INVESTIGATING HOW CHEMISTRY TEACHERS IN GRADE 11 UTILIZE THE PERIODIC TABLE OF ELEMENTS TO FACILITATE THE LEARNING PROCESS OF WRITING AND BALANCING CHEMICAL EQUATIONS

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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 writingand balancing chemical equations. The study was carried out with two chemistry teachers in two rural schools in the northern partof 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 observations. Shulman's Pedagogical Content Knowledge is used as theoretical framework in this study and the data sets were analyzed using the three of 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. The study therefore recommends continuing professional development for chemistry teachers in order to provide teachers with opportunities and spaces to share subject matter knowledge, pedagogical content knowledge, and easily accessible resources that they can use to improve chemistry classroom instruction. *[African Journal of Chemical Education—AJCE 14(3), July 2024]*

INTRODUCTION

This 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. 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.

After Namibia's independence in 1990, the Namibian constitution stipulated that every citizen has the right to a basic education i.e., grade 1-12. Based on this, the National Curriculum for Basic Education (NCBE), a document that guides the planning, organization, and implementation of teaching and learning, was introduced [1]. In addition, Vision 2030 was initiated in 2004 [2], which outlines Namibia's aspiration to become a prosperous, industrialized, peaceful, and politically stable nation based on her human resources by the year 2030.

Notably, the Namibian curriculum has undergone a number of reforms in an effort to address education's challenges and requirements, as well as those outlined in Vision 2030. Unsurprisingly, this curriculum reform in Namibia is comparable to South Africa's outcome-based curriculum

(OBE), which was implemented in 2005 and is henceforth known as Curriculum 2005 (C2005). However, this transformation of the curriculum necessitated new instructional strategies. In other words, it advocated a shift from teacher-centered education (TCE) to learner-centered education (LCE), in which students are expected to take an active role in their own education [3]. Learner-centered education places an emphasis on the interaction between students and curriculum content, and instructors are viewed as facilitators. This translates to a need to consider both the subject matter knowledge (SMK) and pedagogical content knowledge (PCK) of instructors [4].

Like in any other country globally, the NCBE recognizes 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 [5]. The aim of natural sciences in the senior secondary phase as stipulated in the NCBE, 'learners are expected to use methods and skills to develop scientific models on the bases of existing and new information, and communicates their investigations, analyses, and conclusions using scientific and mathematical language, theories, laws, and principles' [1]. From this aim, 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 [6], "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 emphasize 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 [7].

According to the revised curriculum, 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). At the NSSCO level, physical science is split into two components, namely chemistry and physics and these are taught as separate subjects [8]. This suggests that teachers may choose to teach either physics or chemistry depending on what their strengths are in terms of SMK [4]. 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 [8] 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;
- 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" [8].

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 [8]. This makes chemistry a prerequisite subject for most science-oriented courses in tertiary institutions and this calls for the need to teach it effectively [10].

Moreover, 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 in table 1 shows the objectives that should be met under the topic of writing and balancing equations.

Table 1: 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 in table 1, 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. It is recognized, 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 [4, 11] to mention a few.

Our experience as Teachers

Reflecting on our teaching experience of over 12 years as physical science teachers, we observed that the learners' performance in the two components of physical science differ significantly, whereby learners perform better in physics compared to chemistry. Also, being national markers for the Junior Secondary Certificate (JSC) and NSSCO for physical science respectively, we noticed that learners do not perform well, in questions related to the periodic table of elements such as periodicity, chemical bonding, writing, and balancing chemical formulae and equations. It is observed that learners tend not to have challenges writing the word equation since the information needed is always provided within the question. However, writing and balancing chemical equations seems to be a challenge.

In addition, our observation is backed up by the NSSCO examiners' reports for physical science for the years [5-9, 12]. 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 [12].

Based on the aforementioned background, our 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. We 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. We 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, [13] conducted a study on atoms and molecules, [14] study focused on chemical equilibrium, and [16] and [15] 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 [4]. 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, we noticed 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, this 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. Therefore, this paper explores 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, we analysed the grade 11 chemistry teachers' perspectives, experiences, and pedagogical insights on the use of the periodic table of elements in their chemistry lessons. We also observed how grade 11 chemistry teachers make use of the periodic table of elements when mediating learning of writing and balancing chemical equations.

THEORETICAL ASPECTS

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 [17]. 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 [18]. The periodic table then represents and organises all known chemical elements on the basis of their properties [17-19]. 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.

