

**Exploring how Grade 11 Chemistry teachers mediate learning of  
the topic redox reactions in their classrooms in Namibia**

**A thesis submitted in fulfilment of the requirements for the degree**

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**By**

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**January 2023**

## Declaration

I, Junilla Inamudhimbwa Lindombo (17I8177), declare that this thesis: Exploring how Grade 11 Chemistry teachers mediate the learning of the topic redox reaction in their classrooms in Namibia, is a true reflection of my work and that this work or part thereof has not been submitted at any other university. All ideas and citations used in this study derived from other people are acknowledged and indicated in the list of references.

Signature: 

Date: January 2023

## **Dedication**

This thesis is dedicated to my late parents, Ignatius Kathena Iindombo and Junilla Enkara-Iindombo. Your inspiration and strictness have shaped me into the responsible woman I am today. I also dedicate this piece of work to my siblings for being the light for me to continue to struggle to this level and beyond. And finally, to my lovely husband Mr. Romuald Ndombi for his immense support through this journey. I love you all, and may God bless you all!

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## Abstract

The Namibian Chemistry ordinary level syllabus requires learners to study the topic of redox reactions. This topic has proven to be one of the most difficult for Namibian learners as reflected by their poor responses to questions in the Grade 11 and 12 Namibian Senior Secondary Certificate 'O' examinations. Teaching abstract concepts such as redox reactions requires higher cognitive thinking skills and thus presents a challenge. Against this background, this study sought to explore how teachers mediate learning of redox reactions in their classrooms. The focus was on conceptual understanding through linking content to the context of the learners.

The study was underpinned by an interpretivist paradigm, within which a qualitative case study approach was adopted. Two Grade 11 Chemistry teachers from the Ohangwena and Oshana regions in Namibia were the research participants. I used semi-structured interviews, lesson observations and stimulated recall interviews to collect data. I used Shulman's Pedagogical Content Knowledge as a theoretical framework in this study and the data sets were analysed using the Topic-Specific Pedagogical Content Knowledge components. Qualitative data were analysed inductively-deductively.

The study's findings revealed that teachers used various mediation tools such as analogies and prior knowledge. The results further illuminated that teachers should develop strong subject content knowledge and pedagogical content knowledge to have the best strategies in place to mediate learning of this topic.

**Keywords:** Chemistry, redox reactions, hands-on practical activities, pedagogical content knowledge (PCK), topic-specific pedagogical content knowledge (TSPCK)

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## **List of Abbreviations and/or Acronyms**

AfL	Assessment for Learning
CK	Content Knowledge
CPD	Continuous Professional Development
DNEA	Directorate of National, Examination and Assessment
LCE	Learner-Centred Education
LTSM	Learning and Teaching Support Materials
MoE	Ministry of Education
MoEAC	Ministry of Education Arts and Culture
MOK	More Knowledgeable Other
NCBE	National Curriculum for Basic Education
NIED	National Institute for Educational Development
NSSCH	Namibian Senior Secondary Certificate Higher Level
NSSCO	Namibian Senior Secondary Certificate Ordinary Level
PCK	Pedagogical Content Knowledge
PD	Professional Development
PK	Prior Knowledge
SMK	Subject Matter Knowledge
SRI	Stimulated Recall Interviews
TIMSS	Trend in International Mathematics and Science Study
TSPCK	Topic-Specific Pedagogical Content Knowledge
UNESCO	United Nations Educational, Scientific and Cultural Organization

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## CHAPTER ONE: SITUATING THE STUDY

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### 1.1 Introduction

The main goal of my study was to explore how Grade 11 Chemistry teachers mediate learning of redox reactions in their classrooms. This chapter introduces the study and gives the pathway for the thesis. It provides the background of the study, the problem it tried to address and why it was important to do so. It then highlights the goal, research questions used as guidelines to achieve the goal, and the data-gathering techniques used. The conceptual and theoretical frameworks that informed the study are also highlighted as well as the definitions of key concepts used throughout the study. Finally, an outline of the thesis is provided, followed by a chapter summary.

### 1.2 Background of the Study

Despite the attention given to science education nationally and globally, learners seem to perform poorly and show little interest in Science, Technology, Engineering and Mathematics (STEM) (Trends in International Mathematics and Science Study [TIMSS], 2016). For instance, the TIMSS report revealed a decline in performance on average scores in 2015 across the world (TIMSS, 2016). In 2019, only three African countries participated in TIMSS: South Africa, Egypt, and Morocco. Compared to other countries, the results of these three African countries were not good (TIMSS, 2019).

Furthermore, the TIMSS (2019) report revealed that teachers' professional development needs in Mathematics/Science and the shortage of school resources were identified as factors that might cause this poor performance. According to Yücedag and Sevik (2021), professional development (PD) is considered a crucial element for both improving teaching and increasing learners' learning and achievements. Thus, PD is considered a fundamental factor in the professional development and quality of the teacher (Canaran & Mirici, 2020). Therefore, it is understood that teacher PD in turn boosts both the quality of the schools and learners' learning

as well as the whole education system both in developed and developing countries (Dayoub & Bashiruddin, 2012).

Additionally, 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 on their own ideas about the content they teach and about student learning and appropriate pedagogy (Kambeyo, 2021).

Unfortunately, Namibia has not taken part in a TIMSS evaluation or diagnostic test since their inception. I assume that, in Namibia, TIMSS is highly unpopular. Yet, the TIMSS report is a good measure of learners' performance in mathematics and science education in countries worldwide.

Even though Namibia has not participated in TIMSS, Namibia has been implementing the national Standardised Achievement Tests (SATs) since 2009 which is administered by the Directorate of National Examination and Assessment (DNEA). The primary objectives of the SATs are to report learners' performance growth from one year to the next and provide diagnostic information about what knowledge and skills (i.e., basic competencies/standards in the curriculum) learners have mastered and what they have not (Shaakumeni & Mupupa, 2019). Reports have revealed that according to the SATs, for Grade 7 (of which Science is one of the subjects), learners' performances were below the basic or average achievements. This was especially true for learners in rural schools (Ministry of Education [MoE], 2011, 2013, 2015). Moreover, Shaakumeni's (2014) study confirmed that most learners showed limited knowledge and exposure to some of the basic competencies in science.

In addition, despite the expectations of the curriculum, the learners' performance in science and mathematics continues to be worrisome (UNESCO, 2010). The Southern African Consortium for monitoring of Education Quality (SACMEQ) report indicated that teaching Mathematics in Namibia has been unimpressive, especially in the upper primary phase (SACMEQ, 2005). SACMEQ Reports (2005) further confirmed that Namibia's performance has been very poor compared to that of other Southern African countries. Concurring, the Physical Science and Chemistry examiners' reports in the final school-leaving examinations

(MoE, 2013–2021) have repeatedly reported that learners performed poorly in most schools countrywide.

In the Namibian education system, Physical Science is a compulsory subject taught at 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 the Ordinary level (NSSCO). According to the revised National Curriculum for Basic Education (NCBE), at the NSSCO level, physical science is split into two subjects: chemistry and physics. Even though many qualified physical science teachers majored in physical science, a combination of chemistry and physics at the university level, they seem to favour one over the other. Since these subjects are now taught separately, Physical Science teachers may choose to teach either physics or chemistry depending on their strengths in Subject Matter Knowledge (SMK) (Shulman, 1986). This is a relief for most teachers, as the challenges of teaching physical science as one subject (a combination of physics and chemistry) have been reduced.

This study focused on chemistry at the senior secondary phase, that is, Grade 11. According to Uchegbu et al. (2016, p. 1), “Chemistry is one of the science subjects where learners 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”. Also, 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).

Even though Chemistry is important for scientific reasoning, learners find some chemistry topics more difficult than others. For instance, redox reactions have been identified as one of the problematic topics (Adu-Gyamfi et al., 2018; Chiang et al., 2014). Yet, redox reactions form an essential component of the science curriculum. Redox reactions are “an integral component of electrochemistry, cover a wide variety of chemical processes, extending from photosynthesis and metabolism to the combustion of coal and oils and the recovery of metals across a broad spectrum of energy-producing reactions” (Blignaut et al., 1988, p. 10).

In addition, these reactions are covered in several subject areas within Chemistry, and research has shown that these reactions are difficult both to teach and to learn (Mounchide et al., 2021; Nguessan, 2016). This is in accordance with the Chief Examiner report of the Ghana West African Senior School Certificate Examinations which identified the concept of oxidation-reduction reactions as one of the difficult areas for most learners (West African Examination Council, 2013).

The Namibian education system strongly advocates for a learner-centred education (LCE) approach, as laid out in *Toward education for all: A development brief for all Namibian education* (MoE, 1993). According to the MoE, this approach advocates a paradigm shift towards LCE, in order to provide the kind of education that makes it possible for learners with varying sociocultural backgrounds and different abilities to progress (Mavuru & Ramnarain, 2020). For example, the *NCBE* (MoE, 2016) states that learners learn best when they are actively involved in the learning process through a high degree of participation.

However, Nyambe and Wilmot (2012) argue that, while there is consistency in the teacher educators' interpretations and the policy documents, the examples of how the teachers implement the learner-centred pedagogy in their classrooms, indicate a disjuncture by both teachers and learners on the actual LCE approach. This suggests that there seem to be contradictions or tensions between the intended (developers), implemented (teachers) and achieved or attained (learners) curriculum. Yet, the main goal of the *NCBE* (MoE, 2016) is to empower learners for the development of a future Namibia as a knowledge-based society. This is characterised by the effective and wise use of existing knowledge and the creation of new knowledge (MoE, 2016).

The NSSC Chemistry syllabus (MoE, 2019) guides teachers on what content and level to teach. The syllabus is systematically presented in three columns; the topic, general objectives and specific competencies. In the Namibian chemistry syllabus for grades 10–11, the topic of redox reactions is covered under theme 6 of the chemical reactions. Moreover, the teaching of *content* in the Namibian curriculum is arranged in such a way that learners move from 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 redox is covered under theme six, 'Chemical reaction', which comes after the learners are introduced to theme five, 'Electrochemistry'. The extract below shows the basic objectives that should be met under the topic of redox reactions.

**Table 1.1: Extract from the Namibian Chemistry Curriculum**

<b>Topic</b>	<b>General objectives</b> Learners will:	<b>Basic competencies</b> Learners should be able to:
6.6 Redox	<i>know simple redox reaction</i>	<ul style="list-style-type: none"><li>• <i>define oxidation and reduction in terms of oxygen gain/loss and in terms of the transfer of electrons.</i></li><li>• <i>identify redox reactions by changes in ionic charges.</i></li><li>• <i>identify reducing and oxidising agents (including in the context of the extraction of metals).</i></li></ul>

Based on the extract above, learners might not understand the extraction of metals without a good understanding of simple redox reactions. This corroborates the idea of Chiang et al. (2014), who suggested that a better understanding of redox reactions requires knowledge of basic general chemistry concepts: atoms, electrons, acid/base, and chemical reactions. Also, to use the symbols of the elements to construct formulas and equations, one needs a thorough understanding of the group properties and how elements bond to form molecules and compounds respectively (Kambeyo, 2021). It is recognised, however, that to achieve the aims and objectives of the chemistry curriculum, the teachers' PCK plays an important role, as stated by scholars such as Shulman (1986) and Mavhunga and Rollnick (2013), to mention a few.

In the old curriculum, to determine whether the objectives of the syllabus were achieved, learners in Namibia were required to sit for the Namibian Senior Secondary Certificate examinations at the end of grade 12. The assessments were written on two levels, Higher and Ordinary<sup>1</sup>. Both syllabi required learners to study redox reactions.

The extracts below reflect learners' misconceptions in redox reaction questions as written in the examiners' yearly reports.

**Box 1.1: Extract from Examiners' Reports (2013, 2015, 2017 and 2021)**

- *“Most candidates could not score full marks as they could not state the oxidation number of zinc when it was oxidised. Teachers are urged to emphasise oxidation and reduction in terms of electron transfer and should clearly state what happened to oxidation number” (MoE, 2013, p. 392).*
- *“Most candidates acquired no mark as they only referred to the gaining of oxygen instead of gaining of electrons. Only a few candidates were able to grasp the change in oxidation number, therefore*

<sup>1</sup> Namibia Senior Secondary Certificate Ordinary (NSSCO) examination written in Grade 12 at an ordinary level

teachers are argued to explain more clearly on what happens to the oxidation number when an atom becomes an ion and when an ion becomes an atom” (MoE, 2015, p. 422).

- “Poorly answered as most candidates could not identify that carbon in methane is oxidised because it has gained oxygen or has lost hydrogen. Teachers are urged to emphasise the concept of redox reaction. Few candidates could identify that the oxygen is an oxidising agent. Most candidates showed little knowledge on how to identify the substance in the equation as an oxidising agent or reducing agent” (MoE, 2017, p. 380).
- “Poorly answered. The concept of ionic equations in general and specifically those occurring at the electrodes seems to be a challenge for many learners. At the Anode: Loss of electrons (oxidation) takes place at the negatively charged ions ( $O^{2-}$ ) gives its electrons to the positively charged anode to form a neutral molecule, oxygen gas,  $O_2$ . At the Cathode: Gain of electrons (reduction) takes place at the positively charged cathode. Aluminium ions gain  $3e^-$  at the cathode to form a metal aluminium” (MoE, 2020, p. 89).
- “(d) (i) Well answered. Even though, many first answered in terms of oxygen before giving the answer in terms of electrons”.  
“(ii) Is the question only available to advantaged candidates. The candidates needed to first know the correct balance chemical equation for the reaction between zinc and hydrochloric acid, determine the oxidation state of hydrogen ion (+1) and then that of hydrogen gas (0). And finally recognise that there was a decrease in the oxidation number, meaning, it accepted or gained electrons” (MoE, 2021, p. 82).

The box above contains the comments which I extracted from the examiners’ reports for those indicated years, 2013, 2015, 2017 and 2021. Being a national marker for the Namibia Senior Secondary Certificate (NSSC) Physical Science and Chemistry, I have also noticed that learners perform poorly in questions related to redox reactions. For instance, a typical examination question about redox reactions from the 2013, 2015 and 2021 Physical Science and chemistry examinations was as follows:

**Box 1.2: Extract from 2013 (p. 9) Physical Science National Examination**

*Large lumps of zinc, in excess, are added to dilute sulphuric acid. Hydrogen is emitted which is observed as bubbles. This reaction also produces zinc (II) sulfate.*

*(d) In the reaction in (c) (i), zinc is oxidised to produce zinc salt. In terms of electrons transfer and oxidation number, explain why zinc is not oxidised. [2]*

Based on learners’ written responses in the 2013 National examination, the national markers for Physical Science concluded that most learners had not understood redox reactions concepts well during teaching and learning. As a result, most candidates “could not state the oxidation number of zinc when it was oxidised” (MoE, 2013, p. 392). Similarly, this is in agreement with the findings of Supasorn (2015) and Nyachwaya et al. (2011), which showed that learners

attributed incorrect oxidation numbers to various species and neglected the oxidation numbers of charged species.

I assume that this could be because learners tend to master the oxygen model (which is the loss of oxygen for reduction and the gain of oxygen for oxidation) more than other models of redox reactions. As a result, examiners' reports suggested various improvements to prevent such errors from reoccurring in future examinations. They suggested, "Teachers are urged to emphasise oxidation and reduction in terms of electron transfer and should clearly state what happened to oxidation number" (MoE, 2013, p. 392). Despite the examiners pointing this out, learners continue to perform poorly in redox reactions, repeating similar mistakes of previous years, as was revealed by the examiner's report of 2015.

**Box 1.3: Extract from 2015 (p. 8) Physical Science National Examination**

*(d) The reaction of copper carbonate and carbon is a redox reaction. With reference to the oxidation numbers, explain why copper ion in copper carbonate is said to be reduced.*

..... [2]

The main problem learners faced in answering this question (Box 1.3) was identified in the examiner's report. The report revealed that "most candidates acquired no marks as they only referred to the gaining of oxygen instead of gaining of electrons. Only a few candidates were able to grasp the change in oxidation number" (MoE, 2015, p. 422). These results concur with the findings of other studies, which revealed that learners have difficulties in identifying the number of gained or lost electrons in redox reactions, understanding stoichiometry in the electrons transfer process as well as balancing a redox reaction (Cole et al., 2019; Geiger, 2018; Kelly et al., 2017). What I found interesting was when the examiners' reports emphasised that "Teachers should explain more clearly what happens to the oxidation number when an atom becomes an ion and when an ion becomes an atom" (MoE, 2015, p. 423).

It seems that the recommendations which were made in the examiners' reports were not implemented successfully. This was shown by the recent examiners' report of 2021. Learners are still repeating the same mistakes which were addressed in the examiner's reports of 2013, 2015, 2017 and 2020.

**Box 1.4: Extract from 2021 (p. 7) Chemistry National Examination**

*(d) Zinc metal is oxidised during the reaction.*

- i. Define, in terms of electrons, the term oxidation. .... [1]*
- ii. In terms of oxidation number, explain why hydrogen ion is referred to as an oxidising agent during the reaction. .... [2]*

Examiners' reports for the question that requires learners to define oxidation in terms of electron transfer revealed that the question was "well answered. Even though many first answered in terms of oxygen before giving the answer in terms of electrons" (MoE, 2021, p. 82). Based on this report, I assumed that learners had mastered the oxygen model more than other models of redox reactions, which is why they explained the answer first in terms of oxygen before answering in terms of electrons. Barke (2012) suggested that only one model of the electron transfer model of oxidation-reduction reactions should be taught at one particular time and that the oxygen model of learning oxidation-reduction reactions should be avoided. This is because learners prefer the oxygen transfer model and then conceptualise the redox reaction in terms of the oxygen transfer model (Barke, 2012).

Moreover, for the second question in the extract above, the examiner's report revealed that learners have problems balancing chemical equations. This shows that learners have not understood the prerequisite concept of balancing chemical equations before learning to balance redox reactions. The examiner's report (MoE, 2021, p. 82) revealed that "the candidates needed to first know the correct balance chemical equation for the reaction between zinc and hydrochloric acid, determine the oxidation state of hydrogen ion (+1) and then that of hydrogen gas (0). And finally recognise that there was a decrease in the oxidation number, meaning, it accepted or gained an electron".

In the study conducted in Namibia, Kambeyo (2021) stated that to write and balance a chemical equation, learners are 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. Kambeyo (2021) further explained that failing to write the correct chemical formulas will result in an incorrect chemical equation and being able to balance it. Namibians learners are not the only ones who experience this problem. 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). Thus, this study intended to explore how Grade 11 Chemistry teachers mediate learning of redox reactions in their classrooms in the Namibian context.

### **1.3 My Personal Experience: Situating Myself in the Study**

I completed my secondary school education in an under-resourced school. Even though this school was one of the best in the northern part of Namibia, it had laboratories, but they were not equipped with chemicals and apparatus. Also, all our physical science and biology lessons were conducted in a classroom and focused more on theory; we relied heavily on textbooks. I never had the chance to be exposed to chemicals and apparatus or to carry out practical activities. I came to know many instruments from the textbook pictures only.

Since science was taught theoretically, I struggled to understand most abstract topics, including redox reactions and relied on memorisation. The only thing I remember about redox reactions from secondary school education was the abbreviation that we were given by our physical science teacher. The abbreviation was OIL RIG which stands for (OIL – Oxidation Is Loss and RIG – Reduction Is Gain), which was only accurate in terms of hydrogen and electrons but not oxygen. No experiment was conducted to show how atoms or compounds gain or lose electrons, oxygen or hydrogen.

