_4) Why are we not having two (2) here? (*pointing to the equation*)

LLL: Silent

T: Sulphates have a charge of 2, Mg has 2, this one will give 2, the other one donates 2, so the charges will cancel each other's, are we together?

LLL: Yes

T: Let us try this, we have ammonium, NH_4^+. I want you to write for me ammonium nitrates there; Ammonium reacting with nitrate, you know the charge for ammonium, you know the charge for nitrate: (*walks around the class looking at how individual learners try to write ammonium nitrate singing "ammonium nitrate")*

Are you done?

L: Sir, is it aluminium or ammonium nitrate?

T: Ammonium nitrate, not aluminium nitrate

L: But…..

T: *(did not allow this learner to ask further*). I am expecting an answer from you, not a question. Are you done?

L: Me

T: Who else is done? What I want is just for you to write ammonium nitrate, not the whole equation. *(Walking around the class) You need to be very careful. (checking around individual learners work)* I see there is a challenge; ammonium Nitrate *(writes on the board)* NH_4NO_3 We have two elements that are there twice which element is that?

LLL: Nitrogen

T: We have to do something, we have to put brackets, I want to let you know that whenever you find two elements like these you put the brackets $NH_4(NO_3)_2$ (writing on the chalkboard). Now, this is not a problem because we did not yet balance this equation yet. I just wanted to see sometimes you count the number of atoms or use the charges. In this syllabus, you are not going to be asked this.

Ok today we are going to do something very nice; I have something for you here; ok

LLL: *Laughter's*

T: We have these balls; everyone is going to come up with elements and will balance. I am going to demonstrate, let us look at ammonia. Ammonia is made up of which elements?

LLL: Nitrogen and hydrogen

T: Write on the board)

$N_2 + H_2 \longrightarrow NH_3$

Osho ngoo ngaho? (*is it so?)* How many nitrogens are there and how many hydrogens? Now, we have these balls and we are going to form ammonia How many molecules are there?

LLL: Two

T: Now I am going to use this beads for one molecule and another one for another molecule. *(connecting the beads together)* Now we have these two; one molecule of H_2 and one molecule of N_2. Now we need NH_3 molecules *(after connecting the NH_3 molecules)* Now we are going to balance; now we have these two nitrogen', two H_2 and then they are going to form this molecule here one nitrogen and 3 hydrogen Now we are saying; we have two hydrogen this side and one on the other side.

(demonstrates on the chalkboard with the beads) Now I am going to give you these balls (distributing the beads to the learners)

I am going to give you the equation so that you balance it. I want you to come and get the hydrogens

LLL: Collected the H beads

T: Are you all having four hydrogens?

LLL: Yes

T: I want you to form water molecules; when you are forming water molecules what is the formula?

LLL: $H_2 + O \longrightarrow H_2O$

T: Are you sure?

LLL: (*Laughters)* Ahhh, Ahhhh

T: Is it correct?

LLL: Ye, *No*, Yes, No

T: It is correct because H is in group 1. $H+ O_2 \longrightarrow$ H_2O is correct as they exchange charges Why not O_2, O is diatomic

LLL: Yes

T: I want you to have two hydrogens separate, I will bring two hydrogen separates, two; to put them separate. *(Knocking the bead on the chalkboard*) I will bring mhh one oxygen (give beads of a different colour) "Omuunditeko ngaa?" *(Do you understand?)*

LLL: Eeeee (yes)

T: Tova tula ngaha. (*You put them like this*) hydrogen here oxygen there look on the board hydrogens are supposed to be two, oxygen two. Ok, now you have something like this. Hashoo (*Isn't*)? The next one you are going to have two hydrogen and oxygen. I am going to give another one. What you are going to form is a water molecule, and you are going to balance (the equation). If you need if you need hydrogen molecules just let me know if you do not need them just keep quite, it is up to you

LLL: Mhhh,Mhh (*Laughte, excited to receive the beads)*

T: I want you to form a water molecule and everyone should show his

L: Sir this are not correct

T: I know they are not the same colour, let us assume they are the same colour I know they are not enough. Are you done, try to balance the equation now?

LLL: It is balances Sir (*laughter*)

T: Balance? Why do you say it is balanced?