Furthermore, the vast majority of the known stable elements are of central importance to people, biologically, technologically, and/or economically [20]. 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.

Moreover, 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 [21]. Threshold concepts are those key ideas in a discipline that offer the learner a gateway to new ways of thinking [22]. 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 [21]. This agrees with [20] who states 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 [21]. Several studies done in Namibia indicate that topics such as stoichiometry [15-16], rates of reactions [23], and chemical equilibrium [14] 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 [24]. This therefore necessitated looking at the periodic table of elements before getting into the details of writing and balancing chemical equations.

The significance of balanced chemical equations

Several studies have highlighted the importance of balanced chemical equations. For instance, [25] 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

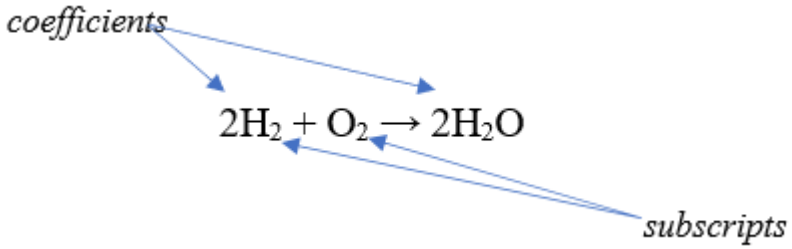
organic chemistry. Other scholars also posit that equations are the language chemistry and fluency in writing these chemical equations is critical for any student studying or intending to study chemistry [26]. Further to this, chemical equations also play a major role in theoretical as well as industrial chemistry [27]. 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 [28].

What is a chemical equation? A chemical equation can be defined as "a language of chemistry, one that chemists and chemical educators use constantly" [29]. Concurring, [27] explains that the language (chemical equation) used to describe a chemical reaction, and every chemical equation is a story of some chemical reaction. Similarly, [28] 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" [29]. 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 [29]. 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.

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, [30] 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 [16] and [15] 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 [31-32]. Additionally, these findings also resonate with those from a recent study conducted by [28] at a teachers' college in Ethiopia. [28] 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 analyses them. Based on [28] 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, [33] 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, [28] 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.). [28] 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 [28]

In addition, several scholars suggest different ways of balancing chemical equations. For instance, [26] 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 engaged 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 [15].

THEORETICAL FRAMEWORK

This study is underpinned by PCK [4]. The PCK is a theory focusing on the knowledge of thinking about the transformation of knowledge into a format which makes it easier for learners to understand. It further defined as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests of learners, and presented for instruction" [4]. [4] suggests that teachers should possess the knowledge to recognize 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, [4] 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 organization. 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. [34] 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 [35] 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, systematizing empirical data and enabling the documentation and exchange of ideas on relevant knowledge to teaching practice.

[36] state that the teachers' PCK is related to their experience, and it entails transforming knowledge so that it makes sense to the learners. It should be noted, however, that the two participant teachers in our 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. We therefore acknowledge that these teachers' personal PCK were unique to themselves [37]. Notwithstanding, the different experiences of these two teachers enriched the insights on the issue under study. [38] further explains PCK as the knowledge that includes "an understanding of what makes learning of a specific topic easy or difficult" [38]. 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. [39] posits that the PCK in science education has not received enough attention, although it is a useful concept in understanding the teachers'

professional practices. Our study thus adds to several studies that have investigated science teachers' PCK.

METHODS

Research Design

According to [40], when designing a research study, researchers should systemically plan how to gather data and how this data are to be analyzed in order to answer the research questions. Concurring [41] 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" [41]. In this study we employed a case study research design. In an attempt to describe a case study, [42] emphasizes 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 [43]. Concurring, [40] 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 we 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 we engaged with the participants [44]. In other words, the in-depth case study analysis helped us to obtain more data from this study [41]. Thus, the results from this case study were analyzed 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 representativeness and a lack of statistical generalizability. Additionally, the richness and complexity of the data collected means that the data is often open to different interpretations, and potential ‘researcher bias [45]. 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.

Research participants and sampling procedures

“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” [41]. Sampling involves making decisions about which people, settings, events, or behaviors a researcher is to include in a study [40]. Sampling in this study was purposive and convenient.

According to [41], 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. Apart from the teaching experience of these teachers as a selection criterion, we 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 [46].

Instruments

Semi-structured interviews

[42] 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 behaviors of the participants". Based on this definition, we engaged in semi-structured interviews with the research participants because we believed that they would help us 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 [21].