I studied for my first Diploma in Education at Mutare Teachers College in Mutare, Zimbabwe. The college had well-equipped science laboratories in Physics, Biology and Chemistry, and all science lessons were conducted in these laboratories. My lecturers used various demonstrations in their teaching and, occasionally, gave us hands-on practical activities (Asheela et al., 2021). I still vividly remember some experiments, such as: how iodine changes into a gas which is sublimation; displacement of copper by iron in copper sulfate; testing of gases such as hydrogen, oxygen, carbon dioxide, and chlorine; and testing of acids and bases. All these experiments were new to me, even though I was supposed to have been exposed to them at the secondary school level. The lecturer would give the class the necessary chemicals and a few instructions, and we would do the experiments very well. I still use the resources I was given at college when teaching physics and chemistry because science has not changed much over the years. After completing my studies in Zimbabwe, I commenced my teaching career at a poorly resourced school located deep in the rural area of Gam, Namibia.

Reflecting on my teaching experience as a Physical Science (Physics and Chemistry) teacher for the past 14 years, I observed that the learners' performance in Physics and Chemistry differ. For instance, learners seem to perform better in Physics than in Chemistry. Also, being a national marker and a team leader for the Junior Secondary Certificate and Namibia Senior Secondary Certificate (NSSC) for Physical Science and Chemistry, I noticed that learners do not perform well, specifically in the questions related to the topic of redox reactions.

Many learners struggle to answer the questions based on the topic of redox reactions in chemistry. As a result, most learners seem to lack interest in it, and some leave those questions unanswered. For instance, many learners in my class fail to understand oxidation and reduction in terms of electrons and hydrogen and the rules to determine oxidation numbers and to make links between prerequisite subtopics such as oxidation state and ionic charge. This has been a common problem over my 14 years of teaching. I assume that it is the leading cause of many learners scoring low marks and eventually contributing to their failing examinations.

Furthermore, my observation is backed up by the NSSCO examiners' reports for physical science for the years 2015, 2016, 2018, 2019, and 2021. These reports revealed that learners do much better in Physics than Chemistry topics. The examiners' reports further indicate that learners' performance in the topics related to the redox reactions of elements was not satisfactory.

Moreover, I have noted that learners struggle to apply prior knowledge or relate the concept of redox reactions to their everyday situations (Gwekwerere, 2016). That is, it seems as though learners do not possess a well-founded basic framework regarding redox reactions into which newly acquired experience can be integrated. However, at this level, learners are supposed to know electron transfer, how to balance a chemical equation, and how to write chemical formulas as well as ionic charges. In a study conducted in Nigeria by Oloruntegbe and Ikpe (2011), it was found that there was a substantial number of chemistry learners who could not establish a bridge between school science and relevant phenomena in their homes. These results match those observed in earlier studies by Aikenhead and Jegede (1999). As a result, the learners perceived a so-called gap between household experience and school chemistry, making learners perceive the subject as fragmented and not making sense. These scholars add that teachers do not consciously use phenomena from learners' daily life experiences to present materials in chemistry classrooms (Oloruntegbe & Ikpe, 2011).

As a concerned science teacher, a national marker and a team leader, I had discussions concerning redox reactions with other Physical Science (old curriculum) national markers and Chemistry (new curriculum) national markers, and they agreed with the examiners' reports. The national markers alluded to the fact that learners in Namibia generally find it problematic to explain the redox reactions during examinations. Moreover, they added that learners' answers to the section often reflect an absence of conceptual understanding. Hence, they argued that the poor quality of the answers might result from how redox reactions are taught in Namibian schools.

Many studies have been conducted in Namibia on how teachers mediate the learning of chemistry topics. For example, Chani's (2014) and Manamike's (2022) studies focused on chemical equilibrium, Kanime's (2015) and Denuga's (2019) studies were on stoichiometry, Kambeyo's (2021) study focused on writing and balancing chemical equations and Likando's (2021) focused on chemical changes. Some of these scholars revealed that the poor performance in science, in general, is attributed in part to a lack of laboratory facilities or under-resourced laboratories resulting in hands-on practical activities not being carried out. Also, these scholars revealed that teachers were trying their level best to mediate learning 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 fail to select appropriate teaching strategies during teaching and learning. Therefore, these findings, combined with my experience, aroused my curiosity to research this seemingly complicated redox reaction topic. I searched for studies done in Namibia on the teaching and learning of redox reactions and could not find any. Consequently, I decided to conduct qualitative research to gain insights into how two teachers in the northern part of Namibia mediate learning of redox reactions in the classroom.

#### **1.4 My Positionality and Reflexivity**

In this study, it was important for me to reflect on my positionality and how this may have influenced the research process. Bertrand and Demps (2018) provide insight into positionality. They insist that every researcher inherently carries assumptions and biases into their work and that these influence the interpretation and representation of the participants' *voices*. Concurring, Holmes (2020) explains that, as a researcher, I could not separate myself from the

social reality in which I live to study it objectively. In light of these arguments, I hereby provide “an open and honest disclosure, and exposition [to] show where and how” (Holmes, 2020, p. 3). I think my beliefs may have influenced the study. Furthermore, I divulge that I used a reflexive approach throughout the research process aimed at understanding the influence of my positionality on the research design, conduct and output (Holmes, 2020).

Firstly, being a master’s scholar at Rhodes University and a national team leader for physical science, I was mindful of the influence of power dynamics this might have during the research process. To overcome this, I had 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 on my project.

Secondly, in my role as the researcher, I needed to communicate with the participants to organise suitable times to meet and collect data while following the data collection procedures. I ensured that the participants in this study were not forced nor felt obligated to participate. Therefore, I conducted my study without bias and treated my participants equally and fairly. As a result, transparency concerning positionality and my intentions as a researcher were central to my research efforts.

In the context of outsider/insider positionality for this study, I assumed an insider position. I am a chemistry teacher who also struggles with teaching redox reactions and has the desire to learn how best to teach them. The research participants were all national markers who I meet annually when we mark the National examinations for Grades 11 and 12. Thus, I had “priori knowledge of the group [and concept] being researched” and this enhanced the advantages of an insider position, such as “being able to ask more meaningful or insightful questions (due to possession of priori knowledge)” and “as a researcher may be more trusted so may secure more honest answers” (Holmes, 2020, p. 6). On the other hand, the disadvantage of the insider position is that participants could assume that I was more knowledgeable.

### **1.5 Statement of the Problem**

A research problem is a problem or issue that leads to the need for a study. It can originate from many sources, such as the researcher’s personal experience as was the case in the context of this study, extensive debates in literature, gaps in the literature, or alternative views that need to be studied (Creswell, 2014).

From my own teaching experience, I have observed that teachers follow the suggested materials in the syllabus to do experiments, and yet some of those materials are not available in the schools. Moreover, in cases where hands-on practical activities are not suggested in the syllabus, teachers do not think of doing practical work (Asheela et al., 2021), resulting in these topics being taught theoretically. That is, the teacher explains the concepts, and the learners memorise them without any conceptual understanding. Hence, learners struggle to comprehend these concepts, resulting in poor performance. Concurring, Reddy et al. (2016) posit that learners' perceptions of the usefulness and relevance of science play a big role in the associations they build with the subject and whether or not they choose to do it beyond their current engagement. Therefore, it is important that science is taught in a way that helps learners build positive associations with science and creates motivation to pursue it further than just high school (Ngqinambi, 2019).

Also, evidence from the examiners' reports revealed that learners often lack critical thinking and the required scientific language to explain redox reactions. For this reason, the examiners have made some suggestions so that learners can be exposed to the reality of science. Despite suggestions for improvement in the examiners' reports (MoE, 2013, 2015, 2017, 2020 & 2021), it seems as though limited or no hands-on practical activities and demonstrations have been implemented or enacted in Namibian science classrooms (Asheela et al., 2021). Findings revealed that this could be due to a lack of resources required by the syllabus and a lack of PCK on the part of the teachers on how to improvise using locally available resources (Asheela et al., 2021).

## **1.6 Rationale and Significance of the Study**

This study aimed to explore how Grade 11 Chemistry teachers mediate learning of redox reactions. Knowledge of redox reactions is necessary for understanding complex chemistry reactions and it is the basis of many chemical processes. It is also an integral component of many topics in other science disciplines. Thus, this study might help in supporting the teaching of the redox reactions topic. In addition, this research is meant to benefit all chemistry teachers so that they can learn how to help their learners become enthusiastic about the different topics they teach. The study might also help me improve my practice in the classroom as a teacher.

## **1.7 Research Goal and Questions**

In the next sub-sections, my research goal and questions are stated.

### **1.7.1 Research goal**

The main goal of this study was to explore how Grade 11 Chemistry teachers mediate learning of redox reactions in their classrooms. To achieve this goal, the study was guided by the following research questions.

### **1.7.2 Research questions**

1. What enables and/or constrains Grade 11 Chemistry teachers when mediating learning of redox reactions?
2. How do Grade 11 Chemistry teachers mediate learning of redox reactions in the classroom?

## **1.8 Theoretical and Analytical Framework**

Biesta et al. (2011) suggest that the importance of theory is to make things known which might not be visible or realised. In this regard, a theoretical framework serves as the structure of support for the rationale of the study, the problem statement, the purpose, the significance and the research questions (Grant & Osanloo, 2015).

### **1.8.1 Theoretical framework: PCK**

This study is informed by Shulman's (1987) theory of PCK, which is believed to be the knowledge teachers develop over time and through experience on how to teach content in a way to enhance learning. This will be discussed in more detail in Chapter Two.

### **1.8.2 Analytical framework: Topic-Specific pedagogical content knowledge**

Within PCK, I used the Topic-Specific Pedagogical Content Knowledge (TSPCK), which focuses on five components such as learners' prior knowledge, curricular saliency, what is difficult to teach, representations including analogies, and conceptual teaching strategies as an analytical lens (Mavhunga & Rollnick, 2013). To foster understanding, a teacher needs to present the SMK in a way that ensures access to the learners. During the teaching process, examples should be drawn from learners' experiences to enhance the subject's understanding (Mavhunga & Rollnick, 2013). This will be explained in more detail in Chapter Two.

## 1.9 Data-gathering Techniques

A variety of data-gathering methods were used to collect data in this study, and these are:

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

## 1.10 Definitions of Key Concepts

In this thesis, I have used terms that could have different meanings in other contexts or could be written differently. The meanings of these terms are explained below.

**Redox reaction** is a type of chemical reaction in which the oxidation states of atoms are changed as a result of an exchange of electrons.

**Mediation of learning** is the process in which the teacher interacts with the learners to scaffold their intellectual development.

**Subject matter knowledge (SMK)** is a concept which describes how information relating to specific topics is possessed.

**Teaching strategies** are the methods that a teacher uses to help learners master concepts in the classroom.

**Pedagogical content knowledge (PCK)** is a concept which describes how teachers present and formulate their subject content to make it easily comprehensible by their learners (Shulman, 1987).

**Topic-specific pedagogical content knowledge (TSPCK)** is the basis by which knowledge of the subject matter of a particular topic is conveyed to learners. This includes learners' prior knowledge, curricular saliency, what makes a topic easy or difficult to teach, representation and teaching strategies (Mavhunga & Rollnick, 2013).

**Prior (everyday) knowledge** is the information that learners bring to the classroom, which can be concepts learnt in earlier grades and/or information gained from their homes/cultures/communities.

**Practical activities** are the learning experiences which are designed, through action, to forge a link between the observations and the theories/ideas of science.

## 1.11 Thesis Outline

This section briefly outlines the different components of this study which was conducted at two secondary schools in the northern part of Namibia. The thesis comprises five chapters and I present each of these below.

**Chapter One:** The first chapter of the study explained the context and background of the study. This included the purpose, outline and structure of the study. A discussion of the background of the research was presented. The reasons for carrying out the study were outlined. The statement of the problem, the significance of my study, the research aim and the questions were specified and theoretical frameworks were introduced. The data-gathering techniques were described, and the key concepts were defined.

**Chapter Two:** The second chapter of the study discusses the relevant literature, situating the study in a context with similar studies to see what has already been researched. It provides an overview of the literature relating to the mediation of learning the redox reactions concept in Namibia. In addition, an account of the theoretical framework used in the research is described.

**Chapter Three:** This chapter provides clarity on the qualitative research methodology adopted in the study. The chapter begins with a profile of the research participants, that is, their qualifications and teaching experience. The data-gathering techniques and the rationale behind their use are discussed. This chapter explains the qualitative research methodology used to answer the research questions. Thus, it answers why a qualitative research methodology was adopted. Further, the reasons behind the use of interviews and lesson observations are explained. The use of purposive and convenience sampling techniques is discussed. Lastly, an overview of the data analysis procedures is presented.

**Chapter Four:** This chapter provides a narrative account of the data generated through both the sets of interviews and lesson observation. The chapter mainly focuses on the qualitative data gathered.

**Chapter Five:** This chapter sums up the main findings. These comprise implications of the research outcomes; suggestions for Physical Science teachers; limitations of the study;

suggestions for further research; lessons learnt from the study; recommendations, and personal reflections.

## **1.12 Chapter Summary**

This chapter discussed the background of the study, statement of the problem, significance of the study, the research goal, research questions, and theoretical and analytical frameworks. Definitions of key concepts as well as the thesis outline were provided in order to give a clear understanding of the research and to enable the readers to easily navigate through the research.

The next chapter reviews the literature relevant to the mediation of redox reactions.

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## CHAPTER TWO: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

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### 2.1 Introduction

According to Cohen et al. (2018), the purpose of a literature review is to review other research to get theoretical ideas about what others have said about the concepts under study. Therefore, the literature reviewed in this chapter is related to the teaching of the topic of redox reactions.

In this chapter, I thus discuss the concepts related to redox reactions, which include eliciting learners' prior knowledge, use of instructional strategies, use of hands-on practical activities, use of learning and teaching support materials, assessment for learning, and use of language. The theoretical frameworks that underpinned this study were focused on the PCK of the teachers involved (Schulman, 1987). Since PCK differs from topic to topic, I adopted the model for TSPCK as an analytical framework (Mavhunga & Rollnick, 2013). I discuss each of these in detail below.

### 2.2 The Concept of Redox Reactions

A chemical change is the formation of new substances (products) which are different from the starting substances (reactants). A chemical reaction is a process through which new substances are formed due to chemical changes. Chemical reactions are classified as redox, acid-base, chemical decomposition, fermentation, combustion, photosynthesis and so on.

In one class of chemical reactions, oxidation-reduction reactions, the oxidation states of elements change (Chang, 2008). The oxidation-reduction reaction is commonly referred to as a redox reaction. The history of oxidation-reduction reactions started with Stahl's "phlogiston theory" in the early 1700s. Stahl explained that all combustible materials contained phlogiston (Asimov, 1966). Ash, for example, was left without phlogiston and could not burn.

Furthermore, with a similar approach, a change of metal ore into free metals could also be explained. Phlogiston-poor oxide ores are heated with phlogiston-rich charcoal. Phlogiston moves from charcoal to oxide ores. The charcoal is then phlogiston-poor, and the oxide ore forms a phlogiston-rich metal (Asimov, 1966).

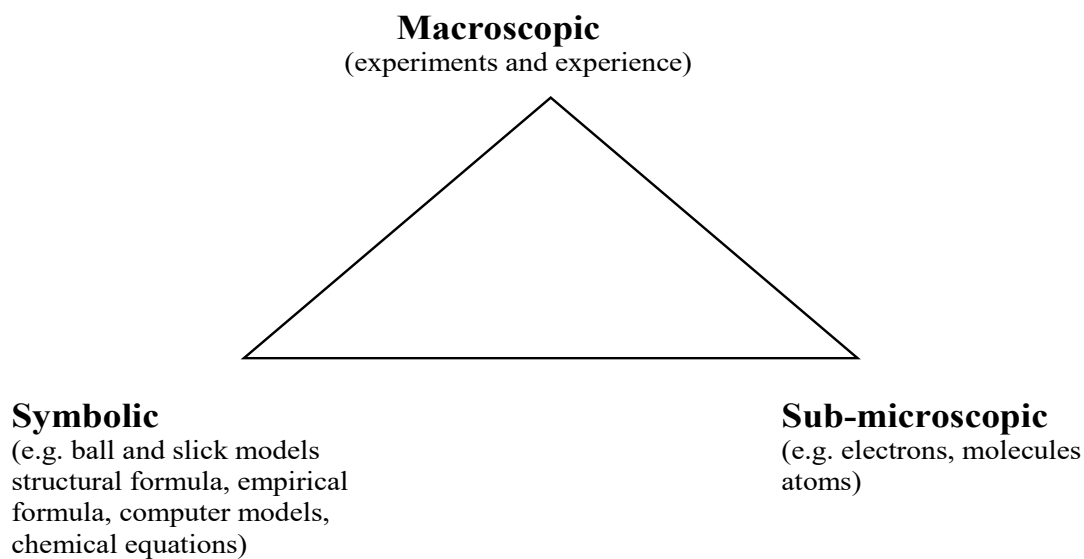
To Österlund and Ekborg (2009), there are four different models for teaching and learning oxidation-reduction reactions in the chemistry curriculum. These models are:

- the oxygen model, which is loss of oxygen for reduction and gain of oxygen for oxidation;
- the hydrogen model, which is the gain of hydrogen for reduction and loss of hydrogen for oxidation;
- the electron transfer model, which is the gain of electrons for reduction and loss of electrons for oxidation; and
- the oxidation number model is the decrease in oxidation numbers for reduction and increase in oxidation numbers for oxidation.

Chang (2008) states that oxidation-reduction reactions were initially used to denote reactions involving oxygen, but the concept has a much broader meaning to chemists today. As a result, academic institutions worldwide present the concept of oxidation-reduction reactions using all four models instead of only the oxygen model (Adu-Gyamfi & Ampiah, 2018).

The complexity of teaching and learning has made redox reactions the object of study for several researchers. Several studies have found that the topic of redox reactions is a complex topic to comprehend for both secondary school learners and university students (Noll & Hughes, 2018; Obomanu & Onuoha, 2012; Paik et al., 2017; Schmidt & Volke, 2003). At the same time, other authors consider it difficult to teach (Adu-Gyamfi et al., 2018; de Jong & Treagust, 2002; Mounchide et al., 2021; Nguessan, 2016).

Accordingly, Johnstone (2000) accentuates that chemistry concepts or knowledge can be represented at multiple representation levels. Some of the learning difficulties experienced in this topic of redox reactions may be due to mixing the representation levels of the content. These multiple representation levels are macroscopic, submicroscopic, and symbolic. Those levels are also known as triplet relationships (Gilbert & Treagust, 2009) or chemistry triplets (Talanquer, 2011).



**Figure 2.1: Johnstone’s triangle represents the three levels of chemical knowledge (Johnstone, 1991, p. 78)**

Johnstone (1991) suggested that this ‘multi-level thought’ requirement makes science difficult for learners to understand. Indeed, chemistry explicitly requires the coordination of the macroscopic and tangible (what can be observed by the senses), the sub-microscopic (atoms, molecules, ions, and structures), and the symbolic (symbols, formulas, equations, molarity, mathematical manipulation, and graphs) (Stanford, 2016).

According to Gabel (1999), learners find it challenging to connect the three levels of representing matter if they are not given the time and opportunity. Concurring, Chiu (2005) points out that the difficulty with chemistry topics arises because, 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 classrooms into meaningful representation” (p. 1). However, this finding differs from previous researchers who stated that redox reactions concepts were mainly the interaction between macroscopic and submicroscopic levels which is the source of difficulty for many chemistry learners (de Jong et al., 1995; Garnett & Treagust, 1992; Sanger & Greenbowe, 1997; Tsaparlis, 2007).

From my experience as a Physical Science teacher in the old curriculum of grades 11–12 and a chemistry teacher for the new curriculum of grades 10–11, secondary school learners have difficulties understanding redox reactions due to the scientific terms that are not understandable to most. In the same vein, some scholars identified that the inexpressive language and

illustrations, sometimes inappropriate and misguided, present in textbooks may cause difficulties related to the subject (Österlund et al., 2010; Sanger & Greenbowe, 1999). I believe that making the redox reactions terminology clear to the learners could enhance their conceptual understanding. In addition, learners have little knowledge of concepts under chemical equilibrium, of which (redox) reactions are one due to their abstractness (Chani et al., 2018; Demircioglu et al., 2013; Sendur et al., 2010). According to Tyson et al. (1999), chemical equilibrium theories are abstract in nature, making them difficult to comprehend.