LLL: They are equal

T: You have two hydrogens there, you have one oxygen there, then you have two hydrogens, it is balanced;

LLL: Yes!

T: What is it so easy to balance? (But at the paper it can balance). Ok, I want you to balance for me Mg + C*l* $\rightarrow$ MgCl_2. This hydrogen is going to represent C*l*, Mg is going to be represented by this, you need one magnesium, you need one chlorine. Balance the equation, balance

L: I need mhhhhh,

T: You need to request what you need; say I need this! Put them on your desk. Do not scatter them, if you scatter them, you will not know, you are not going to balance them

L: Sir *(hand up*)

T: This is…

L: H

T: This

L: Na

LLL: Mhh, sir, sir this is not ok

T: Now, are you listening to me?

LLL: Yes

T: Now from the arrangement do you see that there is something that is not balancing

LLL: Yes

T: Now if I give you a question on balancing, do you think you are going to get it right?

LLL: Yes

T: Ok, is there anyone with a question?

LLL: No

T: Now, why are we learning this topic?

LLL: To know how to balance the equation.

L: I am done.

T: You are done? I said this one represents one chorine and then you add one Mg. when we come here, we have seen that we have one Mg and how many chlorines?

LLL: Two

T; So, we have seen that we have two C*l*, so that is what we have (showing the model) so now we are being forced to add one chlorine here, then we end up having two chlorines here. That is why we have 2 C*l* here now.

LL: Now it is balanced

T: Balanced! you know that side you have C*l*, C*l* are white, you can see they are two and you come this side, you can see they are two, that is balanced very simple so let us also try this one; HC*l* + Na NaC*l* + H_2 *(writes the equations and learners balance it)* Now, for this one there is a challenge, HC*l* one charge each, for this one to be smooth, let us just use one type for hydrogen and

chlorine, let's just say this is? H and this are *Cl (showing the beads*) put the aside, now you have your hydrogen and your chloride. Ok, take one, that represents sodium. Now you are going to form sodium chloride you are going to have something like this; (*showing the ionic compound)* This is Na, that is C*l*. *(showing the model)*

LLL: Ahhaa.

T: Listen here, we are teaching you this topic so that you use this idea and be good citizens. When you are telling stories with parents, those stories you share with friends, you cannot tell them to your parents.

LLL: *Laughter*

T: You must balance, when you are with elders, you know what to talk to elders. You see when you are with rich people, they don't say we are man, they balance the situation. There is one song that says; "*hehee balance, balance osituation oya balance balance" (singing).*

LLL: *Laughter*

T: We are not only teaching you this for the examination purposes but also want to equip you with the knowledge to be used in the communities. This brought us to the end of our lesson. I hope you have learned something any question?

LLL: No

T: Thank you very much, give me hands

LLL: Claps! claps!

Appendix L: Samples of Narratives

Lesson 2 Ms. Iyaloo

This lesson was on writing and balancing chemical equation

To start off the lesson, the teacher gave a description of the PTE as discussed in the previous lesson. She mentioned that the main point of discussion was "How to write chemical equations, and to balance them thereafter. Ms. Iyaloo then distributed copies with notes of how to balance the chemical equations step by step.

Referring to the notes distributed, Ms. Iyaloo stressed the following points:

- A balanced equation has equal number of atoms of each element on both sides of the equation.
- To balance the equation: use the valences of the elements to write the correct formula of compounds write the chemical equation for the reaction
- Count the number of atoms of all elements on both sides of the equation.

To make the explanation more understandable, Ms. Iyaloo gave an example of magnesium reacting with oxygen. She first asked learners to mention the product of magnesium and oxygen. The learners lifted their hands and shouted, "magnesium oxide". She then wrote

$Mg+O_2 \rightarrow MgO$ on the chalkboard.

Furthermore, Ms. Iyaloo looked at some test-tube stoppers with different colors. Her intention is to use them to demonstrate the number of $Mg+O_2$ molecules involved in the equation $Mg+O_2 \rightarrow MgO$.