Furthermore, we used an interview guide with open-ended questions. An interview guide is a schedule of questions which the interviewer intends to ask [43]. In this study, the semi-structured interviews gave us the freedom to change the order and emphasis of questions depending on the answers given. It also enabled us to ask follow-up questions as stated in [41]. This then enabled us

to probe with more questions for clarity and ensure that all the questions were answered in full. We used an interview schedule which we adapted from [47].

Observations *(videotaped lessons)*

Observation is a technique that allows the researcher to gain live data in a social situation or context [40-41]. [40] 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 what was taking place rather than relying on second-hand information [41].

In this study, we observed two chemistry lessons per participant in order to answer the second research question. These observations were done after the semi-structured interviews. we had initially planned to observe three lessons per participant, however, due to the circumstances imposed by the Covid-19 pandemic we 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, we used an observation schedule as a guide that we adapted from [23]. This observation schedule helped me to focus on the key concepts of the lessons. We were thus able to document how teachers mediated learning of writing and balancing chemical equations. Additionally, we 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.

Data analysis

According to [43], when analyzing data in qualitative research, the researcher begins with a larger body of information and must, through inductive reasoning, sort and categorize it and gradually bring it to down to small set of abstract, underlying themes. Concurring, [41] 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. We then used a thematic approach to analyze the data in order to identify categories, patterns, and themes because this approach is flexible with respect to identifying themes [48]. The themes emerged from the data were coded. Coding refers to "segmenting and labelling data" [46]. The figure below indicates how data was analyzed to arrive at themes.

The semi-structured interviews, lesson observations, and reflections were video recorded. We then transcribed the videos which helped us to develop themes and sub-themes. We used the theoretical framework (discussed in the literature review section) to help us interpret the data and to answer the research questions. For research question one, we adapted [49] indicators of conceptions

and dispositions as described in detail in (Table 2). This analytical tool was deemed to be valid and relevant to our study since it has been used before and proven to be useful.

Table 2: 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 [49]

RESULTS AND DISCUSSIONS

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 section, we 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 our 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?

Two grade 11 chemistry teachers that teach at different schools in Ohangwena region were interviewed. The interviews were conducted in the afternoons at the participants' respective schools so that we did not interrupt the normal teaching time. 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 section, and this made it easy for the data handling process. The interviews took about 15 and 19 minutes, respectively. With the permission from the participants, the interviews were videotaped backed up by an audio recorder. We then transcribed the interviews verbatim. A deductive approach was then used to determine the themes and subthemes. Table 3 below shows the themes and sub-themes that emerged from the semi-structured interviews and the relevant literature.

Table 3: 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	[17-21, 49]
	Views on the significance of the periodic table of elements on balancing chemical equations	[20,27,28,34]
	Attitudes towards teaching the writing and balancing of chemical equations	[14-17,23,25,32]
Teachers' experiences and pedagogical insights on the use of the periodic table of elements in their chemistry lessons	The use of prior knowledge	[15, 27, 50-52]
	The use of representations including analogies	
	Challenges encountered when mediating writing and balancing of chemical equations	

Each theme are now discussed in the following sections.

Teachers' perspectives on the use of the periodic table of elements in theirchemistry lessons

From the semi-structured interviews, it emerged that the two chemistry teachers seemed to seevalue 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 knowthe group numbers because group numbers indicate the number of charges for instancethe 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, nowteaching 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 theperiodic table of elements. For instance, Mr. Imagine's description of the periodic table is in line with [17-19] who posit that the periodic table of elements presents and organizes 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 comesto Chemistry not only in balancing chemical equation. We can also use Periodic Tablein 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 PeriodicTable. 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 alreadytell 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 [21] who calls the periodic table a threshold concept. That is, it is a gateway for the learners to new ways of thinking. This view agrees with [20] 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 itis linked to other concepts in chemistry. This also corresponds with the findings of some studiescarried out by different scholars in topics such as

chemical equilibrium [14], rates of reactions [23], and stoichiometry [15, 31] 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 themthe 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 veryfunny 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 realize, they say "Aa, aa, no, this is verysimple". Yeah, and then they get excited when they realize that they are linked (Mr. Imagine).*

Based on the excerpts above, it was evident that teachers have the belief that chemical equationsare 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 towardsthe topic. That is of course similar to Mr. Imagine whose comment seemed to highlight a senseof being happy when his learners realized the link between the periodic table of elements and balancing

chemical equations. According to him, that makes it easy for his learners tounderstand what balancing equation is. This is in line with the ideas of [25] and [26] who stress that chemical equations are a pre-requisite to the meaning of chemistry. Other studies also confirm that learners always have difficulty in solvingstoichiometric problems if they are unable to write and balance chemical equations [15-16, 32].