Under redox reactions, there are three difficulties that learners encounter: 1) comprehension of oxidation and reduction as complementary reactions; 2) identification of oxidising and reducing agents (imprecise terminology and complex language use) (de Jong & Treagust, 2002); 3) definition of a redox reaction as a loss and a gain of oxygen (Österlund & Ekborg, 2009).

Adu-Gyamfi and Amphiah (2019) assessed secondary school learners' difficulties in learning redox reactions. They found that their conceptual difficulties are in the form of alternative conceptions and other conceptual difficulties. This includes reduction half-reaction, which involves loss of electrons, oxidation half-reaction, which involves a decrease in the oxidation state, oxidised substances decrease in oxidation numbers and reduced substance's loss of oxygen. In their study, conducted in Nigeria, Adu-Gyamfi et al. (2018) showed that learners' alternative conceptions arose when  $H_2O$ ,  $H^+$  and  $OH^-$  were introduced when balancing redox reactions.

Moreover, these scholars evaluated learners' alternative conceptions with the application of oxidation and reduction in everyday life. They reported that learners conceptualise redox reactions using oxidation numbers and electron transfers combined, resulting in alternative conceptions. In addition, learners found it difficult to conceptualise that adding oxygen to substances (combustion) is also a redox reaction (Adu-Gyamfi et al., 2018).

Furthermore, Addam (2004) explains that learners' knowledge of science especially that of redox reactions, is often characterised by a lack of coherence. Thus, learners do not possess a well-founded basic framework regarding redox reactions into which newly acquired experiences can be integrated. This knowledge and experience can either help or hinder their understanding and sense-making of scientific concepts (Chiu, 2005).

Many researchers have investigated the misconceptions held by learners concerning learning redox reactions. These studies provide evidence that learners have misconceptions about the topic in the sense that:

- learners find the conception of the four models of oxidation-reduction reactions complex and confusing (Harrison & Treagust, 1998; Hunter et al., 2019; Loh & Subramaniam, 2018);
- learners have difficulty conceptualising oxidation-reduction reactions using electron transfer (De Jong et al., 1995; Österlund & Ekborg, 2009);
- learners struggle to identify reactants as reducing or oxidising agents (de Jong & Treagust, 2002);
- learners attributed incorrect oxidation numbers to various species and neglected oxidation numbers of charged species (Nyachwaya et al., 2011; Supasorn 2015);
- learners did not understand the concepts of oxidation, charges, or the transfer of electrons (Brandriet & Bretz, 2014);
- learners had trouble analysing redox equations (Noll & Hughes, 2018);
- learners conceptualised oxidation-reduction processes using ionic charge, meaning students cannot distinguish between oxidation number and ionic charge of species involved in reactions (Adu-Gyamfi & Ampiah, 2019);
- learners' misconceptions occur in all areas of basic concepts of redox reaction such as redox concept based on losing or gaining oxygen, increase and decrease in oxidation number and reducing agent and oxidising agent concept with various levels of misconception (Gan et al., 2018; Hunter et al., 2019; Masykuri et al., 2019);
- understanding redox reaction at the macro, micro and symbolic levels (Hunter et al., 2019; Kelly et al., 2017); and
- differentiating ions, atoms, ionic compounds and molecules in a redox reaction (Cole et al., 2019; Hunter et al. 2019; Kelly et al., 2017).

Namibian learners are not an exception. Instead, they also face similar challenges regarding redox reactions. Although many do not have problems with the oxygen model, most learners struggle with the hydrogen, electron and oxidation number models.

The Chemistry syllabus for Grades 10–11 requires that learners should study redox reactions under the theme ‘chemical reaction’ (MoE, 2019, p. 22) chemistry syllabus. Learners should be able to:

- define oxidation and reduction in terms of oxygen gain/loss and in terms of the transfer of electrons;
- identify redox reactions by changes in ionic charge; and
- identify reducing and oxidising agents (including in the context of the extraction of metals).

It could be seen from the Namibian chemistry syllabus that the concept of redox reactions is defined in terms of oxygen and electrons only. However, learners find it difficult to conceptualise the two models of redox reactions at the same time. Barke (2012) proposes that only one model of the electron transfer model of oxidation-reduction reactions should be taught at one particular time and that the oxygen model of learning oxidation-reduction reactions should be avoided. This is because learners prefer the oxygen transfer model and then conceptualise the redox reaction in terms of the oxygen transfer model. However, few redox reactions involve the transfer of oxygen (Barke, 2012). On the other hand, in their study that was conducted in Morocco, Mounchide et al. (2021) state that learning about redox centred on the electron transfer model, and this did not allow the learners to link electron transfer and the transfer of hydrogen and oxygen.

The four models of redox reactions seem to confuse learners. For this reason, Addam (2004) opines that all four models should be well explored, and learners should be helped to understand these reactions through developing activities that encourage the construction of knowledge. Arguably, learners will be able to demonstrate the circumstance/s under which each of these models can be helpful and enhance conceptual understanding of redox reactions.

The studies mentioned above suggest the importance of learners’ prior knowledge (Mavhunga & Rollnick, 2013) in learning and understanding redox reactions. Svinicki (1994) indicates that the goal of learning is to incorporate new information into existing memories. Roschelle (1995) adds that learning occurs mainly from what learners already know from previous experiences rather than from what is presented in the classroom. This helps learners assimilate new experiences easily because they incorporate the new information into their existing understanding. However, Tarkin and Uzuntiryaki-Kondakci (2017) report that learners had

difficulty applying their theoretical knowledge about oxidation-reduction concepts when interpreting daily life events.

Moreover, Österlund (2010) states that the taught message is either anchored to an existing, less established, or no, scheme. If the message is assimilated into an existing scheme, the scheme must accommodate the new information until equilibrium has been reached and learning takes place. Since different redox models are used in chemistry education, depending on the context, the learner's scheme must accommodate every new model introduced to reach equilibrium. It is easier for the learner to learn redox reactions in different contexts if the information about a new model can be anchored to a previously existing scheme; otherwise, there is the risk that learners only achieve rote learning.

Similarly, Supasorn (2015) contends that learners' pre-existing beliefs influence how they learn new scientific knowledge and play an essential role in subsequent learning. In addition, learners will build their cognitive structure by linking initial concepts obtained based on their personal experiences with scientific theories from their teachers (Masykuri et al., 2019).

Apart from the difficulties experienced by redox reaction concepts, inadequate teacher knowledge also hinders the effective mediation of learning of the topic. In this regard, Shulman (1986) proffers that teachers should possess SMK and PCK. Preparing this knowledge for teaching requires a teacher to transform the content in a way that will be comprehensible to the learners (Shulman, 1987). This entails that the knowledge has to be altered to fit the level of the learners and their learning abilities.

Rollnick et al. (2008), in their study conducted in South Africa, argue that teachers use simple and inadequate explanations in chemical equilibrium due to their limited SMK. The limited SMK negatively affects PCK and constrains learners' thorough understanding of the topic. Concurring, Lemma (2013), in his study on causes of learners' misconceptions, found that teachers were responsible for their learners' misconceptions in 90% of the cases examined.

Similarly, teachers perceive redox reactions as one of the most challenging topics to teach. One of the problems noted by the teachers is how to explain the transfer of electrons in such a way as to enable learners to adopt the electron model correctly (de Jong et al., 1995). Some teachers find teaching redox reactions challenging, making the lesson plans hard to prepare (Ahtee et al., 2002). In addition, other authors have discovered that the level of abstractness of redox

reactions has caused some teachers to leave it until the end of the school year. This is because they know there will be no time to work on the topic (Sanjuan et al., 2009).

In addition, teacher misconceptions may be attributed in part to inadequate chemistry content learnt at the college level. In this regard, Rollnick and Mavhunga (2014) assert that some of these difficulties have been attributed to shortcomings in initial teacher education. Also, this happens because the knowledge required to become a chemistry teacher varies significantly, depending on the time frame to complete the course and individual state requirements for certification (Schultz et al., 2017). Also, some researchers believe that misconceptions are derived from ineffective teaching strategies and limited curricular resources (Barke et al., 2009). Therefore, teachers should be aware of misconceptions in the different subtopics of chemistry so that instructional practices can change to address the cognitive needs of students (Al-Balushi et al., 2012).

Furthermore, de Jong et al. (1995) observed that chemistry teachers find it challenging to help learners understand the electron model as the concept for explaining and identifying redox reactions. In addition, Österlund and Ekborg (2009) posit that the electron model of illustrating and identifying redox reactions was taught in their study. However, very few learners could understand the concept to explain redox reactions.

Teachers should recognise and remediate the importance of learners' misconceptions and their barriers to learning (misconceptions) when discussed in class (Guzel & Adadan, 2013). However, Khourey-Bowers (2011) argues that learners enter the classroom with naive conceptions about chemistry and, even after direct instruction by their teacher, they sometimes leave with those same beliefs.

Also, research has revealed that learners have difficulties determining the correct oxidation number of atoms involved in a given reaction. For this reason, Adu-Gyamfi and Ampiah (2019) suggest that chemistry teachers should deploy the most appropriate pedagogical content knowledge. In this way, they can help high school learners conceptualise the concept of oxidation numbers and not confuse it with the ionic charges of particles involved in chemical equations.

As discussed in the previous section, understanding learners' difficulties and misconceptions about oxidation-reduction reactions can result in effective teaching. Various approaches to teaching have been reported to have affected learners' performance in redox reactions (Hunt et

al., 2010). However, regardless of how important redox reactions are in chemistry education, and the instructional strategies used in teaching, research findings have revealed that there are difficulties associated with teaching the concept (Adu-Gyamfi et al., 2018). In their study, Goes et al. (2020) inferred that the challenges related to teaching this content must be addressed in the teachers' training. They further argue that this will contribute to the PD of in-service and pre-service teachers. Investment in continuing teachers' education programmes on redox reactions could be a solution to accompany the development of hands-on experience-based PCK (Mamlok-Naaman et al., 2022).

Instructional strategies, learning to learn, and reflecting on the methods are equally crucial in constructivist lessons (Hendricks, 2010). In addition, a poor instructional approach could result in learners' alternative conceptions and other conceptual difficulties in redox reactions (Adu-Gyamfi et al., 2018). However, teachers could use these alternative conceptions to develop the best teaching and pedagogical strategies to rectify and reformulate the misconceptions that might arise (Osman & Sukor, 2013). As a result, teachers could provide learners with opportunities to develop a deep understanding of concepts, internalise the concepts, understand the nature of the development of knowledge and develop complex cognitive structures for connections to other bodies of knowledge.

The following section discusses how teachers elicit learners' prior everyday knowledge while teaching the topic of redox reactions.

### **2.3 Prior Knowledge**

For effective teaching to take place, Geddis et al. (1993) suggest that learners' prior knowledge should be considered. Agreeing, Roschelle (1995) accentuates that to help learners make the most of a new experience, educators need to understand how prior knowledge affects learning. It is recognised, however, that learners' previous knowledge of a particular concept can contribute positively or negatively to the learning process – negatively in the sense that they may come to the classroom with misconceptions.

The curriculum documents, such as the syllabus and textbooks, do not have enough examples of learners' everyday lives (Nanghonga, 2012). Hence, she recommended that the curriculum make provisions whereby teachers use learners' daily life experiences to introduce the lesson. Aung and Tepsuriwong (2017) emphasise that the success of the lesson depends on how it is

introduced. An introduction plays a significant role in the lesson presentation as it could determine to what extent learning will occur.

The Namibian curriculum prescribes that learning must proceed from what the learners already know (MoE, 2016). This is based on the understanding that learners do not come into the classroom as blank slates but rather with knowledge gained from earlier classes and also possess knowledge accumulated through daily life. Wessels (2012) emphasises that background knowledge plays a role in a learner's understanding of new concepts.

Hofstein and Mamlok-Naaman (2011) assert that when learners are able to see the relationship between their everyday lives and science, they are most likely to develop a positive attitude towards science. Similarly, some scholars such as Agunbiade et al. (2017) and Kuhlane (2011) agree that linking schoolwork to everyday life helps learners understand which promotes engagement as the learners begin to see how science can be used in real-life situations. When teachers link new information to the learners' prior knowledge, they are likely to activate their interest in and curiosity towards science.

There are numerous arguments in support of recognising and including learner contexts in teaching. Roschelle (1995) confirms that everyday experiences are the primary sources of learning rather than new material presented by the teachers. This shows that learning is impossible without integrating prior knowledge into learning because it can lead to conceptual change. Gee's (2012) study indicated that learners build on what they already know, and from that, they create, construct and reconstruct their knowledge as they learn from their past and incorporate their present experiences and perceptions of reality. As prior knowledge is transformed, new ways of knowing emerge. Even though prior knowledge can enhance understanding of different concepts, learners with strong beliefs need to be assisted in transforming such knowledge into meaningful scientific knowledge (Rennie, 2011).

Everyday contexts allow learners to take control of their own learning, which will lead to increasing active participation in class (Sedlacek & Sedova, 2017) and help them to determine what is to be learnt. Moreover, teachers should have proper and well-developed subject content knowledge in addition to cultural knowledge or everyday community knowledge (Kanime, 2015). Likewise, Oloruntegbe and Ikpe (2011) argue that conceptual achievement increases when learners' experiences are included in the classroom. They noted that learners' prior

knowledge helps them develop an in-depth understanding of concepts during the mediation of learning.

Furthermore, if the teacher lacks the knowledge, they will find it challenging to direct the learners to appropriate information (Kasanda et al., 2005). If the teacher does not have adequate knowledge of the subject, they are likely to mislead the learners instead of directing them, negatively impacting their conceptual understanding.

Moreover, teachers need to be explicit when they link everyday knowledge to what they are teaching in the classroom (Oloruntegbe & Ikpe, 2011). Making links between real life and the scientific knowledge learnt or being taught in the classroom is very important, as this helps to catch learners' interest in the topic resulting in them becoming more active during the lesson. If learners cannot link science to real-life experiences, they are likely to become discouraged from studying it (Oloruntegbe & Ikpe, 2011). Richardson (2011) adds that learners' conceptions are influenced by specific contexts and are affected by previous experiences they may have had.

There is a need for teachers to understand the communities and cultural practices of their learners. In that way, they will get to understand how to elicit and integrate their prior knowledge and use it to bridge the gap between science in their classrooms and what they are experiencing in their environments. Hence, this will allow learners to construct their own knowledge to promote meaningful learning.

On the other hand, Taylor (1999) criticises the use of prior knowledge during the mediation of learning. He maintains that everyday knowledge is unstructured and wide. As a result, it is difficult to develop an organised and in-depth understanding of scientific knowledge when incorporating individual experiences. Concurring, prior knowledge may help or hinder learning (David, 2017). For instance, learners' backgrounds are all different. Moreover, learners absorb a broad range of pre-existing knowledge, beliefs, skills, and attitudes, which could affect how they receive, understand and organise new knowledge (Diaz, 2017). Taylor (1999) deduces that the inclusion of everyday knowledge during learning mediation is at the cost of a logical and deep understanding of concepts. However, Taylor (1999) does mention that learners are confused when the curriculum structures do not include everyday contexts.

Some teachers do not always consider learners' prior knowledge in their classrooms. In a study conducted in Nigeria by Oloruntegbe and Ikpe (2011), it was found that there were a substantial number of chemistry learners who could not establish a bridge between school science and relevant phenomena in the home such as boiling, evaporation, condensation and filtration despite daily exposure to all of them.

## **2.4 Instructional Strategies**

In this section, I review some literature concerning teaching strategies to provide insight into how teachers should teach the topic of redox reactions to make it clearer to the learners. Teaching strategies have to do with the various methods used by a teacher to teach lessons. Similarly, Ayeni (2011) explains that teaching is a continuous process that involves bringing about desirable changes in learners by using appropriate methods.

Ogunmade (2005) presents that teaching involves the knowledge teachers possess on subject content and methods they use, knowledge of the curriculum and efficient control of classroom management as well as self-reflection to improve the learning outcomes of the learners. He further argues that teachers should plan, implement and assess students' engagement in meaningful science teaching. This also includes teaching methods which are active, relevant, and developmentally appropriate, build on learners' prior knowledge through the use of inquiry-oriented activities, support the social construction of accurate scientific knowledge, and develop a sense of classroom community. Concurring, Adunola (2011) indicates that in order to bring desirable changes in learners, teaching methods used by teachers should be best for the subject matter. Furthermore, Bharadwaj and Pal (2011) maintain that teaching methods work effectively when they suit the learners' needs since every learner interprets and responds to questions in a unique way.

According to the MoE (2008), teachers should be creative by using different teaching styles. Their teaching and learning materials should be relevant to practical activities in topics such as redox reactions. The policy further states that Physical Science is a subject through which the mysteries of the physical world around us are disclosed and basic laws are exposed. It should therefore be the target of every science teacher of any science subject to create an exciting, interesting and encouraging learning environment. Thus, how teachers organise their teaching and activities in classrooms will have an effect on the atmosphere in the classroom as well as learners' engagement with the activity.

The challenge in preparing learners for a knowledge-based society is to provide well-managed flexibility in the approach to teaching and learning, and provide learning experiences which motivate the learner to learn more (MoE, 2016, p. 32).

The curriculum further stresses that teaching strategies must be varied but flexible within well-structured sequences of lessons:

Learner-centred education does not mean that the teacher no longer has responsibility for seeing that learning takes place. It means that the teacher has to take on a wider repertoire of classroom roles ... A variety of teaching techniques need to be used, such as direct questioning, eliciting, explaining, demonstrating, challenging the learners' ideas, checking for understanding, helping and supporting, and providing opportunities for active practice and problem solving (MoE, 2016, p. 32).

Moreover, various teaching methods are available to teachers. A study conducted in South Africa on teaching methods and learners' academic performance revealed that the method of teacher-learner interaction was the most effective teaching method, followed by the learner-centred method while the teacher-centred approach was the least effective teaching method (Ganyaupfu, 2013). In the same vein, learners should be exposed to democratic learning where learners' roles are considered (McLeod, 2014).

Moreover, teachers should create a conducive learning environment in order to enhance the development of learners' learning experiences. Potenza (2002, p. 1) emphasises that being a mediator "requires you to be sensitive to the diverse needs of your learners, construct appropriate learning environments and demonstrate sound knowledge of your subject". Hence, teachers should increase their knowledge of various teaching strategies in order to keep learners engaged and motivated throughout the learning process. Concurring, Adu-Gyamfi et al. (2018) state that teachers could provide learners with opportunities to develop a deep understanding of concepts, internalise the concepts, understand the nature of the development of knowledge, and develop complex cognitive structures for connections to other bodies of knowledge.

In their study, Adu-Gyamfi et al. (2018) recommend that teachers be mindful of learners' characteristics in relation to the chemistry concepts and that they select and use appropriate instructional strategies for teaching. He further suggested that chemistry educators and researchers should design and develop TSPCK for teaching redox reactions in senior high schools.

Furthermore, another teaching strategy science teachers can use to teach redox reactions is practical work. I will now discuss practical work as one of the tools to enhance teaching and learning.

## **2.5 Use of Hands-on Practical Activities**

According to the Namibian NCB (MoE, 2016) understanding scientific processes, the nature of scientific knowledge and the ability to apply scientific thinking and skills are requirements in the natural sciences. The curriculum further prescribes a need to empower learners with the scientific knowledge, skills and attitudes to formulate hypotheses, investigate, observe, make deductions and understand the physical world rationally (Shinana et al., 2021).

Practical work in the kindergarten years is an effective strategy for science teaching and learning as it acts as groundwork for future science literacy (Pereire et al., 2020). Some kindergarten teachers have a solid scientific background to support the implementation of adequate and motivating scientific activities based on interactionist, hands-on and socio-constructivist approaches (Pereire et al., 2020).