She arranged the stoppers as per the equation and asked the learners what to do in order to balance the stoppers. Learners answered that some stoppers should be removed from one side. Ms. Iyaloo explained that when balancing an equation, you do not remove anything but rather add. Learners then shouted, "add some". From this however, some learners looked confused because they did understand from the beginning which stoppers represented Mg and which represented O_2. (Ms. Iyaloo did not make this clear).

Furthermore, in order to verify if the equation $Mg+ O_2+MgO$ is correct, Ms Iyaloo asked learners to mention the valences of the $Mg + O_2$. A learner answered Mg_2 and O_2, negative 2,

which she wrote on the chalkboard. Learners counted the number of atoms on both sides of the equation and mentioned that 1 Mg atom both side, 2 oxygen on the left side and one on the right. Ms Iyaloo explained that a number is to be placed in front of the compound and element that they should watch and check whether another element is disturbed/affected by this number. If so, students should add another number that would balance them all. Based on the explanation, ms Iyaloo wrote the correct balanced equation

$2Mg+ O_2 \rightarrow 2MgO$.

The next part, Ms Iyaloo gave another example of sodium reacting with hydrochloric acid. She asked learners to mention the product of NaCl. One learner stood up and mentioned sodium chloride. Ms Iyaloo asked if there is or not any other product in this reaction apart from sodium chloride? The silence among learner was a clear indication that they did not know or perhaps they had forgotten about the acid + metal reaction they learnt in grade 9. The teacher balanced the sodium chloride equation on the chalkboard while the learners looked on.

$2Na+2HCl \rightarrow 2NaCl+H_2$

After the demonstration, Ms Iyaloo wrote five chemical equations on the chalkboard and asked learners to answer them individually. She then asked individual learners to balance the equation on the chalkboard. This was interesting as learners paid attention to others and compared their answers. It was evident that learners understood the solving of equation because of the five that had a chance to work on the chalkboard, only one of them that could not balance the equation. This learner however got assistance from the others and the teacher to write the correct equation.

In the last part of the lesson Ms Iyaloo gave some work to the learner as homework that she asked learners to submit on the following day for marking. This was however the last day of the observation.

Mr. Imagine Lesson 1

The theme of Mr. Imagine's lesson was on PTE. Before the lesson commenced, I observe that both the teacher and learners observed the COVID-19 protocols. We washed our hands before entering the classroom and social distancing was observed and we all wore our face masks.

To begin the lesson, Mr. Imagine distributed copies of TPE to the learners. He told the learners that the discussion will be on balancing chemical equations, and they have done some basic already in their previous grades. He then asked question "what do we call this"? Learners answered: PTE. Mr. Imagine said: Why do we need it? The learner mentioned that "because we are going to work with elements and we need to know the mass number and atomic number of elements.

This dialogue between the teacher and learners demonstrates that learners have some information from their previous grade that is relevant for the topic to be taught. The teacher further asked learners questions such as: What can we get from the group number? The learners mentioned the number of valence electrons. What is valence asked Mr. Imagine? Leaners mentioned the number of electrons in outer shell of the atom. Mr. Imagine chose carbon as an example and asked the learners to mention the total number of elements, carbon has and its valence electrons.

With a smile on his face, Mr. Imagines thanked the learner for the correct answer. He then asked them to write a balanced chemical equation, which they wrote as:

$Na + Cl \rightarrow NaCl$

Similarly, Mr. imagine also asked one learner to write word equation for the reaction of magnesium and chloride, then he balanced chemical equation;

Learners wrote it as **Magnesium+ Chloride=Magnesium Chloride**

$$Mg + Cl \rightarrow MgCl_2$$

From the learners' faces, I observed that they were comfortable with writing the chemical formula of compounds and understood the use of compounds and understood the use of charges of elements. Mr. Imagine then went on to highlight polyatomic ions and their respective charges.

SO_4^{2-}, NO_3^-, NH_3^-. He first gave an example of magnesium reacting with a sulphate as

$Mg^{2+} + SO_4^{2-} \rightarrow MgSO_4$. (Charges cancel)

He then asked learners to write the chemical equation when ammonium ions react with nitrate ions.