Teachers' experiences and pedagogical insights on the use of the periodic table ofelements 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 orless the same. For instance, the experiences shared were on teaching and learning materials aswell 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 learnersto 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 thenyou can ask them to balance it … I have taught at different schools, so, I did that at myformer school (Ms Iyaloo).*

Mr. Imagine indicated that their school laboratory is equipped with some materials that can beused 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 [51], 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 haveor 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 sideand 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 eenyandiand 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 [50], [53], and [51]. 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 availableand 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 inorder to make science more understandable to the learner as noted by [50] and [52]. This is also in line with [16]'s study which reports that teachersused 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 as shown in table 4.

Table 4: Challenges encountered by teachers when teaching balanced chemicalequations.

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., 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 towhat they have learnt in mathematics. These findings corroborate what [27] did with his students. According to him, balancing equations is purely algebra, hence, he preferredhis students to solve chemical equation problems by writing them as linear equations. The useof brackets when dealing with polyatomic ions is mostly emphasized 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 to that, 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 indicatedthat they give remedial lessons to the learners.

Data Presentation and Discussions from Lesson Observations

Observations of lessons by two teachers provided us a first-hand opportunity to look directly at what took place in the classrooms. That is, the observations enabled us to experience how teachers actually mediate learning of writing and balancing chemical equations as opposed to what they said they do. During the observations, we were 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 [11].

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 [53] study conducted in South Africa; we also wrote narratives based on all the lessons that we observed followed by verbatim transcriptions

of each videotaped lesson. As highlighted by [54], the narratives afforded us an opportunity to identify episodes from the video whereas transcriptions helped the researchers with identifying excerpts from the lessons. Also, during the observations, we took some field notes on any aspects that we found to be interesting.

As indicated in the literature review section, this study is informed by [4]' PCK, and the analytical tool was the five components of the TSPCK as narrated by [11]. 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 difficultto understand (WDU), representations including analogies (REP), and conceptual teaching strategies (CTS) [11]. We now give a detailed account of each component beginning with the learners' prior knowledge.

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 youto 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

ourunderstanding is aimed at helping learners to recall the elements see figure 1.

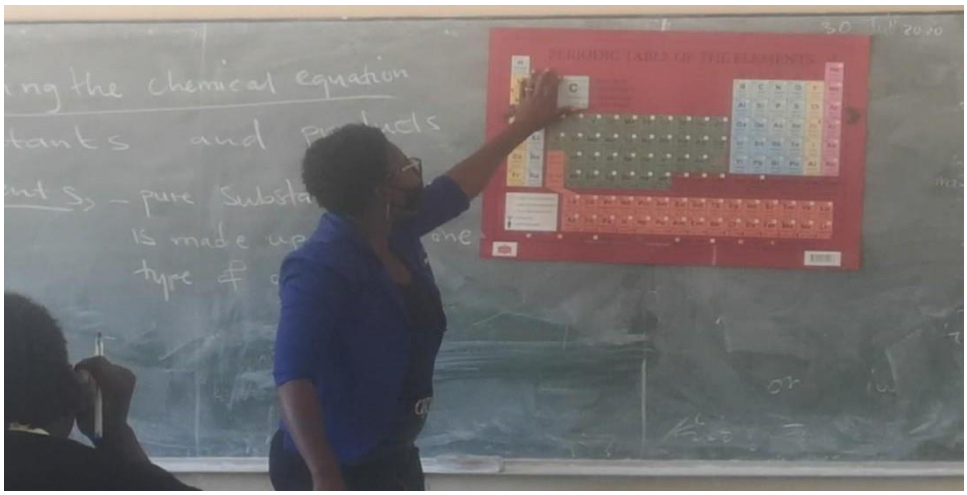


Figure 1: Ms. Iyaloo pasting a periodic table of elements on the chalkboard.

From her questions above, it could be surmised that the teacher kept in mind that it is importantto consider what learners acquired from the previous grades as noted by [56] and [55]. 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. 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 learnerscould recall what a periodic table of elements is and why learning about it is important in othertopics in chemistry [20-21]. 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.