Klainin (1995) explains that scientists believe that learners should learn by doing what scientists do and that is the way we can educate future leaders. Klainin (1995) further outlines that learning science is seen by science educators as likely to be more effective if the child is involved in practical learning and takes an active part in the learning process. In the same way, if learners do not experience science as a real-life practice, they are likely to experience difficulties in learning science and become disinclined to study it (Oloruntegbe & Ikpe, 2011). Asheela et al. (2021) state that practical activities should be ‘hands-on’, ‘mind-on’ and ‘words on’. These scholars believe that hands-on practical activities, if well structured, could enhance the understanding of scientific knowledge. Okoye (2013) agrees that doing practical science develops learners’ scientific knowledge and is most effective when the learning objectives are clear and relatively few for any given task. Similarly, Achimugu (2014) opines that science learning involves experimentation that uses hands-on and mind-on activities for better understanding. This is because experimental methods enable learners to verify theories, laws and principles surrounding scientific phenomena (Etiubon & Udoh, 2017).

A good question to ask before conducting practical activities is, “what do I expect the learners to learn after doing this practical activity that they could not learn at all, or not so effectively when they were merely told what happens?” (Woodley, 2009, p. 50). For this reason, it is

considered obligatory for science teachers to help learners to see the connection between the theoretical ideas taught and the phenomena seen in practical activities (Jokiranta, 2014).

Although science is regarded as a practical subject, Toplis and Allen (2012) posit that most of the time allocated for science lessons is spent on teaching theory. They thus suggest that hands-on practical activities should supplement the approach and provide elucidation and consolidation for the content learnt theoretically, as scientific knowledge cannot be effectively learnt merely from textbooks.

Hands-on practical activities are considered to have a key role in teaching scientific evidence; their value can only be relevant if the type of activity is selected with care and there is a clear purpose in mind (Asheela et al., 2021). Lastly, learners' involvement in hands-on practical activities encourages active participation in the learning process (Al-Naqbi & Tairab, 2005; Sedlacek & Sedova, 2017). This is the core principle of constructivism, which can lead to meaningful learning of scientific concepts like redox reactions.

Millar (2004) opines that learners naturally accept knowledge they discover through their efforts. This approach helps them remember that knowledge for longer and encourages them to be more independent. Moreover, Asheela et al. (2021) aver that hands-on practical activities encourage active participation, highlighting that it enables identification of critical concepts, conceptual understanding, education quality, and relevance and makes learners experience science first-hand. Learners find practical activities enjoyable as they engage their learning at different levels and challenge them mentally, compared with other teaching and learning approaches in science (Abrahams & Millar, 2008; Woodley, 2009). In light of these preceding arguments, Wilson (2013) considers the objectives of doing practical science to include motivation for learners, consolidation of theory, development of manipulative skills and understanding of data handling,

On the other hand, some researchers have questioned the effectiveness of practical work. There are also challenges associated with practical activities. Hodson (1990) took a critical look at practical work as practised in many schools and found that the laboratory activities relating to learning scientific concepts, understanding science, and acquiring a scientific attitude influence the learning outcomes. Abrahams and Millar (2008) state that although learners like practical work, they often do not learn the things they are expected to learn from a practical task. They further claim that after a few weeks of experimental work, most learners recall only specific

surface details of the task, and many cannot say what they learnt from it. Although this may be true, he further argues that practical work practised in many schools is ill-conceived, confusing, and unproductive and has not yet been successful in achieving the goal of science education because teachers use practical activities without thorough planning.

Furthermore, Abrahams and Millar (2008) state that, to make the practical work effective, teachers need to identify the objectives, clarify the task well, monitor learners' activities, and judge what learners have learnt. Consequently, if practical work is not effectively conducted, it becomes a game for the learners instead of a real "discovery of knowledge" (Millar, 2004, p. 40). One of the critical conclusions of Dillon's (2008) report was that learners "fail to perceive the conceptual and procedural understandings that were the teachers' intended goals for the laboratory activities. Learners spend too much time following 'recipes' and, consequently, practicing lower-level skills." (p. 8). Asheela et al. (2021) caution that teachers should not equate activity with learning. Those practical activities should not be of a recipe/cookbook approach but suggest that the approach of predict-explain-explore-observe-explain should be employed during practical activities (Shinana et al., 2021).

## **2.6 Use of Learning and Teaching Support Materials**

Learning and Teaching Support Materials (LTSMs) are prepared materials that structure and support learning and teaching. Teachers could prepare materials in schools and other educationalists in non-governmental organisations, publishers, and other institutions. In their preparation and presentation of lessons, many teachers do not make a clear difference between the role played by the learning programme (materials that frame the learning programme) and worksheets, games, puzzles, and activity manuals (materials that are supplementary and practical or 'hands-on' in support of the learning programme) (Czerniewicz et al., 2000).

Currently, there is interest in the role of textbooks, and other LTSMs, as effective learning systems. New policy papers from both UNESCO (2016) and the World Bank (Fredriksen & Brar, 2015) emphasise the potential of textbooks as cost-effective inputs for improving learning outcomes. However, there is mixed evidence for how books can contribute to such improved outcomes (Read & Bontoux, 2016). Significantly, there is little evidence that LTSMs use affects disadvantaged learners most. Kuecken and Valfort's (2013) findings revealed that the use of textbooks only positively impacts learners with higher socioeconomic status.

Teachers must consider various appropriate learning approaches and be aware of the differences in their learners' capabilities to construct knowledge. This will inform the teachers on how to teach effectively and use LTSMs in teaching and learning (Mdlungu, 2006). Mdlungu (2006) argues that science teachers should use LTSMs such as maps, wall charts, flip charts, flashcards, scientific models, kits and toys, audio tapes, and other technologies to support teaching and learning in science subjects.

In addition, teachers need to understand that the learning process has three interrelated components: teachers, learners, and teaching materials. The interactions of these three components form an integrated process entity, where there is a transfer of knowledge from the teacher to the learner (Anwar, 2015).

The Namibian curriculum outlined that teachers and learners should use LTSM to enable positive learning environments and improved learning outcomes. Thus, this document further outlines that teachers need to be creative in organising their LTSMs to enhance learning.

The learner-centred classroom is a text-rich and visually tactile-rich learning environment... Knowledge and knowledge production are shared through displays of learners' work, charts, posters, and easily accessible information sources. Effective learning and teaching are closely linked to the use of teaching and learning material (for example, books, posters, charts, and recycled waste materials) and ICTs (for example, computers and audio and visual media) in the classroom (MoE, 2016, p. 33).

The Namibian curriculum encourages teachers to select and develop the most appropriate resources and media to enhance learning. Also, the learners use various materials and media in their work.

Wider knowledge sources must be readily available in the school library, software, and the Internet. It may be necessary and sometimes preferable for teachers to improvise by finding teaching and learning material from easily available and inexpensive objects in the immediate environment, such as sticks, string, bottle tops, and cardboard (MoE, 2016, p. 33).

Lestari (2013) states that teaching material for teachers serves to direct the learning activities and the substance of competence that should be taught to learners. On the other hand, learners' teaching materials have a function as a guide in the learning process and are a substance of competence that should be studied and as an evaluation tool for learning achievement.

Furthermore, according to Haury and Rillero (1994), teachers who use LTSMs during science lessons seem to recognise learners' outcomes and use a learner-centred approach during their teaching. A learner-centred approach promotes learners' interest, analytical research, critical thinking, and enjoyment (Hesson & Shad, 2007). This would mean that the learners are more involved in the learning process. In addition, these authors state that research has confirmed many of the benefits of LTSMs with other unanticipated uses. Nyambe (2008) posits that LCE in post-apartheid Namibia embodies the slogan 'Education for All.'

Nyambe (2008) further argues that LCE should foster successful learning for all learners by taking into consideration their existing knowledge, skills and interests derived from their previous experiences in and out of school. Additionally, the MoE (2003) the improvement of the quality of learning in Namibian classrooms should be realised through the correct and continuous application of LCE. Teachers should have good knowledge about the subject they teach to guide learners on the science learning content (MoE, 20023).

Haury and Rillero (1994) stress that learners who are exposed to LTSMs during science lessons might remember the material better, feel a sense of completion when the task is concluded and be able to transmit that experience more easily to other learning situations. This only happens when the teacher uses LTSMs correctly while teaching concepts like redox reactions in the science classroom. The benefits of LTSMs in school revolve around those children who are less academically talented or are disinterested. The use of LTSMs tends to motivate these learners into participating and eventually absorbing information that I believe they would not get from the usual *show-me-tell-me* methods (teacher-centred method).

Most teachers have said that they use materials and tools during science teaching to attract their learners' attention and increase the effectiveness and efficiency of the science education teaching setting (Eksi, 2014). However, the review of the literature has suggested that the evidence regarding LTSMs often assumes that they are used in the same way in different classroom contexts. Instead, it can be argued that how LTSMs are used, is dependent upon a range of factors: the competence and confidence of the teacher; the pedagogical approach of

the teacher; whether teachers have been trained in the use of the LTSMs; and the classroom environment (Milligan et al., 2018). I now discuss the role of language during teaching and learning.

## **2.7 The Role of Language during Teaching and Learning**

Language is the most important thing for people as a means of communication. Brown and Hudson (1998) point out that language and society are intertwined, and it is impossible to separate one from the other: society cannot exist without language, and language cannot exist without society. Language helps people to show their perspective concerning something in a multitude of situations (Wahyuni, 2022).

Language is central to the mediation of learning. Vygotsky (1978) views language as the most crucial tool by which knowledge can be constructed. He explains that mental development occurs in two dimensions: social and psychological. Firstly, information is passed through language during social interactions, such as between the teacher and learners and between learners – more knowledgeable others. In this way, children develop their reasoning and problem-solving skills. Secondly, the psychological stage involves using language to assimilate cultural tools into thinking structures. This means that language enables external experiences to be organised into thoughts. In short, Vygotsky (1978) claims that language is the medium through which concepts are acquired in the human intellect.

Hodson and Hodson (1998) opine that “language creates the possibility of thought, organizes the thinking process and both reflects and shapes the human society in which it is used” (p. 36). They illustrate that language can also be an essential tool for learners, especially when working in small groups. Through group work, learners can use language to organise their work in the group and co-construct their knowledge (Hodson & Hodson, 1998). Similarly, Lemke (1990) raises the importance of ‘learner talk’ and urges teachers to use teaching strategies that encourage learners to ask questions instead of teachers asking them questions and learners merely responding. During collaborative group activities, especially in the laboratory, learners use language to interact and explain concepts to others in the group (Kanime, 2015).

Moreover, Hendricks (2003) points out that science is a discipline of communication, where language is central to the collaborative nature of scientific discourse. Oyoo (2005) echoes the same sentiment by indicating that science involves not only practical work but also the use of language, either written or in the form of teacher and learner talk. Learning is enhanced when

it occurs in contexts that are culturally, linguistically, and cognitively meaningful and relevant to students (Babaci-Wilhite, 2013; Lemke, 2001).

Even though language plays a critical role in the mediation of learning, it impacts the education of the learners because it can be a barrier to learning and lead to poor academic achievement. Learning barriers are associated with learners' inability to express their views, which usually lean towards difficulties with the language. Language barriers can have a long-term effect on learners' academic performance (Ellsworth, 2013).

As a matter of fact, without understanding the language used to mediate science it will not be easy to understand the terminology and concepts of science (Gudula, 2017). In many African countries, English is the medium of instruction which is often neither the learners' nor the teachers' home language. As a result, learning science in a second language limits comprehension of scientific concepts for high school learners (Kocakulah et al., 2005).

Language, rather than content, is the central learning problem in science classrooms (Brock-Utne, 2001). For instance, for learners whose language of instruction is a second language, there is an added burden of translating the language of instruction into their home language when being taught. The same learners are also faced with the challenge of thinking of answers in their language and then translating them into the language of instruction before answering them (Gudula, 2017). In the same way, language in chemistry makes learning difficult because the meanings of some words in chemistry are different from the language used in daily life (Herron, 1996). I now discuss the role of assessment for learning.

## **2.8 Assessment for Learning**

The quality of education is influenced by the quality of learning and the quality of assessment. Also, the quality of knowledge can be determined if the teacher evaluates learner learning outcomes (Mutmainah & Muchlis, 2022). Assessment is widely considered a powerful tool for enhancing learners' learning achievement when embedded in the teaching and learning process (Black & Wiliam, 2018; Ellegaard et al., 2018; Wiliam, 2011).

Assessment in learning plays a role in measuring learners' understanding during the learning process. It is also about learners assessing themselves, which may provide information for feedback to modify the teaching and learning activities in which they are engaged. Assessment, both summative and formative, is one of the strategies teachers can use during teaching.

Formative assessment is an assessment during the learning process where learners get feedback to improve their knowledge (Bahriah et al., 2021), while summative assessment assesses the achievement of learners' learning outcomes as a determination of graduation or grade promotion (Susilo et al., 2021).

Assessment for learning (AfL) has been defined as an assessment during the learning process that provides feedback used to determine the extent to which learners are learning to determine the best steps for further learning to improve learning outcomes (Rosana et al., 2020). Similarly, AfL is an assessment carried out in the learning process that involves finding and collecting evidence of decisions about what teachers and learners need to do next to improve the quality of learning (Nurkamto & Sarosa, 2020).

For this study, my focus was on how teachers mediate redox reactions. This study viewed AfL as a strategy that can be used to enhance learning and improve active engagement during a science lesson. With AfL the focus is on learning rather than grading.

Paulo (2014, p. 144) points out some of the challenges teachers face when they try to implement AfL:

Teachers view assessment for learning practices as different from the summative form of assessments. This perception results in low adoption of assessment for learning because summative assessment is prioritized in the national assessment systems; Lack of positive personal experience of assessment for learning among teachers is also a barrier; Assessments may be practically constrained by the shortage of time and large class size.

However, if implemented effectively, AfL is essential in teaching and learning. Various authors have revealed a significant positive impact on learners' performance when evaluation for education is done well, as well as how AfL informs both teachers and learners about the learning process and progress thereof (Black & William, 2002; Willis, 2009). Researchers such as Linqunti (2014) and Thomas (2012), speaking of the results of studies done outside Namibia, concur that AfL can improve the quality of teaching and learners' learning outcomes (Mutmainah & Muchlis, 2022). Ardiansyah and Diella (2018) emphasise that there is a positive influence of using AfL in providing feedback on learners' cognitive learning outcomes.

William (2011) believes that assessment has considerable potential to enhance learning under certain conditions. These include differences in teachers' understanding and experiences about AfL since they were trained at different institutions. For instance, a recent study conducted in Asia by Rashid and Jaidin (2014) revealed that some teachers experience AfL in the following ways:

- learners playing an active role in learning;
- making lesson objectives explicit and transparent to learners;
- a tool to continuously assess the learners' understanding during lessons, and
- a directive from the authority.

Gioka (2007) emphasises that giving feedback involves making time for learners to talk and teaching them to reflect on the quality of their responses. In their study, Rashid and Jaidin (2014) highlight that giving feedback is a central element of AfL as it helps show the learners where they are on their path to attaining the intended learning outcome. Feedback is important so that learners can build on their strengths and work on their weaknesses (Paulo, 2014).

Furthermore, assessment criteria and learning goals need to be expressed in a language that learners comprehend to understand their goals and the quality of work they are aiming for. Various authors have emphasised that teachers need to be clear about the intended learning goals so that learners can understand the goals they are pursuing and what they are aiming to achieve (see Gioka, 2007; Linqanti, 2014; Paulo, 2014; William, 2013). In a study by Gioka (2007), it was observed that most teachers presented the learning goals and objectives in the form of key scientific terms at the beginning of a new model or a lesson unit and summarised them at the end of the lesson, in the plenary session.

Kuze and Shumba (2011), in their study conducted in South Africa, highlighted some factors inhibiting formative assessment, such as the teacher's lack of knowledge, training and resources, and the willingness of learners. They further concluded that non-implementation of policy is attributed to a lack of knowledge and a lack of training. The assumption is that these teachers find it challenging to understand the policy, resulting in them failing to implement it in their classrooms as required.

Concurring, Uugwanga (2015) claims that while Namibian science teachers are fully aware of what is expected, some teachers are reluctant to change and implement what is stipulated in the Namibian curriculum. Some challenges are attributed to, among other things, a lack of subject content knowledge for some teachers, poor teaching strategies and a lack of teacher commitment.

Thomas (2012) found that Pakistan's teachers are pressured by their assessment system, resulting in them focusing on giving tests and examinations. They also tend to complete the prescribed syllabus but overlook assessing the students' knowledge and skills. In a study conducted in Tanzania, Ndalichako (2015) states that because of the pressure to reverse the declining trend in performance, teachers use assessment as a tool to prepare learners to pass examinations rather than as a tool to enhance teaching and learning. Sheehama (2017) in her study conducted in Namibia further explained that, despite some teachers being trained, they do not use the learner-centred approach or AfL strategies due to the pressure of examinations. Having a good document policy alone is insufficient for teachers; thus, there is a need to provide strategies to assist teachers in effectively implementing them.

Various scholars have made suggestions on how to assess learning effectively. Kandjeo-Marenga (2008) emphasises that teachers need to be equipped with instructional skills that will enable their learners to acquire higher-order thinking and practical skills. Agreeing, Thomas (2012) states that teacher education institutes should reconsider their curriculum, and schools should have more PD activities to encourage teachers to equip themselves with contemporary assessment approaches.

A study carried out in South Africa by Jane (2012) recommends that there is a need for systematic and continuous support to be given to teachers as they attempt to integrate AfL into their lessons. Concurring, Flórez and Sammons (2013) also suggest that teachers should attend well-developed and recognised PD programmes that help them develop a flexible and deep understanding of the approach. If teachers' PD is taken seriously, teachers might be equipped with the necessary skills and they will experience a change in views and attitudes towards AfL.

Since classroom assessment is one of the learning processes, good teaching is impossible without good assessment (Eckhout et al., 2005). The following section focuses on theoretical frameworks which informed my study.

## **2.9 Theoretical and Analytical Frameworks**

This study was informed by Shulman's (1986) PCK theory. Within this theory, the five components of TSPCK (Mavhunga & Rollnick, 2013) were used as an analytical framework.

### **2.9.1 Theoretical framework: Pedagogical content knowledge**

Shulman's (1986) PCK has to do with the successful ways of presenting topics, the most powerful analogies, illustrations, examples, explanations, and demonstrations. In other words, it is the way of representing and formulating the subject to make it understandable to others.

Shulman (1986) describes PCK as "the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the learners" (p. 15). Shulman based his argument on teachers' knowledge. His interest was more in how teachers transfer knowledge to learners. In particular, that is, the source of teachers' knowledge from which teachers draw to teach and how they present their lessons to learners. It is recognised, however, that teachers might have a strong understanding of subject content but fail to explain it effectively to the learners. Thus, teachers should possess PCK, "which goes beyond knowledge of subject per se to the dimension of subject matter knowledge for teaching" (Shulman, 1986, p. 9).

Furthermore, Shulman clearly states that to clear up certain misconceptions that learners may have about specific topics, teachers need to know the subject matter and have knowledge of the best strategies on how to mediate on learning particular topics to make it understandable to the learners and to clear up certain misconceptions learners may have about the topic. Mediation involves using tools such as language and materials to achieve the learning goal (Vygotsky, 1978). That is, teachers are expected to be mediators of learning for the learners to play an active role and learn effectively.

However, Kind (2009) defines PCK as a concept that represents the knowledge teachers use in the teaching process and a means of enhancing both teachers' professional status and the process of educating them. She posits that even though PCK is a helpful construct, finding out exactly what it comprises and then using this knowledge to support good practice in teacher education is not easy and is not clearly defined and classified. She added that PCK is not yet an explicit concept used by teachers.