He walked around the class looking at how individual learners are working out the equation. He noticed that it was a challenge to the equation. He noticed that it was a challenge to the learner to write NH_4NO_3. He explained that there is a need to use brackets in order to separate number of charges. He then wrote NH_4NO_3

From there, Mr. Imagine touched on the charges of elements in each group. The learners mentioned all charges as groups1-H, Group 2, +2 groups 3, +3. For group 4, I observed that learners were not sure. Mr. Imagine then asked what determine the charge of an element. Learner mentioned that when electrons are gained or lost. Based on the learners answer, Mr. Imagines asked:' do group 4 elements gain or lose electrons? These elements can gain or give four elements, therefore that are 4+ OR 4-. The discussion then continued to group 6, 7 and 8.

Furthermore, Mr. Imagine explained that, when sodium reacts with chlorine, ions are formed and charges cancel because each one has one charge (equal charges). He also gave an example of Mg reacting with Cl. Based on the differences in the charges he explained that these charges do not cancel but cross-multiplication is required to balance the equation. He wrote the equation on the chalkboard as $Mg_2 + Cl \rightarrow MgCl_2$.

Mr. Imagine further explained the importance of writing word equations and asked learners to write the word equation for the reaction sodium and chloride. Learners put their hand up and one mentioned 'sodium +chloride=sodium chloride". Mr. Imagine wrote on the chalkboard sodium chlorine. Learners, shaking their heads; said it loud, sir! It is not sodium chlorine but sodium chloride".

From this explanation a very interesting event followed. Mr. Imagine had a small box in his hands. He opened it and there were some beads with different colours and sizes that he called balls. From the learners faces, I could tell they were wondering, what their teacher was going to do with the beads.

Mr. Imagine told the learners, we have these balls and everyone is going to come up with elements and balance them. He took out some beads and learners were listening and watched him attentively as he demonstrated the formation of ammonia by using beads of different colour to represent nitrogen and hydrogen.

After the demonstration of how the bonding in ammonia, he then distributed beads to each learner. This was the most interesting part of the lesson as most learners were involved in connecting beads together to form the water molecules and used them to balance an equation for the formation of water. Learners were excited to complete the task, even though there were some who did not have an idea of how of how the beads are supposed to be arranged. I observed a misconception which was caused by the colour of beads. Some learners did not receive beads of different colours simply because they were not enough for everyone.

The next equation to be balanced was sodium chloride formation from HCL and sodium atoms. Mr. Imagine wrote on the chalkboard: $HCl+Na \rightarrow NaCl+H_2$. This was more challenging and most of the learners could not balance the equation. Mr. Imagine however explained and balanced it on the chalkboard as the learners observed him. All learners shouted it is balanced with a smile on their faces.

To conclude the lesson, Mr. Imagine mentioned that the topic is taught not only for examination purposes but also to balance situation in everyday life. He asked if there is anyone with a question, but the response he got from the learner was ‘NO’. He asked learners to return his beads and the lesson ended at this point.

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Appendix M: Table 4.3: Components of PSPCK

COMPONENTS	DESCRIPTION	LP^{--} (Weak)	LP^{-} (Moderate)	LP^{+} (Strong)	LP^{++} (Very strong)	Comment
Learner Prior Knowledge L(PK)	Includes common learner misconceptions known in a topic	No identification or no acknowledgement or no consideration of learners' prior knowledge or misconceptions; no attempt to address the learners' misconceptions.	Identifies prior knowledge or misconceptions; provides standardized definition as a means to counteract the misconception; no evidence of drawing on other TSPCK.	Identifies prior knowledge or misconceptions; provides standardized knowledge as definition; expands and re-phrases explanations using one other component of TSPCK interactively.	Identifies prior knowledge or misconceptions; provides standardized knowledge as definition; expands and re-phrases explanation correctly; confronts misconceptions or confirms accurate understanding drawing on two or more other components of TSPCK interactively.	• Both teachers referred to the what an Element is as learnt in the previous grades. • Both teachers gave copies the Periodic Table of Elements and asked learners to describe its features as learnt in their previous grades. • Who is T1? identified a misconception when one learner