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 [11] and [57]. For instance, the fact that both teachers' introductory part of the lesson was on the periodic table of elements is a very strongpoint 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 periodictable of elements. They emphasized that learners need to understand the chemical symbols of elements in order to be able to write correct chemical formulae of compounds which makes iteasy to formulate chemical equations and balance them. Figure 2 and Figure 3 indicate how the two teachers use the chalkboard to facilitate the writing of balanced equations by starting first with word equations to chemical equations.

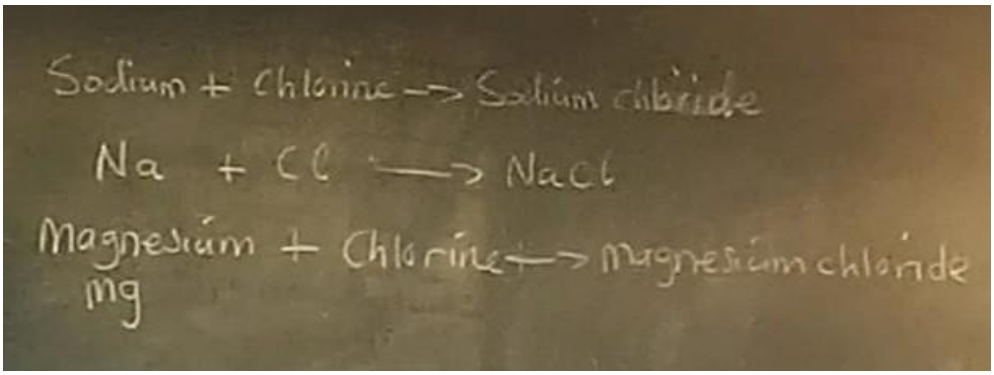


Figure 2: An example showing Mr. Imagine use of a word and a chemical equation.

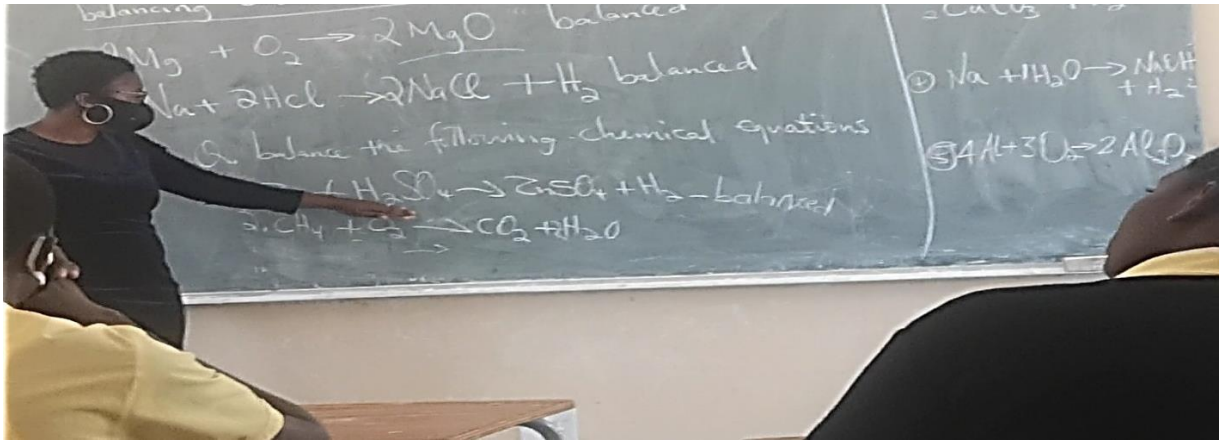


Figure 3: Examples showing chemical equations written by Ms Iyaloo

From Figures 2 and Figure 3, 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 forthe learners.

CONCLUSIONS AND RECOMMENDATIONS

In response to the research questions, 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 [31], [14], [15], [23] and [21]. 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 [25-26].

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 understandthe writing and balancing of chemical equations. They indicated the use of hands-on practicalactivities and the use of easily accessible materials to make the topic more understandable as highlighted by [50-52].

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 suchas algebra in mathematics which is in line with [27] who suggests a system of solving chemical equations by using linear equations. Also, teachers indicated that they try togive more written work to the learners

in an attempt to make the writing and balancing of chemical equations understandable to the learners. Therefore, the study recommends that science teaching should strongly make use of the periodic table of elements as a cornerstone to teaching and learning chemistry. Moreover, the study also suggest that science 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. This study opens up some opportunities for further research such as '*learners' views, attitudes, and experiences regarding the writing and balancing of chemical equations'* or '*the role of technology during mediation of writing and balancing chemical equations.'*

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