Even though Shulman views PCK as a distinctive body of factual knowledge for teaching, some scholars criticise his theory that it is not yet backed up by theoretical evidence to support the existence of PCK (Bromme, 1995; Kind, 2009). Bromme (1995), for instance, argues that defining PCK as an instructional strategy and knowledge of learners' difficulties gives the impression that the influences of other factors on teaching and learning are not acknowledged. She found that, within PCK, mediating factors such as content presentation should be considered. In addition, she laments that PCK is regarded as difficult to measure because it is tacit and not easy to document (Kind, 2009).

The above explanations of PCK represent it as a teaching theory. Shulman's work on PCK led to scholars embarking on studies on the components and sources of PCK and how it is developed. It was concluded from these studies that there are several views regarding PCK, yet a standard view was needed for a common understanding of PCK. Therefore, to reach a standard agreement on PCK, a group of researchers met in 2012 in Colorado Springs and created an agreed model, referred to as the Teacher Professional Knowledge (Consensus PCK Model) (Gess-Newsome, 2015, p. 31). This is shown in Figure 2.2 below.

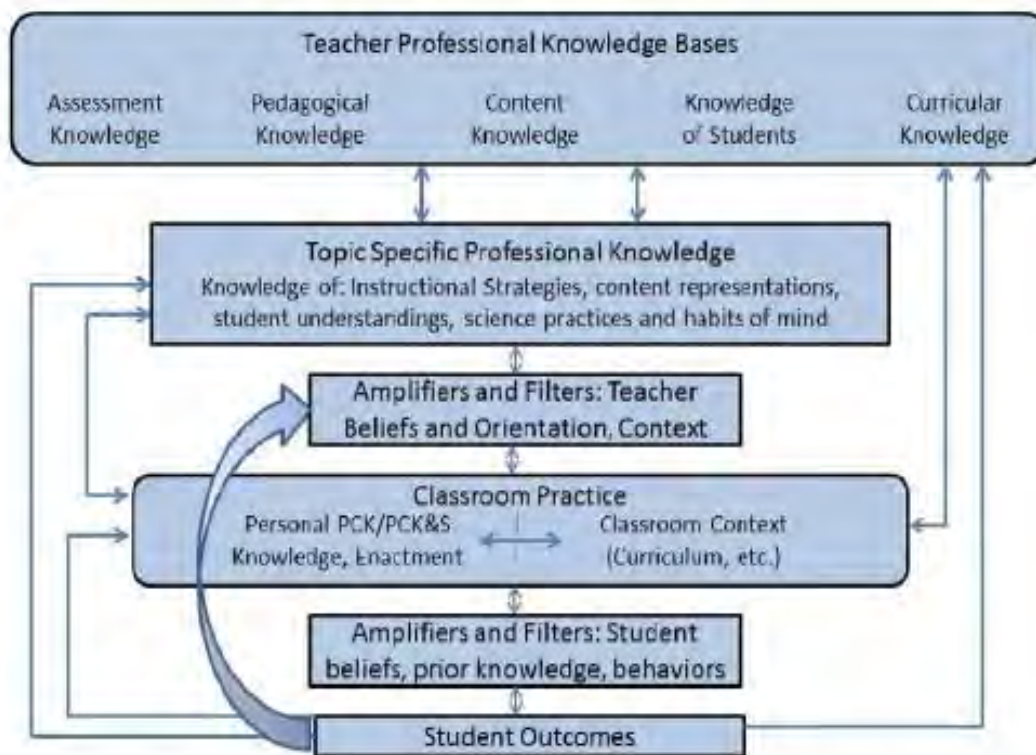
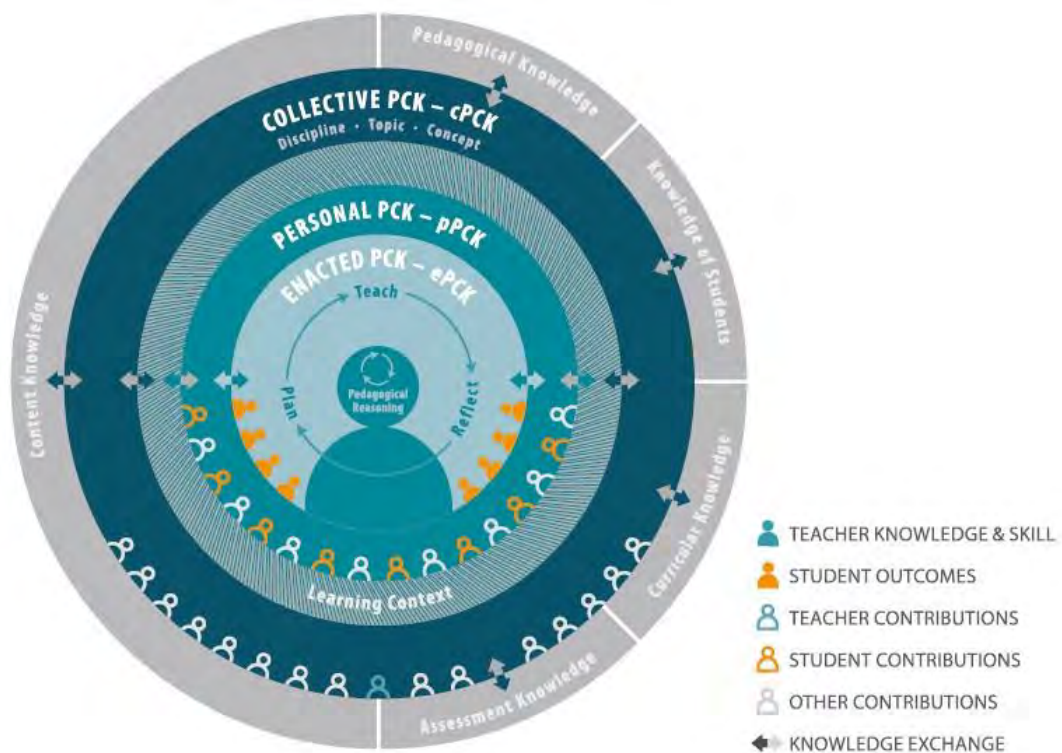


Figure 2.2: Consensus model of PCK from PCK Summit 2012 (Gess-Newsome, 2015, p. 31)

In this model, PCK is defined as a knowledge base used in planning for and delivering a topic in a specific classroom context and as a skill used in teaching (Gess-Newsome, 2015). The use of this model has limitations as it has minimal details about PCK. Some limitations pertain to the place for knowledge about instructional strategies, which is not accommodated in the model. Consequently, the model has been further refined to reflect the multi-dimensional nature of PCK (Carlson & Daehler, 2019). The new Refined Consensus Model of PCK introduces the three realms of PCK, namely, collective PCK, personal PCK and enacted PCK, shown in Figure 2.3 below (Carlson & Daehler, 2019).



**Figure 2.3: Refined Consensus Model of PCK (Carlson & Daehler, 2019, p. 83)**

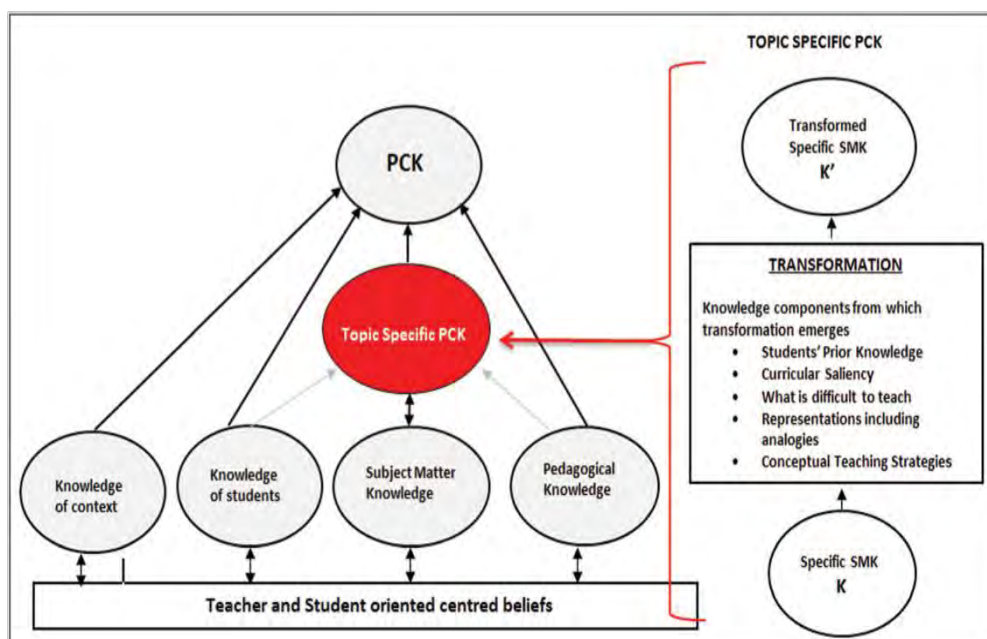
To Carlson and Daehler (2019), the collective PCK (cPCK) is the specialised knowledge held by multiple educators in a field. It is collective because it publishes information about PCK that is shared by the broader science education community. The teacher has learnt this knowledge in a course, for example, at a teachers' college. Hence, this knowledge is possessed by more than one person; it is no secret knowledge but rather knowledge that is public and held collectively. The teachers then take in cPCK, think and reason on it, to find a way to show their PCK. As a result, the teachers offer their PCK uniquely, making this their personal PCK. Thus, the personal PCK (pPCK) is the cumulative and dynamic pedagogical content knowledge and

skills of individual teachers that reflect these teachers' teaching and learning experiences, along with the contribution of others.

Lastly, there is the enactment of PCK (ePCK), the unique subset of knowledge that a teacher draws on to engage in pedagogical reasoning while planning, teaching, and reflecting on a lesson. According to Carlson and Daehler (2019), a teacher's pPCK is developed, shaped and refined over time through formal education, teaching experiences, and professional sharing. During the learning mediation, the teachers drew on their PCK to explain their ePCK on redox reactions, making their PCK explicit (Carlson & Daehler, 2019). In this study, the teachers showed their enacted PCK by explaining their PCK on redox reactions.

### **2.9.2 Analytical framework: Topic-Specific pedagogical content knowledge**

In their study, Mavhunga and Rollnick (2013) focused on exploring PCK at a topic level rather than a domain level because they attest that PCK has a topic-specific nature. These scholars attempted to improve the quality of PCK in pre-service teachers in a specified topic in science, reasoning that teachers cannot use the same teaching methods for different topics within a particular subject. They define TSPCK "as the knowledge that enables teachers to transform their understanding of content knowledge of a topic" (p. 3). They further stated that when a specific topic is taught, particular topic-specific components of PCK are considered. In the context of this study, which aimed at exploring how teachers mediate redox reactions, the study adapted the model for TSPCK (see Figure 2.4 below) used in Mavhunga and Rollnick (2013, p. 115) as an analytical framework. The model adapted the five content-specific components used by Geddis and Wood (1997). Mavhunga and Rollnick (2013) termed these components "content-specific components" that educators need, to enable the pedagogical transformation of content knowledge. They are found on the right side of Figure 2.4 below.



**Figure 2.4: A model of five components of TSPCK (Adapted from Mavhunga & Rollnick, 2013, p. 115)**

For teachers to transform their subject knowledge effectively into a meaningful form, they must consider other areas of PCK. On the right-hand side of the model (Figure 2.4) are the five knowledge components: learners' prior knowledge, curricular saliency, what is difficult to teach, representations including analogies, and conceptual teaching strategies (Mavhunga & Rollnick, 2013). All five components were used to analyse data gathered during the lesson observations and stimulated recall interviews. Below I discuss each component and how it was used in this study.

### ***2.9.2.1 Learners' prior knowledge***

This component emphasises a teacher's ability to elicit learners' prior learning experiences (Mavhunga & Rollnick, 2013). Teachers are required to have specialised skills and knowledge of dealing with learners' preconceptions and misconceptions (Mavhunga et al., 2016). In this study, the lesson observations and stimulated recall interviews captured qualitative data on how the Grade 11 chemistry teachers elicited and made use of their learners' prior knowledge. Furthermore, this component was used to analyse the teachers' perspectives, understanding and pedagogical insights in the mediation of redox reactions.

### ***2.9.2.2 Curriculum saliency***

To Mavhunga and Rollnick (2013), curriculum saliency is about teachers' awareness of major concepts of a topic which learners need to understand, without which, understanding such a topic would be difficult for learners. To promote awareness, Shinana (2019) and Magwentshu (2020) suggest that before a new topic is presented to the learners, the prerequisite concepts should be learnt or elicited. Sharing the same sentiments, Sibida (2018) states that when teaching the concept of chemical bonding, the correct sequencing of concepts is vital for learners' understanding of the topic. Also, this allows teachers to sequence these ideas to facilitate comprehension and understanding.

Moreover, teachers are also expected to allow the development of big ideas (Mavhunga & Rollnick, 2017). The limited SMK negatively affects their PCK which constrains learners' comprehension of this topic (Rollnick et al., 2008). In this study, curriculum saliency was used to analyse qualitative data about how teachers mediate the learning of redox reactions in their classrooms.

### ***2.9.2.3 What makes the topic easy or difficult to teach?***

The category of 'what is difficult to teach' describes teachers' awareness of the gatekeeping concepts within a topic that makes it difficult for learners to understand new concepts.

Masykuri et al. (2019) point out that learners' misconceptions occur in all areas of the basic concepts of a redox reaction, such as those based on losing or gaining oxygen, increasing and decreasing in oxidation numbers and reducing agent and oxidising agent concepts with various levels of misconception.

In the case of this study, learning redox reactions has been difficult for many learners as well as science teachers. This component was used to critically analyse the teachers' responses in the semi-structured interviews and stimulated recall interviews.

### ***2.9.2.4 Representations***

Representations involve presenting the subject matter to make it easier for learners to understand. These representations include illustrations, metaphors, demonstrations, experiments, analogies, simulations or models. Furthermore, Geddis et al. (1993) point out that alternative representations of subject matter, especially in abstract chemistry, play an indispensable role in transforming content knowledge. For instance, chemical symbols and

physical models can be used to demonstrate abstract concepts. Similarly, in their study, Tibell and Rundgren (2010) found that analogies are helpful as they help learners to visualise abstract concepts. Concurring, Shinana (2019) states that one advantage of representation is that learners can easily attach meaning to the content being taught.

Moreover, Sanger and Greenbowe (1997) emphasise that electrochemistry, which includes redox reactions, deals mainly with the macroscopic and submicroscopic levels. In addition, Jaber and BouJaoude (2012) further explain that failure to understand chemistry at multiple representation levels could lead to alternative conceptions and prevent learners from learning and appreciating chemistry. Similarly, Li and Arshad (2014) emphasise that if a teacher fails to explain chemistry concepts at multiple representation levels, it may lead to misconceptions.

#### ***2.9.2.5 Conceptual teaching strategies***

Lastly, the category of conceptual teaching strategy focuses on teaching strategies that teachers employ to help learners to acquire conceptual understanding. The choice of teaching strategy should consider the misconceptions if there are any, the educational purpose, as well as the learners.

Having said that, the data obtained from this study were 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 since 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.

### **2.10 Chapter Summary**

In this chapter, I explored the relevant literature on redox reactions that informed this study and related to the effective mediation of learning abstract topics requiring high cognitive demand. Some aspects of studies on teachers' perspectives towards teaching redox reactions were discussed. Various essential cultural tools such as language, learners' prior knowledge, assessments, instructional strategies, LTSM and hands-on practical activities that help enhance conceptual development and learners' conceptual understanding were also discussed. Lastly,

the theoretical and analytical frameworks which underpinned my study, namely, PCK and TSPCK, were also reviewed.

In the next chapter, I discuss the research methodology used in this study, which consists of the paradigm and a research design.

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## CHAPTER THREE: RESEARCH METHODOLOGY

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### 3.1 Introduction

In this study, I sought to understand how two selected Grade 11 Chemistry teachers mediated learning of redox reactions in their classrooms. The following research questions were addressed:

1. What enables and/or constrains Grade 11 Chemistry teachers when mediating learning of redox reactions?
2. How do Grade 11 Chemistry teachers mediate learning of redox reactions in the classroom?

In this chapter, I thus discuss the research methodology underpinning this study. Accordingly, Kivunja and Kuyini (2017, p. 28) view research methodology as “a broad term used to refer to the research design, methods, approaches and procedures used in an investigation that is well planned to find out something”. In other words, the methodology articulates the general plan of the investigation, including the assumptions and philosophical underpinnings guiding the research process.

I, therefore, start by discussing the research paradigm informing this study, followed by the research design. Under my research design, I discuss the research sampling, data-gathering techniques, data collection procedures and analysis processes, the validity, ethical issues or considerations undertaken in this research, and the limitations of the study. I complete this chapter with a chapter summary.

### **3.2 Research Paradigm**

The research paradigm has to do with how people make sense of and look at things to study and make conclusions or recommendations based on the findings. An interpretive paradigm informed this study. This paradigm was deemed appropriate for this study as it gave me a deeper understanding of how the teachers mediate redox reactions in their natural classroom contexts.

Essentially, the premise for an interpretivist paradigm is people's response to a given situation which largely depends on their past experiences and circumstances (Bertram & Christiansen, 2020). Put differently, the purpose of interpretation is to comprehend the meanings that inform human agency, behaviour, attitudes, beliefs and perceptions, which in turn influence the methods they choose (Bertram & Christiansen, 2020). The interpretive paradigm involves understanding human experiences from within the individual's intentional behaviours and actions (Cohen et al., 2018). Kivunja and Kuyini's (2017) review attempted to understand the subjective world of human experience and thus interpretivism was considered an appropriate paradigm because it focuses on individuals and their context.

Despite the above-mentioned strengths of interpretivism, I am mindful of the criticisms of the interpretive paradigm. Firstly, it is focused on providing descriptions of contexts as they are, without seeking to change or improve them. Secondly, the interpretive paradigm tends to ignore the influence of biological factors and social structures on individual action (Weaver & Olson, 2006). Thirdly, it is argued that the interpretive paradigm is more subjective than objective (Thanh & Thanh, 2015). Within the interpretive paradigm, a qualitative case study research design was adopted.

### **3.3 Research Design**

A research design is a plan of how the researcher will systematically collect and analyse the data needed to answer the research questions (Bertram & Christiansen, 2020). 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). There are specific criteria that a research design must meet. One criterion is the type of evidence or data that the researcher needs to collect to arrive at answers to the research question(s). Secondly, the

research design stipulates the methods the researcher should employ to gather the expected data. Also, the design indicates what the researcher does with the data once it has been collected, in other words, how the data analysis is to be carried out. In this study, I employed a qualitative case study research design.

### **3.3.1 Qualitative case study research design**

Qualitative research is characterised by the focus on the search for meaning and understanding (Merriam & Tisdell, 2016). That is, the interest of qualitative research lies in understanding how people interpret their experiences, how they construct their worlds and what meaning they attach to their experiences. By conducting this study, I was interested in finding out how chemistry teachers mediate learning of redox reactions. Creswell (2015) accentuates that a qualitative researcher collects data by observing participants and directly asking them open-ended questions. During the lesson observations, I observed how teachers interacted with their learners, learner-learner interactions, and how teachers explained the content to their learners. One advantage of a qualitative study is that the researcher can expand their understanding through non-verbal and verbal communication (Merriam & Tisdell, 2016). In this regard, I accessed information from the observations that I made and from the interviews that I conducted.

Yin (2014) defines a case study as an empirical inquiry that investigates a contemporary phenomenon in-depth and within its real-life context, especially when the boundaries between phenomenon and context may not be evident. Concurring, Merriam and Tisdell (2015) explain a case study as an intensive, holistic description and analysis of a single instance, phenomenon, or social unit. Several researchers highlight the importance of setting a case within its context. As a result, context is one main feature of a case study. In case studies, researchers tend to specifically concentrate on a particular topic to understand the problem in a natural setting (Leedy & Ormrod, 2014; Maree, 2012). A case study approach was appropriate for this study because I intended to obtain in-depth information on the teachers' views and experiences on teaching strategies they use when mediating redox reactions.