						defined an element wrongly.
		CS^{--} (Weak)	**CS^{-} (Moderate)**	**CS^{+} (Strong)**	**CS^{++} (Very strong)**	
Curricular Saliency (CS)	Refers to the identification of the most important meaning of major concepts of a topic, without which understanding of the topic would be difficult for learners. It also includes the knowledge to logically sequence the learning and knowledge	Identified concepts are a mix of Big ideas and subordinate ideas; identified pre-concepts are far from topic; sequencing of no value due to mixed concepts; reasons given are generic benefit of education.	Identifies at least 3 Big ideas; identified pre-concepts are far from the current topic; suggested sequencing has one or two illogical placing of Big ideas; reasons exclude conceptual considerations and show no evidence of drawing on other TSPCK components.	Identifies at least 3 Big ideas; subordinate concepts correctly identified for all Big ideas; identifies pre-concepts relevant to the topic; provides logical sequence; reasons given for importance of the topic include reference to conceptual scaffolding/sequential development draws on other TSPCK components, e.g., what makes topic difficult.	Identifies at least 3 Big ideas; subordinate concepts correctly identified for all Big ideas with explanatory notes; identifies pre-concepts relevant to the topic and explanatory notes given; provides logical sequence of all Big ideas and with reasons; reasons given for importance of the topic include reference to conceptual scaffolding/sequential development draws on other TSPCK components, e.g., what makes topic difficult.	• Both teachers presented the content through giving explanations and descriptions. • Understanding the bonding and the involvement of valency electrons. • Understanding the reactions writing chemical formulae

	of pre-concepts needed prior to teaching a topic					
		WDU^{-} (Weak)	**WDU^{-} (Moderate)**	**WDU^{+} (Strong)**	**WDU^{++} (Very strong)**	
What is Difficult to Understand (WDU)	Refers to gatekeeping concepts which are difficult to understand often because they cause conflict with previously established understanding	Identifies broad topics without specifying the subordinate sub-concepts that are problematic	Identifies specific concepts but provides broad generic reasons such as abstract concepts.	Identifies specific concepts leading to learner difficulty; reasons given relate to one other TSPCK component.	Identifies specific concepts with reasons linking to specific gate keeping concepts and to TSPCK components such as prior knowledge and aspects of curricular saliency.	• The teachers explained all instructions and defined concepts where necessary • Question and answer method used to clarify misconceptions.
		RP^{-} (Weak)	**RP^{-} (Moderate)**	**RP^{+} (Strong)**	**RP^{++} (Very strong)**	
Representations (RP)	Refers to a combination of representat	Limited to use of only macroscopic representation (analogies, demos etc.)	Use of macroscopic representation (analogies, demos etc.) and use of scientific symbolic	Use of macroscopic representation (analogies, demos etc.) and use of scientific symbolic	Use of macroscopic or symbolic representation with sub-microscopic representation to enforce a	• T1 used a poster of the Periodic Table of Elements.

	ions at macro, symbol and sub-microscopic levels that may be employed to support an explanation	with no explanation of specific links to the concepts represented	representation without explanatory notes to make the links to the aspects of the concept being explained.	representation with explanatory notes linking the two representations to the aspect(s) of the concept being explained; use of combination of representations above with reference to one other TSPCK components, e.g., prior knowledge.	specific aspect; Explicit link with other components of TSPCK, e.g., emphasis on core aspect of CK demonstrated in the representations and learner prior knowledge.	• T2 used beads to represent atoms as they bond together • T1 used test-tube stoppers to represent atoms
		CST^{-} (Weak)	**CST^{-} (Moderate)**	**CST^{+} (Strong)**	**CST^{++} (Very strong)**	
Conceptual Teaching Strategies (CTS)	Refers to teaching strategies derived from the considerations made from the other four components and excludes general teaching methodologies	No evidence of acknowledgement of learner prior knowledge and misconceptions; lacks aspects of curricular saliency; use of representations limited to macroscopic or symbolic scientific symbolic representation.	Acknowledges learner misconceptions verbally with no corresponding confrontation strategy; lacks aspects of curricular saliency; use of macroscopic or symbolic representation with no linking explanatory notes.	Considers confirmation/confrontation of learner prior knowledge and/or misconceptions; considers at least one aspect related to curricular saliency, e.g., sequencing or what not to discuss yet or emphasis of important aspects; uses at least two different levels of representation to enable understanding.	Considers learner prior knowledge and evidence of confrontation of misconceptions; considers at least two aspects related to curricular saliency, e.g., sequencing or what not to discuss yet or emphasis of important aspects; uses either the macroscopic or symbolic representation with sub-microscopic representation to enable understanding.	• Both teachers interacted with learners to clarify concepts through a question and answer method.