Yin (2014) argues that the central factor which qualifies a case study lies in 'delimiting the object' of the study. This delimiting is often referred to as a 'bounded system' or an 'integrated system'. Therefore, there must be boundedness or boundaries in the topic of research, whether it is bounded by a limited number of participants or a limited amount of time for observations; if there are no bounding factors, it is not a case. A case study can best understand complex

social activities such as the learning of practising teachers because it offers numerous variables that might be critical in understanding the social unit under investigation. This might, in return, result in a detailed description of the case.

Moreover, the participants of this case were bounded by the fact that they are permanent employees of the Department of Education in the Ohangwena and Oshana regions, who are qualified to teach chemistry to high school grades. These are factors which made them a bounded system. Thus, the case study was found to be the most relevant research design for this particular study. The benefits embedded in this research design included an opportunity to get deeper insights into the phenomenon through different data sources as mentioned above. Similarly, case studies interpret the world as consisting of multiple versions of reality or truth. In return, the research methodology and strategy used in this study were in harmony with each other and sought to provide deeper insights and more clarity on the phenomenon under study through different data sources.

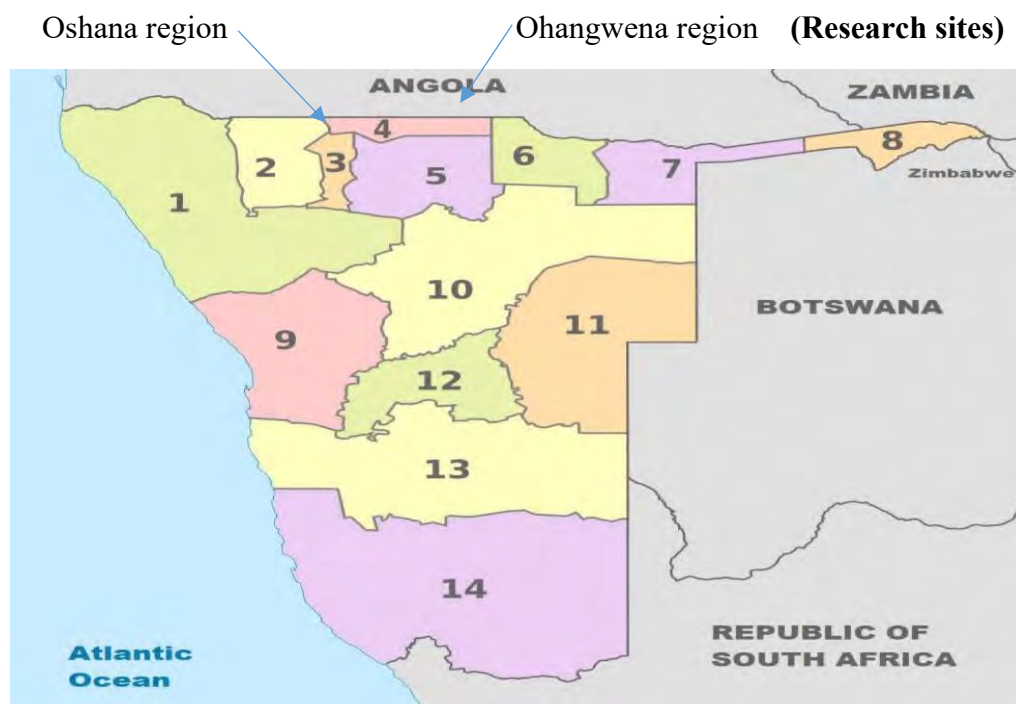
In qualitative research, “researchers are interested in understanding how people interpret their experiences, how they construct their worlds and what meaning they attribute to their experiences” (Merriam & Tisdell, 2016, p. 6). One advantage of qualitative research is that the researcher can expand their understanding through non-verbal and verbal communication (Merriam & Tisdell, 2016). The case in this study was the two Grade 11 chemistry teachers. The unit of analysis, in this case, was how they mediate learning of redox reactions in their classrooms. Three sources of data gathering were used: semi-structured interviews, lesson observations and stimulated recall interviews.

### **3.3.2 Research Site and Sampling**

Initially, this study was supposed to be conducted in the Erongo region in Namibia. However, due to COVID-19, the Erongo region was declared the epicentre of this pandemic and placed under a restricted lockdown. Hence, this caused me to change the region and the participants.

I thus decided to conduct the study in Otjozondjupa region schools in the Okahandja circuit because it was near the Erongo region where I was based. Therefore, I wrote a letter to the director seeking permission to conduct my study in that region. While waiting for his response, COVID-19 cases erupted in Okahandja, which also went under restricted lockdown. Therefore, I never received a reply from the director of the Otjozondjupa region and as a result my study never took place in the Okahandja circuit. This forced me again to look for another alternative.

I then applied to the regional directors of Oshana and Ohangwena, who promptly responded to my request, and I was given the green light. Therefore, the research was carried out in two government secondary schools in those regions with two teachers. Both schools offer chemistry in Grades 10 to 12, and they are about 25 kilometres away from one another. Because these two schools are close to each other, they were more convenient and accessible. Since I reside in Omaruru in the Erongo region, the distance between Omaruru and the two regions where the study was conducted is approximately 600 km. Figure one below shows the research site.



**Figure 3.1: Map of Namibian regions**

According to Bertram and Christiansen (2020), sampling is all about selecting the people, setting or behaviour that has to be included in the study. There are different types of sampling, namely random, purposive, stratified and convenience sampling (Bertram & Christiansen, 2020). In this study, I applied a combination of purposive and convenience sampling to identify participants.

Purposive sampling is about selecting a small unit of the population that can provide sufficient and valuable information that can answer the research question (Cohen et al., 2018). A purposive sample was used in which the teachers were selected based on the level of their

knowledge regarding the subject matter (Palinkas et al., 2015); that is, both participants had to be familiar with the Namibian Grade 11 Chemistry syllabus. Purposive sampling was also considered for this study to allow me to select participants who were likely to be available and willing to take part in this study and were also able to communicate their experiences and opinions in an articulate manner (Palinkas et al., 2015). Two experienced Grade 11 Chemistry teachers were approached and served with invitation letters to voluntarily participate in my study.

On the other hand, convenience sampling refers to when individuals are selected because they are easily accessible and available (Bertram & Christiansen, 2020; Creswell, 2012). The school where these teachers were teaching are approximately 25 kilometres apart and this was very convenient in terms of transport cost for me.

Two Grade 11 Chemistry teachers were involved in the study and the teachers were from different schools. The teachers were selected based on their experience. Both teachers have at least four years of experience teaching chemistry, which implies that they are fairly experienced in teaching redox reactions. I, therefore, considered them to be ‘more knowledgeable others’ as proposed by Vygotsky (1978). The study involved teaching two Grade 11 classes because the topic of redox reactions is covered in that grade.

### Teachers’ profiles

The teachers who participated in this study were from the Ohangwena and Oshana regions. Table 3.1 below provides a summary of the teachers’ biographical information. The codes used were T1 and T2 which represent teachers 1 and 2. Table 3.1 shows the teachers’ profiles.

**Table 3.1: The biographical information of the teachers**

	<b>Participant 1 (T1)</b>	<b>Participant 2 (T2)</b>
<b>Age</b>	30-35	30-35
<b>Gender</b>	Male	Male
<b>Home language</b>	Oshiwambo	Oshiwambo
<b>Qualifications</b>	Bachelor of Science & Diploma in Education	BEd (Honours)
<b>Teaching experience</b>	10 years	5 years

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 as they were just 25km apart. Thus, that made it easy for me to access the participants within a reasonable time and it made the research process convenient as noted by Bertram and Christiansen (2020). 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 (see Section 1.4). I also asked permission from all the participants, building rapport with them and involving them to interact fully in the research study.

### **3.3.3 Data-gathering methods**

The term ‘data’ refers to small pieces of information and the raw materials for the research project (Walliman, 2018). In a qualitative study like this, the data gathered should help gain more insights into and an understanding of the topic of interest (Gay et al., 2009). Three data-gathering techniques were used in this study: semi-structured interviews, lesson observations, and stimulated recall interviews to help me understand and make meaning of the issue at hand. Cohen et al. (2018) argue that the aim for using a variety of data generation techniques is known as triangulation which ensures trustworthiness, validity and reliability. Similarly, in their study, McMillan and Schumacher (2010) encourage using multiple data-gathering techniques to corroborate the data obtained. In the following section, I discuss each data-gathering method in detail and provide an insight into what transpired during that process.

#### ***3.3.3.1 Interviews***

According to Maree (2012), interviews are a type of communication where the interviewee responds to the questions posed by the interviewer to collect the intended data or information. Moreover, a research interview is a conversation with a structure and purpose, and its primary purpose is to obtain unique information (Brinkmann & Kvale, 2015; Merriam & Tisdell, 2016).

The researcher wants to discover what is “in and on someone else’s mind” (Patton, 2015, p. 426). Furthermore, Creswell (2012) points out that an interview is a valuable source of information because it provides data which might not be observable. Also, the interviewer can control the facts they gather by asking particular questions (Creswell, 2012). On the other hand, interviews have their disadvantages. Interviewees may not express themselves adequately, or they may only say what they think is expected of them (Creswell, 2012). I employed interviews

to gain perceptions of the teachers' views on teaching redox reactions issues, such as the challenges they face during the mediation of learning. This study used semi-structured and stimulated recall interviews (SRI). The interviews are explained in the next paragraph.

### **Semi-structured interviews**

Semi-structured interviews can be defined 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” (Maree, 2016, p. 92). It usually requires a participant to answer a set of pre-determined questions and it also allows for probing and clarifying answers from the interviewee (Maree, 2011).

Moreover, semi-structured interviews are usually conducted before observing the teachers' lessons (Denuga, 2019). The semi-structured interview guide was structured in such a way as to obtain the level of pedagogical and content knowledge of teachers on the redox reactions concepts (Denuga, 2019). I employed semi-structured interviews in my study because it helped me obtain in-depth information about the mediation of learning, understanding of the concept, and participants' views and experiences on teaching redox reactions in their classrooms. It also enabled the participants to discuss their interpretations of the world in which they live and to express how they regard situations from their points of view (Cohen et al., 2018). Further, I considered interviews suitable because I could judge the quality of the response and notice when a question had not been understood properly and could rephrase the question to obtain a better response (Walliman, 2018).

I conducted one-on-one semi-structured interviews with each of the two selected Grade 11 chemistry teachers. The two interviews were planned to be conducted on the same day. However, this did not materialise. I only managed to interview T2 as T1 had a busy schedule. So, I had to postpone the interview with T1. Since I had their mobile cell numbers, this made it easier for me to communicate with my participants. On the rescheduled day, I contacted T1 to confirm the interview time, and he agreed to 3:00 pm, soon after school. Thus, the interview was conducted and lasted for 13 minutes, which was more or less the same duration I had with teacher 2. The interviews were conducted in each of the participant's classrooms.

Open-ended questions, specific in their intent, were asked to allow for individual responses (McMillan & Schumacher, 2006). I used an interview schedule to direct me during each interview. I prepared six open-ended questions in advance (see Appendix F). Open-ended

questions allow interviewees to express their opinions without feeling restrained (Leedy & Ormrod, 2014).

Furthermore, I asked follow-up questions when I required more detailed responses. Semi-structured interviews allowed the respondents to give more detailed answers and the interviewer a chance to explore further through follow-up questions (Creswell, 2014). I also used probing to clarify what the interviewee said and ensure they had answered the question fully. Also, semi-structured interviews helped in clarifying some concepts and questions after observing teachers' lessons (Denuga, 2019).

The interviews, with the teachers' consent, were video and audio-taped. The main advantage of video and audio tapes is that they provide a detailed account of an interview, which can be replayed (Davies, 2007). In addition, I could play the audio tape numerous times when I transcribed the interview.

### **Stimulated recall interview**

After the lesson observations, I conducted SRIs. The SRI is a follow-up interview that seeks clarification through watching the video tape with the participants. The SRIs were conducted individually with each teacher while watching their videotaped lessons. The video recordings were replayed to the individual teachers to recall their reasoning during lessons (Nguyen et al., 2013). Concurring with Paulus (2017), the purpose of the SRI was to allow the teachers to give their thoughts on their decision-making processes for their teaching behaviour as they viewed their lessons. Also, the SRIs followed soon after the lesson for the participants to provide more insight into their choice of activities and the teaching method used (Paulus, 2017). Consequently, the SRI is an excellent PD tool whereby teachers can critically reflect and rectify some aspects to understand their teaching practice (Gazdag et al., 2016)

In this study, the SRIs were employed to give descriptive explanations for the events that occurred during the lessons taught. These could also help clarify some questions the researcher had after having watched and analysed the lessons. The semi-structured and SRI were recorded for in-depth analysis to give more explicit descriptions of the participants' narratives.

After every lesson presentation, together with the teacher, we reviewed the video and critically reflected on what happened during the lesson, as Cohen et al. (2018) and Nguyen et al. (2013) suggest. This time I also asked questions on areas requiring clarification. I chose this method

because it allowed me to identify and examine teachers' thoughts, decisions and reasons for acting (Reitano, 2005). This allowed me to ask for clarity on ambiguous issues during the observations. Essentially, this could potentially be a validation process rather than relying solely on member checking.

### ***3.3.3.2 Observations and field notes***

According to Cohen et al. (2018), observation is the technique researchers use to generate data in a social situation and this technique resonates with Shulman's (1986) PCK. In addition, through observation, one gathers open-ended first-hand information on a specific issue (Creswell, 2012). Thus, observation gave me primary information on what was happening in the classrooms regarding the mediation of learning redox reactions.

Observing the teachers generated data from an actual situation to answer research questions. Observation, as a qualitative data-generating method, was used to enable me to gain deeper insight into and understand the phenomenon being observed. Along the same line, Bertram and Christiansen (2020) and Cohen et al. (2018) affirm that observation means that the researcher sees for themselves the context and site of the research study and thus can gather information about a wide range of phenomena.

I observed four lessons (two lessons per teacher), which were all videotaped with the participants' permission, to gain insight into how these teachers mediate the learning of redox reactions. Two lessons were observed for each teacher because redox reaction is a concise topic with only three lesson objectives in the chemistry syllabus. I was able to observe interactions between the teachers and learners. During lesson observations of T1, there were two cameras in the classroom. My critical friend was operating the primary camera and I had the second one. I used a camera to capture and record information such as learners' written work. However, due to time constraints and the busy schedule of my critical friend, all lessons for T2 were video recorded by me. All of the lessons were then transcribed and analysed. As only one video camera was used for recording, I was able to make short field notes throughout the recording of the lessons of T2.

Moreover, during lesson observation, I paid special attention to how the teachers used the following activities: teaching and learning resources, eliciting learners' prior knowledge, teaching strategies to mediate the learning of redox reactions, and preparing learners' activities. I tried to reduce bias as a non-participant observer (Maxwell, 2008). A non-participant is not

involved in the activities of the participants. The observer sat in a strategic position to view and record the phenomenon under investigation (Chani, 2014; Chani et al., 2018).

Observations have some limitations. It is recognised that although observation helps a researcher to see first-hand what is happening in the classroom (Bertram & Christiansen, 2020), the challenge is that participants could do well or slacken off when they know that they are being observed – this is known as the Hawthorne Effect (Kawulich, 2005). Thus, the presence of the researcher may alter the behaviour of participants. As a result, the data collected gathered by this method can be biased (Kawulich, 2005). In this study, I observed two lessons for each teacher to mitigate against such an effect and collect accurate data (Borner, 2012). Creswell (2014) agrees that a better understanding of situations is gained by prolonged observation.

Leedy and Ormrod (2014) state that field notes may not sufficiently capture all the data as it unfolds, hence the need for recording. Video recording enables one to capture events as they occur (Merriam, 2009). It also captures other non-verbal communication such as movements and facial expressions (Merriam, 2009). Nevertheless, video recording can be intrusive; that is, it can disturb the natural flow of the events (Davies, 2007). My critical friend sat at the back of the classroom to minimise disruption while recording.

In summary, the observations aimed to determine how teachers mediate learning. The information obtained from the observations was compared with the interview data during my analysis. I then did SRIs with the teachers.

### **3.3.4 Data analysis**

Cohen et al. (2018) describe data analysis as a process that involves organising, accounting and explaining data. Qualitative data analysis is a systematic process of coding, categorising and interpreting data to provide explanations of a single phenomenon of interest (McMillan & Schumacher, 2010). In this study, I adopted a thematic approach to data analysis. I analysed my data inductively-deductively by organising it through coding, categorising it into categories and sub-categories and then forming themes and patterns (McMillan & Schumacher, 2010). Data coding helps the researcher to classify similar information (Cohen et al., 2018).

The data collected were analysed deductively and I used Shulman's (1987) PCK theory and adopted Mavhunga and Rollnick's (2013) TSPCK as lenses. I used TSPCK to scrutinise how to use learners' understanding, their common misconceptions and gatekeeping concepts in the

curriculum that make the topic difficult to understand and the teaching strategies used in the classroom.

Moreover, regarding using TSPCK as a lens to analyse data, learners' prior knowledge (including misconceptions), curriculum saliency, what makes the topic easy or challenging to teach, and representations (including analogies) and conceptual teaching strategies, these were the categories that the data were divided into and analysed. These key themes were featured in the interview questions and the lesson observations.

### **3.3.5 Validity and trustworthiness**

According to Cohen et al. (2018, p. 245), "validity is an important key to effective research". These scholars further state that it concerns the nature of what is valid and knowing if one has achieved an acceptable level of validity. Therefore, the research methods I selected in this study have been used to ensure validity through data triangulation. Cohen et al. (2018) explain that triangulation is using two or more data collection methods in a study that serves a specific purpose.

In this study, I used different methods to capture data from different perspectives to strengthen the validity of the study (Maree, 2016). The data were collected using semi-structured interviews, lesson observations and SRIs. For instance, during the lesson observation, my focus was on the five components of TSPCK during the mediation of learning redox reactions. This method alone could not give an actual reason or clear indication for any action that happened in the classroom. However, during the interview, the researcher can probe (Bertram & Christiansen, 2020). Therefore, to strengthen the validation process, the SRIs were used to follow up on aspects observed in the class.

Moreover, validity was enhanced when I presented my study at the Southern African Association for Research in Mathematics, Science and Technology Education Namibian Chapter colloquium on Thursday, 6 October 2022 that was held at NIED. The positive comments that I received from other scholars, lecturers and my supervisor who were present during my presentation helped me to shape my thesis, improved my ability and inner morale, and acknowledged the extra effort and results of my work. On the other hand, the negative comments helped me as a researcher to realise the gaps in this thesis and provided the opportunity for improvement. Furthermore, their contributions helped me recognise how valuable the thesis is. Also, their positive contributions helped me to recognise the sense of

being valued. Finally, validity was also enhanced through member checking (Hamilton & Corbett-Whittier, 2013). That is, research participants were provided with a copy of the transcript of the interviews and were given the opportunity to confirm or deny the research conclusion.

### **3.3.6 Ethical considerations**

Research ethics refers to all values that ought to inform the work of a researcher (Coe et al., 2017). These values can be epistemic (as this research aimed at producing knowledge, thus the researcher should be committed to the honesty of what was discovered and disseminate the knowledge), and practical – the goal of the research should serve the public or improve education (Coe et al., 2017). The following are considerations that I took into account when dealing with the ethics underlying the study (see Appendices A-F).

#### ***3.3.6.1 Respect and dignity***

I tried, by all means, to ensure good communication with my participants and establish trust so that participants would feel at ease working with me. I also asked permission for the data to be collected using recording devices during observations, and I took cognisance of the research time of the participants to ensure that I did not unnecessarily interfere with their work schedules. Throughout the study, research participants were guaranteed confidentiality. Only I had access to the participants' information (DePoy & Gitlin, 2011). Pseudonyms were used for schools (School 1 and School 2) as well as for the participants (T1 and T2) so that no information could be linked to the research participants.