Appendix N: Stimulated Recall Interviews for Ms Iyaloo

Kambeyo: Mmm, Ms Iyaloo, thank you for once again for making it to our interview, eeh, this is a stimulated record interview where we refer to our observations then we discuss eeh based on what transpired during the lessons eeh we started watching

Ms Iyaloo: Wow! I did not see myself in a video before. Can I get this video also? I want to keep watching myself."

(**Kambeyo:** en eeh I just have the first question, if I listened very well you referred to the grade eeh to the previous grade work when you were introducing the balanced chemical equations. May you briefly explain why you did so.

Ms Iyaloo: Thanks for the question, actually I did so because I knew it is not the first time. they are hearing about balancing chemical equation. Of course, they did it in the previous lessons or to say it previous grades and it is very important for me to aah refer them back so that they can remember what they were taught previously and then they can now aah use their ideas that they have just aah learnt previously so that they can now aah use in them in the present.

Kambeyo: Alright, aah thank you aah we go ahead then we see what the video has in store for us, ok eeh Ms Iyaloo, another thing caught my attention here. You are trying to introduce balancing chemical equations, then there you refer to the previous knowledge that learners are acquired from the previous grades, eeh you, you mentioned that aah learners should look at elements, why did you decide to start with elements why do you have to start with elements as a starting point for this topic?

Ms Iyaloo: Alright, I did so because I believe that the one that I used especially in the reactions cause know their substances that react, and once they react then they use the products so now for them to know what are they going to use they should at least know what elements are.

Kambeyo: Ok, soo, yeah, I think I am getting your point now let us go ahead and see more…there is another interesting question that you have asked here. You asked aah learners

to eeh tell where the elements are found, eeh may you briefly explain to me why do you why do learners need to know this what is the, the reason behind that question?

Ms Iyaloo: Ok I happen to ask them because, uhm, like I said that for them to know that aah the chemical reaction happens when you have elements. So at least they need to know where do we find elements and when they realised that the elements are found in the periodic table. So, in the periodic table or let me say the periodic table shows more, on the periodic table is the one that shows in which group or perhaps period or the valences and elements, coz in most cases when balancing equations, we look at whether the element has aah a certain number of valences. For instance, you want to balance a reaction has between magnesium and oxygen, you need to know the magnesium is aah a metal which found on which side of the periodic table and it got which valency so that when we, we count the number of valences that also determine the compound the name or the formula of the compound and from the formula of the compound. Let me say the formula of the compound is the one that gives you the number of atoms that present and for you to balance the equation you have to count the number of atoms that are present both side the side of the reacted and the side of product.

Kambeyo: eeh I have observed that you have prepared some notes let me say a summary for learners and I think that is your way of teaching. Why did you choose to do that, aah, rather than for example letting learners summarise based on your discussion?

Ms Iyaloo: right so I actually did it because I know the standard of my learners. Everybody knows what type of learners she is dealing with now in time some cases if you do not give them the summary so some learners are going to miss out a lot of things. It also saves time….

Kambeyo: In another, in other words you mean eeh you know the learners that you are dealing with, they there they are those type of learners that hardly do something for themselves.

Kambeyo: aah Ms Iyaloo, there aah why did you refer to that eeh reactions, why did you mention the reaction in that part.

Ms Iyaloo: uhm I did so cause at the beginning if you just listen very well, I said that in the periodic table , it is where elements are found and elements are the one that react now what brought me to that point is to refer them that once you know elements and where they are found then you can able to see how to how they react because one of the properties which show in

the periodic table is also the reactivity how elements reacts, now it just takes me took me to that point so that I can refer them I can tell them that since now you know what elements are and where they are found and know that they are the one that take point in the reaction so that is why I just quote to that point.

Kambeyo: Ok, een Ms Iyaloo, eeh, I have seen that after discussing the periodic table, you have given uhm learners an activity as an assessment eeh to see or to check their understanding, that of course will be you will tell after the, after the lesson, and, and also there initially you have given them, the, the notes of the summary, now my question, what are the main sources of information that help you to prepare this, that help you to prepare the notes and the learners activities what are your sources of information, what are the ok, like the books that you use or maybe, yeah.

Ms Iyaloo: ok, so I have used aah aah the book of an, Macmillan physical science textbook and I have also used a textbook of NAMCOL that is all those ones I have used them to prepare the, the, the notes and then for the activity, I just took the questions from old question papers.

Kambeyo: and on the old eehm eeh question papers aah are you not afraid that these learners are simply going to copy, cut and paste since I have observed that most of them have booklets with those aan questions and answers.

Ms Iyaloo: ok anyway I have made sure that the questions that I am going to use, although I have taken them from the old question paper, I did not just give them the same way they are I have change them somewhere somehow so that they cannot just copy, make copy and paste (**Interviewer**: aah, alright), yes.

Kambeyo: alright, thank you aah Ms Iyaloo, eeh, I also want to see eeh a sample of aah how you marked eeh that activity, and I really like it. I enjoyed our conversation, eeh, the comment is this lesson was really super beautiful, if it was me I (laughs), really understood the periodic table and it is eeh relevance aah to, yes to other aah sciences. Let me say to other topics in chemistry, thank you very much, this marks the end of our interview for today.

Ms Iyaloo: ok, thank you, you more than welcome.

Kambeyo: thank you

Appendix O: Stimulated Recall Interviews for Mr Imagine

Kambeyo: Mr Imagine, good afternoon,

Mr Imagine: good afternoon

Kambeyo: Aah, thank you for making it a success to our interview today, I am going to ask you a few questions. Actually, for clarity sake, eeh these questions are going to be based on the, on our lessons and eeh we are going to watch the video together and then pause here and there eeh just for a few clarifications right.

Mr Imagine, I have observed when you eeh started this lesson what was your intention for asking the learners to ah mention what they need in order to balance a chemical equation?

Mr Imagine: Yaa, eeh, the reason why I asked learners is just to, aah, to find out whether they know they know anything that they can help them to, to, to balance chemical equation easier, I mean easier and what I expected from them was a usage of periodic table that is what I wanted, if they know it.

Kambeyo: So, in other words you are looking for the prior knowledge for the learners which aah basically includes the use of the periodic table.

Mr Imagine: exactly.

Kambeyo: Oh, wow, thank you that was amazing. Aah, another question Mr Imagine, I have seen something that caught my attention there. You wrote a chemical equation eehm but actually I, I suppose you start with aah a word equation, why did you just choose to write aah, aah, aah chemical equation without starting with a word equation.

Mr Imagine: o thank you very much, eehm the reason why I started with aah, with aah, aah, chemical equation is because we have already discussed about aah word equation with them and then from the word equation that we have discussed with them. I am sure that they have understood now that that is the reason why we started with chemical equations and, and most of the questions in chemistry they are focusing on chemical equations say, they are calculating the number of moles you cannot calculate the number of moles using chemical equations those are the eeh equation that they use, you cannot use word equations to calculate number of moles.

Kambeyo: So which means to this lesson eeh writing word equations is one also of the prior knowledge that the leaner is supposed to bring with to class.

Mr Imagine: That's a prerequisite for them, is a prerequisite to chemical equation.

Kambeyo: Oh, alright, that's very, very interesting. Aah, this one also, eeh eeh caught my attention Mr Imagine what is the reason behind, why are you giving the learners to solve aah these equations eeh I, I, I, I thought than you supposed to aah have aah solved one as an example to them.

Mr Imagine: Yeah, the, the reason why I am using learners is because I want to apply a learner-centred approach. Learners learn more when they are doing things on their own rather than just a teacher who is aah you know just doing things on their own, I mean on their behalf, so is just a learner-centred method that I am trying to apply.

Kambeyo: So you mean than learners will learn better when they do these practice on the chalk board rather than just you writing and talking on the chalk board?