Furthermore, negotiations took place with research participants so that they understood their power in the process. I explicitly indicated that lessons and interviews would be video and audio-taped for the purpose of the study only. Participants were urged to be truthful as the outcome of the study would not only benefit me but also other chemistry teachers and could inform important interventions for the advantage of others. Informed consent takes place when individuals decide whether they still want to participate in an investigation or study after being informed of all aspects that could impact their participation (Cohen et al., 2018). Participants were informed that participation was voluntary and withdrawal at any point would be allowed (see Appendix D).

### ***3.3.6.2 Transparency and honesty***

Before the research, I sought permission from the regional director in the Ohangwena and Oshana regions, the school principals of the identified schools and the teachers. This was done in writing, where the research aim was clearly explained. A copy of the approved letter from the director was then sent to the office of the inspector responsible for the schools where the research was conducted. The school principals authorised the research to be undertaken. I clearly explained the purpose of the study to the participants so they understood what they agreed to. On the consent letter, I created a reply slip at the bottom of the letter, which the participants signed to indicate that they were willing to participate.

### ***3.3.6.3 Accountability and responsibility***

In my research, my participants were chemistry teachers. Issues of power gradient were also discussed because I was a master's student, and the participants could have been reluctant to deny participation because of my seniority in terms of study. Also, I kept my position as a teacher like them so that I did not abuse my position as a researcher. I had to ensure that I created a friendly, communicative environment where participants were treated equally, regardless of their educational background. I established a good rapport with the participants regularly to run the research study effectively.

### ***3.3.6.4 Integrity and academic professionalism***

I ensured that I collected accurate data and avoided fabrication, manipulation of data or misreporting. I also acknowledged others' work by adhering to referencing where I cited other authors' work. Lastly, data were generated using reliable instruments.

## **3.4 Chapter Summary**

This chapter presented the research design and methodology used to collect and analyse the data. The chapter discussed the research design and orientation, research site, research participants and sampling. The research data-gathering tools such as interviews and observation were explored. This chapter also explained how the data were organised, gave an account of how the data were analysed and gave an understanding of how the data were validated. Trustworthiness and the ethical considerations of the study were highlighted.

In the next chapter, I will present the analysis and discussion of the qualitative data obtained.

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## CHAPTER FOUR: SEMI-STRUCTURED INTERVIEWS, LESSON OBSERVATIONS AND STIMULATED RECALL INTERVIEWS

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### 4.1 Introduction

The main goal of the research was to explore how Grade 11 Chemistry teachers mediate learning on the topic of redox reactions in a Namibian context. In the previous chapter, I presented the research methodology underpinning this study. In this chapter, I thus present, analyse and discuss the qualitative data generated from semi-structured interviews, lesson observations and SRIs. The qualitative data were analysed inductively-deductively and discussed in relation to the themes that emerged from the data. I first present the data from semi-structured interviews, followed by the data from the lesson observations and SRIs. These data sets were gathered from two Grade 11 Chemistry teachers from two secondary schools in the Oshana and Ohangwena regions to answer my research questions 1 and 2:

1. What enables and/or constrains Grade 11 Chemistry teachers when mediating learning of redox reactions?
2. How do Grade 11 Chemistry teachers mediate learning of redox reactions in the classroom?

### 4.2 Data Presentation and Discussion from Semi-structured Interviews

The purpose of semi-structured interviews was to find out teachers' experiences and pedagogical insights on the topic of redox reactions. The semi-structured interviews took place after school hours on the school premises to avoid interrupting the teachers' teaching time. To protect the participants' identities, I coded them as follows: T1 and T2, respectively (see Table 3.1). The semi-structured interviews were videotaped with the participants' permission and transcribed verbatim so that no information was lost. Good data management includes effective processes of consistency, collecting, recording and storing data securely (Peersman, 2014). I first colour-coded my data to develop categories or sub-themes (see Table 4.1). I then combined similar categories to form sub-themes and similar sub-themes to form the themes. Themes were then discussed in relation to theory and/or literature as highlighted in Table 4.1 below.

**Table 4.1: Themes that emerged from the teachers' interviews with relevant literature**

Themes and sub-themes	Literature / theory
<b>Theme 1: Teachers' perspectives and challenges regarding the mediation of redox reactions</b>	
<ul style="list-style-type: none"><li>Teachers' views, experiences and conceptions of teaching redox reactions</li><li>Challenges encountered when mediating redox reactions</li><li>How do teachers deal with those challenges?</li></ul>	Adu-Gyamfi and Ampiah (2019); Paik et al. (2017); Barke (2012)
<b>Theme 2: Teachers' experiences and pedagogical insights on redox reactions</b>	
<ul style="list-style-type: none"><li>Eliciting learners' prior knowledge and learner every day's prior knowledge</li></ul>	Kuhlane (2011); Roschelle (1995); Shulman (1986); Nyambe (2008); Agunbiade et al. (2017)
<b>Theme 3: Teachers' views on the use of learning support materials</b>	
<ul style="list-style-type: none"><li>Different LTSMs used by teachers</li></ul>	Haury and Rillero (1994); Mdlungu (2006)
<b>Theme 4: Assessment for learning</b>	
<ul style="list-style-type: none"><li>How teachers assess learners to help them understand</li></ul>	Eckhout et al. (2005); Sheehama (2017)

I now discuss each of these themes below.

#### **4.2.1 Teachers' perspectives and challenges regarding the mediation of redox reactions**

The semi-structured interviews revealed that although redox reactions is a short topic with only three specific objectives in the Grade 11 syllabus, these teachers experienced some challenges when teaching it. Even though both teachers were teaching in a government school located in a rural and an urban environment respectively, they seemed to share the same challenges because they were both teaching in an under-resourced school. For instance, T1 and T2 commented that respectively:

*I think in most cases, when we teach this topic it is one the most difficult topic to teach. Especially in terms of learners' understanding of the topic itself. Not necessary that the teachers do not understand but we still find it in some cases where teachers are also finding it challenging. Also we have I think problem in learners defining terms like oxidation number and them differentiating between oxidation number and ionic charge and also a problem in defining oxidation and reduction in terms of like electrons transfer and all that (T1).*

*But ... most learners tend to fail especially when it comes to the half-reactions. I think maybe they confuse the word oxidation and reduction. So they do not really master the definition of the two key words oxidation and reduction then they tend to mix up the two (T2).*

Regarding the above excerpts, it could be argued that the teachers seemed to understand the complexity of teaching and learning redox reactions. These teachers were also aware of the difficulties that their learners experienced with this topic of redox reactions. This finding seems to be consistent with other researchers who affirmed that learners did not understand the concept of oxidation, charge or the transfer of electrons (Brandriet & Bretz, 2014). Similarly, in a recent study conducted in Morocco, Mounchide et al. (2021) found that learners had great difficulty in differentiating between the terms 'oxidant' and 'reductant', and reduction and oxidation as well as in identifying the equations of redox reactions.

In addition, this also accords with my experience as a chemistry and physical science teacher for the past 14 years that learners usually have problems with defining oxidation and reduction, in terms of the four models of redox reactions thereby identifying reactants as oxidising and reducing agents and many more. Besides, the difficulties which were identified by the teachers are also in line with what is reported in the examiners' reports from 2013, 2015, 2017, 2020 and 2021 (MoE) that learners struggle to answer questions related to redox reactions (see Figure 1.1).

The topic of redox reactions is not only problematic for the learners but also challenging for the teacher: *"Not necessary that the teachers do not understand but we still find it in some cases where teachers are also finding it challenging"* (T1). This quote suggests that there is a need for continuing development of Chemistry teachers. This view is supported by Ahtee et al. (2002) who also stated that some teachers find it difficult to prepare lesson plans. This also

corresponds with the findings of Sanjuan et al. (2009) who stress that as teachers consider this topic difficult to teach, its abstractness has caused some teachers to leave it until the end of the school year, even knowing that there will be no time to work on the topic. In this regard, T2 reflected that *“it is a very short topic, from the look of things it looks very easy, yes, when you look at it and it has few objectives one would think it is very easy”*.

On a different note, it appeared that T1 and T2 differed in the expression of the challenges they encounter when mediating redox reactions in their classrooms. In response to the question that intended to explore the difficulties experienced by the teachers and how they deal with those challenges when teaching redox reactions, T2 seemed to be optimistic about this. For example, he indicated that:

*Challenges from my side when delivering, challenges are not really a lot from the side of a teacher because I find it as an easy topic maybe the challenges is coming from the side of the learners, they don't want to grasp the content within a short period of time.*

From this quote, it seemed that T2 shifts the blame to learners instead of pointing out why he finds this topic challenging to teach and this is not surprising. On the question as to how they deal with those challenges, T2 commented:

*We do have a system where we teachers have their own days in a week for instance Monday can be Mathematics and Physics that whole Monday during afternoon Physics and Maths teachers stays behind with the learners to either give them activities or teach them, but in most cases, we give them more activities after school.*

Similarly, T1 also acknowledged that there are challenges he encountered when teaching redox reactions and he commented that:

*Yes, as I mentioned previously that there are quite a lot of challenges, aah some of the learners may not be able really define oxidation and reduction in a given equation when oxygen is not involved is one of the challenges there. And also learners might not be able to explain transfer of electrons as to where they are coming from and where they are going. So, those are some of the challenges that we face when you are teaching redox reaction.*

T1 further explained that:

*When it comes to defining oxidation-reduction in terms of electrons transfer it is ... what I do is before we define oxidation in terms of oxygen loss and gain then we start with defining oxidation and reduction in terms of electrons transfer and in terms of increase of oxidation number and reduction in oxidation number. So, when they grasp that then it will be easier for them to grasp the concept of loss and gain of oxygen atoms.*

From the above extract, it seems that T1 understands the importance of sequencing new information, what Mavhunga and Rollnick (2013) refer to as curricular saliency. However, it seemed that the teacher starts with complex concepts such as electrons and then moves to the simple concept which is oxygen. This finding is similar to what Barke (2012) suggested in his study that only one model of oxidation-reduction reactions should be taught at one particular time. He further added that the oxygen model of learning oxidation-reduction should be avoided. This is because the oxygen transfer model appeals to learners such that they usually conceptualise the oxidation-reduction reactions in terms of the oxygen model.

#### **4.2.2 Teachers' pedagogical insights on redox reactions**

From the semi-structured interviews, both teachers indicated that before starting their mediation process, they expect learners to enter the classroom with prior knowledge or beliefs about redox reactions. Also, they seemed to believe that to teach new concepts successfully, a bridge must be created between learners' pre-existing understanding and new scientifically accurate ideas. In this regard, for instance, T2 commented that:

*Learners need to know about the transfer of electrons, that is like metals they lose electrons to form positive ions and non-metals they gain electrons to form negative ions. They also need to know types of reactions such as combustion reactions, decomposition reactions, yeah those are the type of reactions.*

T2 added: *“What we will be doing is chemical equations, so they need to know the reactants and products in chemical equations”*.

Based on these extracts, it could be argued that these teachers seemed to understand that learners do not come into the classroom empty but have the knowledge they acquired from the previous grades. This is in line with the findings of Gee's (2012) study, which also indicated that learners build on what they already know and create, construct and reconstruct their knowledge. Additionally, they learn from the past and incorporate their present experiences and perceptions of reality. Emphasising the value of using prior knowledge, Roschelle (1995) and Kuhlane (2011) indicate that if prior knowledge is used constructively, it can support and enhance learning. Teachers are, therefore, encouraged to elicit learners' prior knowledge when mediating the learning of redox reactions. However, Kuhlane (2011) refers to this as prior everyday knowledge which includes what learners come with from their home or their community. This aspect seems to be missing in Mavhunga and Rollnick's (2013) conceptualisation of learners' prior knowledge.

According to Aung and Tepsuriwong (2017), the success of the lesson depends on its introduction. Expressing how they introduce the lesson on redox reactions, T1 articulated that for learners to grasp the content of redox reactions well, it is crucial to introduce a lesson by:

*... giving examples that are more related to real-life things that they experience, things like how the battery works, things like extraction of metal because probably they have done it in their previous grade, chemical processes like in living organisms like photosynthesis.*

Based on these quotes, it could be argued that T1 seemed to understand that it is very important to give examples that learners can link to their everyday lives (Gwekwerere, 2016) and this has an affinity to what is reiterated by Kuhlane (2011) in her study. This is in line with the finding of Childs et al.'s (2015) study, which also indicated that there are different ways of relating everyday chemistry to the school curriculum and the learners' interests. These scholars further reiterated that materials used daily, or the chemistry of everyday objects or everyday activities that learners are involved in, should be considered. Moreover, the main factor for the missing perception of relevance is suggested to be the lack of connections between the teaching of science and the everyday life of students as well as society (Hofstein & Mamlok-Naaman, 2011).

In addition, T1 narrated that “*Giving everyday life examples such as how a battery works, extraction of metals, rusting and photosynthesis when mediating redox reactions, is important to learners because they feel that, yes, we are learning something that happens daily*”.

Furthermore, it could be deduced that T1 felt that understanding is an integral part of our learning. This promotes even more engagement because the learners build on their knowledge. Other scholars such as Hofstein and Mamlok-Naaman (2011) assert that when learners are able to see the relationship between their everyday lives and science, they are most likely to develop a positive attitude towards science. As a result, learners will begin to see science as relevant and valuable, indicating a positive attitude towards science. Agunbiade et al. (2017) and Kuhlman (2011) agree that linking schoolwork to everyday life helps learners understand and understanding promotes engagement as the learners begin to see how science can be used in real-life situations.

#### **4.2.3 Teachers’ views on the use of learning and teaching support materials**

In response to the question that intended to explore the LTSMs used by teachers when mediating redox reactions, the participants shared their experiences:

*I use a textbook as a learning material that is the basic one. It is unfortunate that we have to learn how to work with it and at the end of the day to make learners understand the little learning material available to us (T1).*

*I usually take my learners to the computer lab and show them some videos... I usually download a lesson or go on YouTube to download a video of a different person explaining the same content (T2).*

These extracts show that these teachers clearly understand the importance of using LTSM. However, due to the conditions of the school where they are teaching, T1 is somehow limited because his school is in a rural area; hence he uses textbooks only. Even though they have electricity in their school, they do not have a laboratory and just rely on textbooks and flipcharts. The learning process has three main interrelated components: teachers, learners and teaching materials. The interactions of these three components form an integrated process entity, where there is a transformation of knowledge from the teacher to the learner so that the student gains the learning experience (Anwar, 2015).

In addition, Lestari (2013) states that teaching materials for teachers direct the learning activities and the substance of competence that should be taught to learners. While for learners, teaching materials have a function as a guide in the learning process and are a substance of competence that should be studied and as an evaluation tool for learning achievement.

Moreover, teachers must consider various appropriate learning approaches and be aware of the differences in their learners' capabilities to construct knowledge. This will inform the teacher on how to teach effectively and use LTSMs (Mdlungu, 2006). Mdlungu proposes that science teachers should use LTSMs such as maps, wall charts, flip charts, flashcards, scientific models, kits and toys, audio tapes and other technologies to support teaching and learning in science subjects.

Furthermore, Haury and Rillero (1994) stress that learners using LTSMs during teaching science lessons could remember the material better, feel a sense of completion when the task was concluded and be able to transmit that experience more easily to other learning situations. This only happens when the teacher uses LTSMs correctly while teaching concepts like redox reactions in the science classroom. The benefits of the use of LTSMs in school revolve around those learners who are either not as academically 'talented' or have not shown 'interest' in school. This method tends to motivate these types of learners into participating and eventually absorbing information that I believe they would not get from 'normal' *show-me-tell-me* methods (lecture method). The importance of providing learners with direct experiences with materials, objects, and phenomena is supported by experience and understanding of how learning takes place.

#### **4.2.4 Assessment for learning**

In response to the questions that intended to explore the assessment methods used by teachers when teaching redox reactions, T1 indicated the following:

*You can make use of assignments, group work, working in pairs, and homework, you can make use of probes where they ... you give them a diagram and ask them which one do they agree with and explain Why? Just to make them work because it is a challenging topic. If you don't give them a lot of work or activities on it at the end of the day, you will rush through and they will not understand the topic at all.*

T2 added: “*I ... secondly giving them more question papers or oral questions like assessing them orally randomly and so on and give them homework and test and so on*”.

From the two excerpts above, it could be surmised that these teachers seemed to understand the purpose of assessment as well as various assessment tasks that can be given to learners. For instance, T1’s description is in line with Mutmainah and Muchlis (2022) who posit that the quality of knowledge can be determined if the teacher evaluates learners’ learning outcomes. Learners’ assessment is one of the teachers’ most important responsibilities because the quality of teaching in the classroom is closely associated with the quality of the applied assessment. Assessment is very crucial because it helps teachers to perceive, analyse and use data on learner performance to improve teaching.

### **4.3 Data Presentation and Discussion from Lesson Observations**

A total of four lessons were observed, two for each teacher at the beginning of the third term. All the lessons were video recorded with the permission of the participants and transcribed. As the lessons progressed, I made field notes of any aspect I found interesting. The data sets presented in the following section are thus from the videotapes and the field notes.

Lesson observations enabled me to gather data from the teachers’ natural settings, resulting in a first-hand account of phenomena. The lesson observations helped me experience how the teachers mediated the learning of redox reactions as opposed to what they say they do. During the lesson observations, I witnessed teacher-learner interactions, learner-learner interactions, and the teachers and subject content and the use of representation as highlighted by Mavhunga and Rollnick (2013).

As alluded to earlier, this study was informed by Shulman’s (1986) PCK theory. Within this theory, the five components of TSPCK (Mavhunga & Rollnick, 2013) were used as analytical lenses. These categories are identified as: learners’ prior knowledge (including misconceptions), curricular saliency, what makes a topic easy or difficult to understand, representations, including analogies and conceptual teaching strategies (Geddis, 1993; Geddis & Wood, 1997; Mavhunga & Rollnick, 2013).

These scholars explain these components as the understanding that provides the knowledge needed for Content Knowledge (CK) transformation in a particular topic. I now give a detailed account of each component beginning with learners’ prior knowledge.

### 4.3.1 Learners' prior knowledge

I observed that both teachers wrote the concept of redox on the chalkboard before they started with their actual mediation process and gave an overview of the topic of redox reactions. Both teachers explained that Redox is a concept that is made up of two words reduction and oxidation.



**Figure 4.1: A snapshot showing T1 and T2 breaking down redox reactions on the chalkboard**

The study revealed that both teachers demonstrated various ways to elicit learners' prior knowledge. However, each teacher approached the learners in their own way depending on their chosen teaching approach. I observed that T2 began his lesson by reading the lesson objectives for that specific lesson to his learners. He also tried to find out what learners already knew about the previous chemistry topics. On the other hand, T1 kept reminding his learners of what they had learnt about chemical reactions and ionic bonding.

The teacher-learner interactions were mainly in the form of dialogues in which the teacher asked leading questions. The teacher (T1) used questions as a way of scaffolding learners to make sense of concepts, clearing up misconceptions and soliciting learners' prior knowledge. In some instances, the learners would ask questions the teacher answered. Based on the vignettes below, both teachers wanted to find out if learners could still remember what they had learnt earlier about chemical reactions and ionic bonding on how electrons are transferred from metals to non-metals.