Mr Imagine: yeah, yes, yes, yes, yeah, that is the best method of teaching

Kambeyo: aah another question Sir, you opted to give this individual work and I and I hope you have marked them, aah how to do you really tell the performance of this, eeh I mean the assessment is this the only way that you use for as assessment or is there any other aah any other method that you, you use as an assessment method?

Mr Imagine: yeah, to me individual work is not the best method, but that is the only method that I use to assess individual performance just to see if everyone has understood but the method that the best method is to use group work where you are using learners, I mean where you grouping learners to share ideas you know, to exchange ideas with each other that will also help them to, to be independent to be you know, fearless and then they can also free to share ideas with others that is the best method that is, that is just to assess individual performance.

Kambeyo: But I haven't observed any, any group work there.

Mr Imagine: I think that is one of the assessments methods that has missed in my lesson and I have, have put it, it in my evaluation and reflections on the lesson next time.

Kambeyo: I, I, I, I, understand group works during this pandemic are also discouraged I think in a way Mr Imagine you did a very great job there, I commend you for that. I still aah have one more question, looking at this at your 2 lessons, aah how do you aah I mean what, what difficulties have you encountered according to you?

Mr Imagine: eish

Kambeyo: eeh, which part is difficult to learn here and perhaps how to you deal with this in your everyday teaching?

Mr Imagine: Okay, uhm the most difficult thing that I have experienced is uhm how to make really learners understand the balancing of chemical equation, most of the learners confuse aah between like, we have some elements with diatomic molecules and uhm now when you balance that chemical equation at the counting the counting the number of elements becomes a problem to them. I have always tried to make learners understand using the periodic table how the molecules how the diatomic molecules are formed and how the elements are formed and their symbols and then if they know all those things they will not get confused. And then they will not have problems of when to balancing chemical equations

Kambeyo: aah, alright, I have seen that you have covered that eeh based on the syllabus did you cover all the basic competencies that aah are required to be touched under writing and balancing chemical equation?

Mr Imagine: yes, all the specific objective that are stipulated in the syllabuses has been covered and aah when I made an assessment at least the, the most of objectives were effectively achieved and most of the learners now have an idea on how to balance chemical equations as per the requirement of the syllabus.

Kambeyo: alright let me take you back on the assessment on the, on this activity now, after having marked, aah what was the performance that is eeh giving you to say the basic competencies were, were met?

Mr Imagine: wow, the, the performance was good, most of the learners have, have done very well, they did very well which shows that the objectives of the lessons have been achieved and they have understood at least what I wanted to give to them was successful and that is the

reason why I am saying eeh, all the basic competencies have been successfully achieved and eehm learners have understood when I have checked the performance.

Kambeyo: aah, one more last eeh question Mr Imagine, per, perhaps I ask you to comment on aah on, on, on, on, on the equations, it can be to chemistry or to in general.

Mr Imagine: yeah, aah, aah, aah, to, to chemistry itself it is very, very, very important because even when you want to do medicine and you want to put some for instance some chemicals to inject for instance a patient there, there are some you know, you have to you know you have to use that knowledge of balancing like there must be a certain level that is now when it comes to the career and then now generally this chemical equation, this balancing issue will also teach learners to be able to balance the situations in there, really life situations.

Kambeyo: Soooo, you mean eeh, eeh, this one does not only apply to books and studies or but also in our everyday lives where we are, where we happen to find ourselves in our everyday conversations this, this, this topic will basically help us in that case?

Mr Imagine: yeah, I even gave them an example of a car tires that whenever you are driving aaah car the tires must have the same you know the gas which is in the tires must be the same, they must be balanced and that can also cause the car tires to be bust or maybe it also causes car not to be balanced when you are driving in the road and it can also cause car accident, those are some of the things that learners also need to know, the reason why we are learning those things.

Interviewer: ooh is very interesting, aah thank you very much Mr Imagine, it was a very amazing having aah done this one with you. I enjoyed your lessons and your learners are just super beautiful.

Mr Imagine: aahm it is pleasure I am also very excited to have watched my own videos, laughs

Kambeyo: Oo. this is an experience you have, have you ever watched yourself teaching?

Mr Imagine: oh wow, this is beautiful, Yeah, thank you very much

Kambeyo: thank you too

Mr Imagine: thank you