#### Box 4.1: Vignettes on learners' prior knowledge

*T1: When we did chemical reaction, we know that electrons are transferred from one component to another, or during ionic bonding when we did ionic bond, we know that metals lose electrons to form positive ions isn't it?*

*L: Yes*

*T1: So where are these electrons going in ionic bonding?*

*L: Non-metals*

*T1: So, non-metals gain electrons to form what ions?*

*L: Negative ions.*

*T1: Negative ions, good. So, at the same time, this is what is involved in redox reactions, Ok. Electrons are being transferred from one species to another. Now when electrons are being transferred, there is an increase in what we call the ionic charges or in the oxidation number of an element.*

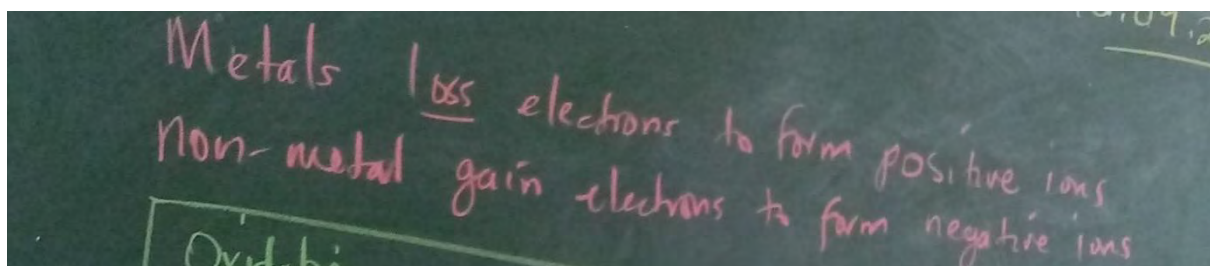
*T2: Who can remember what electron transfer is from a previous chemistry topic? Electron transfer? Anyone?*

*L: Metals transfer electrons.*

*T2: How is it going to transfer?*

*L: Metals lose electrons to non-metals*

*T2: Ok*



**Figure 4.2: Portrayal of part of T1's lesson on how metals and non-metals become ions**

With reference to the above vignettes and the snapshot above, this indicates that teachers brought in what the learners had already learnt in the previous topics with the hope of building on that as a starting point. This finding resonates with Roschelle (1995), who states that learning proceeds primarily from prior everyday knowledge and only secondarily from the presented materials. Learners only use the materials presented to them to enhance their understanding once their prior knowledge is elicited. If learners' prior everyday knowledge is neglected, the intended outcomes of the learning process cannot be realised.

In addition, this study's findings indicate that learners' prior knowledge is crucial in helping teachers build on learners' understanding to make sense of a conceptual topic like redox reactions. The prior everyday knowledge that learners come with should be used as a foundation for classroom science study. On the other hand, Mounchide et al. (2021) conclude that learners have not correctly assimilated the basic notions necessary to acquire the concept

of redox reactions. Therefore, the learners' lack of mastery of these basic notions leads to a poor understanding of the redox reactions. Hence, background knowledge plays a role in learners' understanding of new concepts (Wessels, 2012).

Moreover, with the use of prior everyday knowledge (Kuhlane, 2011), the duty of the teacher is to mediate learning. This implies that the teacher's role is not simply to transfer knowledge to learners but to create conditions in the classroom where learners can construct a different understanding of the concepts taught. Potenza (2002, p. 1) emphasises that being a mediator "requires you to be sensitive to the diverse needs of your learners, construct appropriate learning environments and demonstrate a sound knowledge of your subject". Concurring, teachers are expected to demonstrate such teaching and learning strategies to elicit learners' prior knowledge and help learners to generate new knowledge (MoE, 2016).

#### 4.3.2 Curricular saliency

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. My observation during the lesson presentations revealed that both teachers seemed to know the prerequisite concepts learners need to know before the topic is presented. However, the way they sequenced their presentation differed. Furthermore, their teaching started with an explanation of redox reactions. They explained what reduction and oxidation are, regarding oxygen gain/loss and the transfer of electrons. This reflects curricular saliency (Mavhunga & Rollnick, 2013) because it corresponds with what the syllabus requires learners to know.

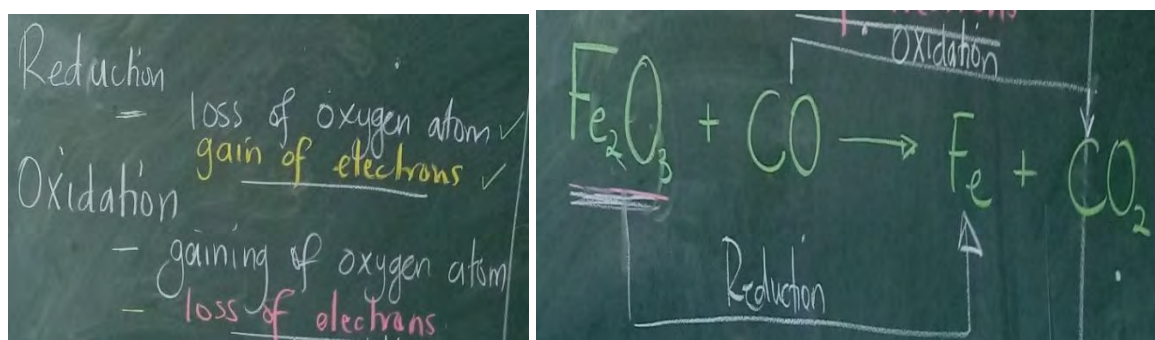


Figure 4.3: T1's chalkboard summary of oxidation and reduction

On the other hand, T2 gave various chemical reaction examples throughout his teaching. The snapshot below, Figure 4.4, shows how T2 used different chemical reactions to show his learners how oxygen atoms and electrons can be gained and lost. The central part of the lesson consisted of a significant amount of lecturing interspaced with oral and written questions.

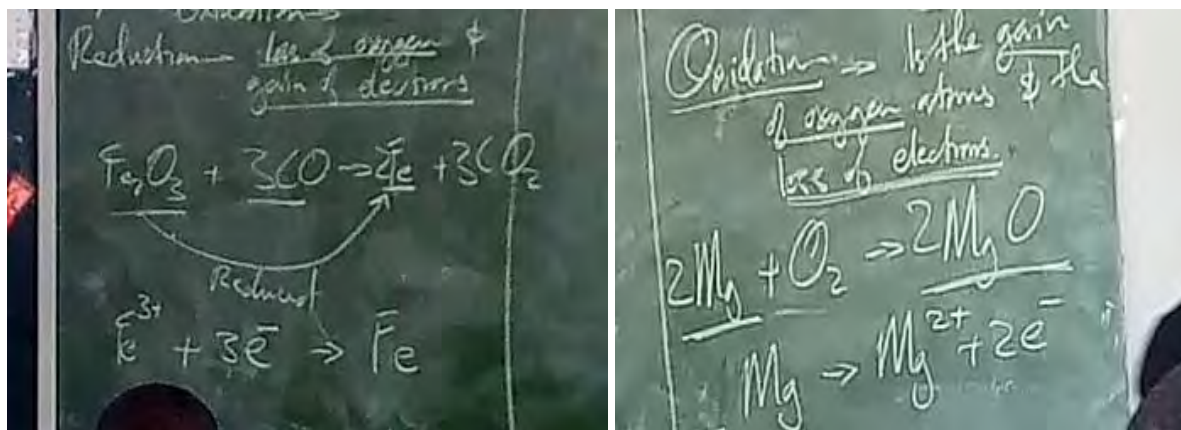


Figure 4.4: T2's chalkboard summary of oxidation and reduction

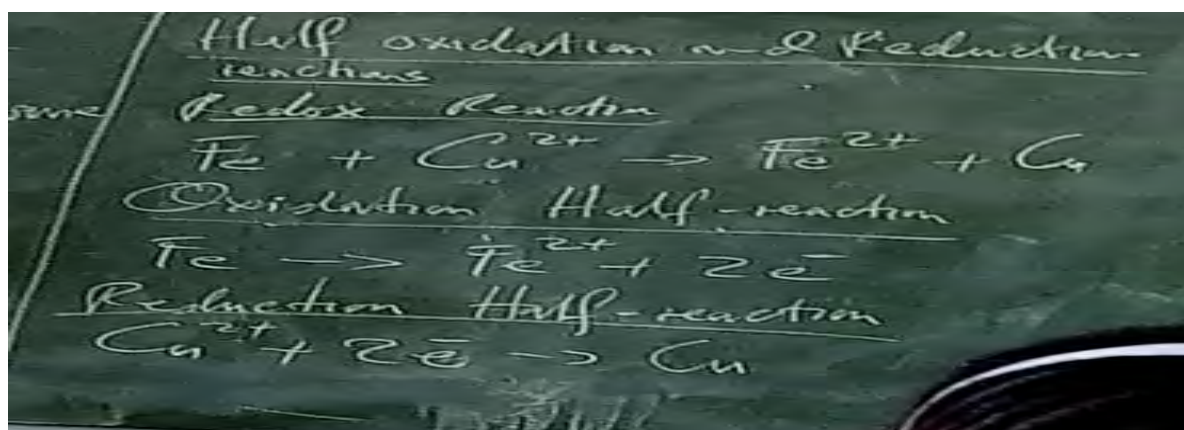
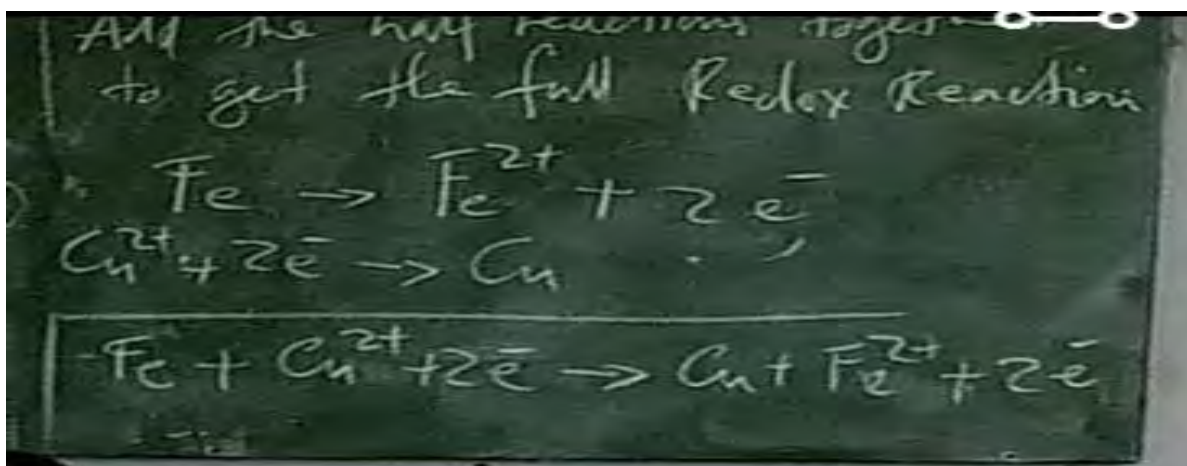


Figure 4.5: T2's chalkboard summary of oxidation half-reaction and reduction half-reaction



**Figure 4.6:** T2's chalkboard summary of a redox reaction from half-reactions

This demonstrated his sound SMK as he was able to explain concepts easily. Ball (1993) states that teachers cannot help learners learn things they themselves do not understand. Concurring, Rollnick et al. (2008) argue that limited SMK negatively affects teachers' PCK and constrains learners' comprehension of this topic.

It was also evident that the concept of redox reactions was well explained, and learners were able to respond to the questions posed by T2 and were actively involved. The snapshot below shows one piece of classwork that was given to learners during the lesson by T2.

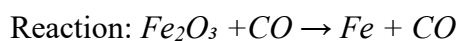


**Figure 4.7:** A snapshot showing T2 marking his learners' classwork

Since this component of curricular saliency demands that teachers identify the major concepts of the topic, this was evidenced by how the teachers identified the major ideas such as half-reaction, ionic charges and oxidation numbers during their presentation. The mention of the reduction half-reaction and oxidation half-reaction indicates that both teachers knew the concepts that make up the topic. This, too, is a manifestation of curriculum saliency. To Mavhunga and Rollnick (2013), knowledge of concepts that make up a topic, and the relationship between them, is fundamental for a teacher to choose the correct content to be taught to the learners. Sharing the same sentiment, Sibida (2018) also agrees that when teaching the concept of chemical bonding, the correct sequencing of concepts is key for learners' understanding of the topic.

#### 4.3.3 What makes a topic easy or difficult to understand

From my observation, it was revealed that the two teachers (T2 and T1) seemed to have some insights on what makes the topic of redox reactions challenging to understand. For instance, T1 used an example of the extraction of iron to illustrate the concept of redox reactions. He explained how haematite (iron oxide) reacts with carbon monoxide to produce iron and carbon dioxide.



#### Box 4.2: Vignette on reduction of haematite

*T1: Now from here you can tell that this  $Fe_2O_3$  change from  $Fe_2O_3 \rightarrow Fe$  there is a reduction in because this  $Fe_2O_3$  has lost oxygen, so this step is called reduction. You can tell from  $CO \rightarrow CO_2$ , this one is what step is that?*

*L: Oxidation*

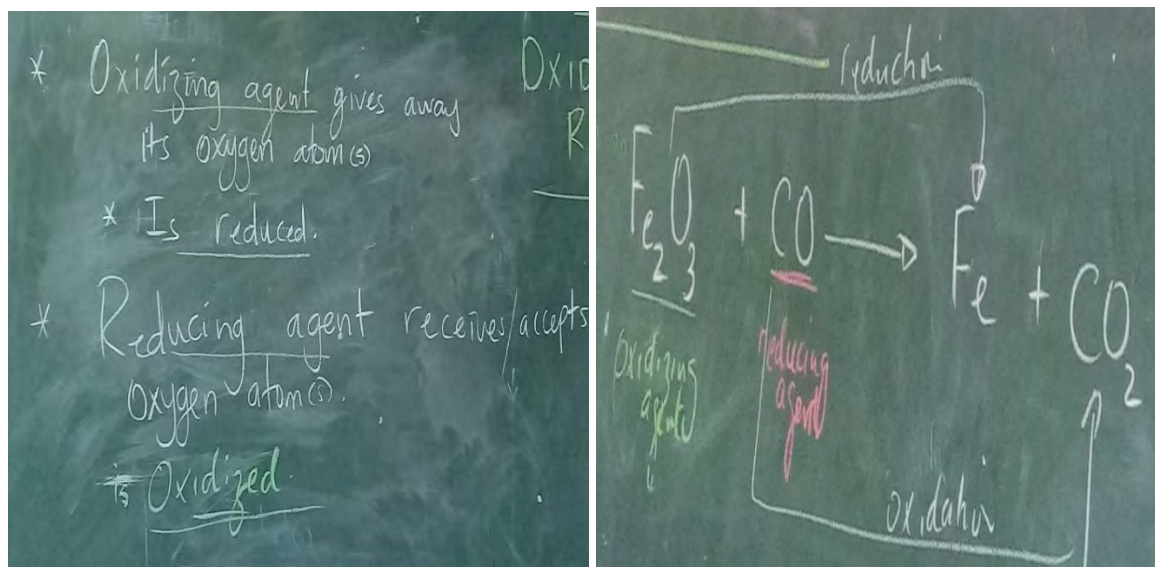
*T1: Oxidation step, Good. And why are we saying it is oxidation step?*

*L: Carbon monoxide has gained oxygen.*

*T1 further explained that: so, that is why we are saying we need to relate this type of reactions to things that happen on daily basis because the extraction of iron is very important and most of metals that we use are made up of iron.*

Although learners could identify the reduction and oxidation step in terms of oxygen in the vignette above, I observed that many learners failed to correctly show oxidation and reduction in terms of oxygen using the same chemical equation when they were given a task to complete

during the lesson. For instance, learners could not explain which species gained or lost oxygen. These findings corroborate what various authors discovered. They affirmed that learners did not understand the concept of oxidation, charges, or electron transfer (Brandriet & Bretz, 2014; Hunter et al., 2019; Loh et al., 2018)



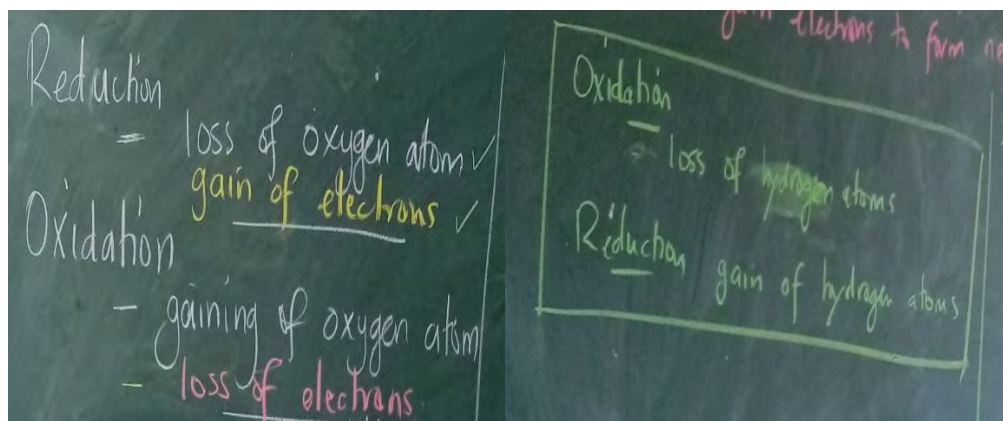
**Figure 4.8: T1's chalkboard summary of oxidising and reducing agents**

Even though learners were given this summary before the worksheet, it seems that learners had a problem identifying the oxidising and reducing agents. This tallies with the findings of the studies of Supasorn (2015) and Rosenthal and Sanger (2012) that say learners had difficulties identifying the species that reduce and oxidise. Schmidt and Volke (2003) showed that learners confused reducing or oxidising agents with reduction or oxidation. This could be because they had trouble analysing redox equations (Noll & Hughes, 2018). During the interview, for instance, T1 commented:

*Learners may not be able to really define oxidation and reduction in a given equation when oxygen is not involved and learners might not be able to explain the transfer of electrons as to where they are coming from and where they are going.*

From my observation, even though the definition of reduction and oxidation were written on a chalkboard as shown below, I noticed that T1's learners demonstrated little knowledge about the definition of reduction and oxidation in terms of oxygen, electrons and hydrogen. These

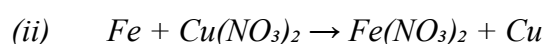
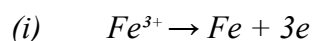
many definitions of the same terms seem to confuse learners, which is in agreement with Silverstein (2011).



**Figure 4.9: T1's definition of oxidation and reduction in terms of oxygen, electrons and hydrogen**

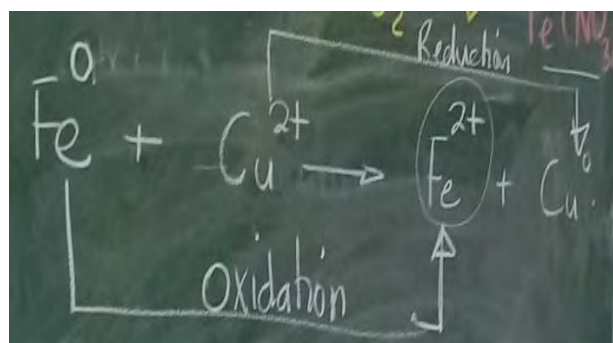
Also, although learners were aware of ionic bonding, T1 spent time trying to explain the definition of reduction and oxidation in terms of oxidation numbers. He explained that:

*Reduction can also be defined in terms of oxidation number. We can say reduction is a decrease in the oxidation number. In the example below, there is reduction in oxidation number because this ionic charges or oxidation number has decreased from 3 to 0.*



Referring to the above reaction in (i) and (ii), T1 explained:

*Iron has a charge of zero ( $Fe^0$ ) because it is an element and that copper ( $Cu^{2+}$ ) because it forms a compound therefore when iron comes here to form this compound it will have ( $Fe^{2+}$ ) and copper will have zero ( $Cu^0$ ).  $Fe^0 + Cu^{2+} \rightarrow Fe^{2+} + Cu^0$*



**Figure 4.10: Oxidation and reduction**

Nyachwaya et al. (2011) and Supasorn (2015) reported that learners attributed incorrect oxidation numbers to various species and neglected oxidation numbers of charged species. Essentially, according to Österlund and Ekborg (2009), there are four different models for the teaching and learning of oxidation-reduction reactions in the chemistry curriculum. For learners to understand redox reactions, they need to know that those four models can be defined in terms of reduction and oxidation.

**Table 4.2: Definition of oxidation and reduction in terms of the four models of redox reactions**

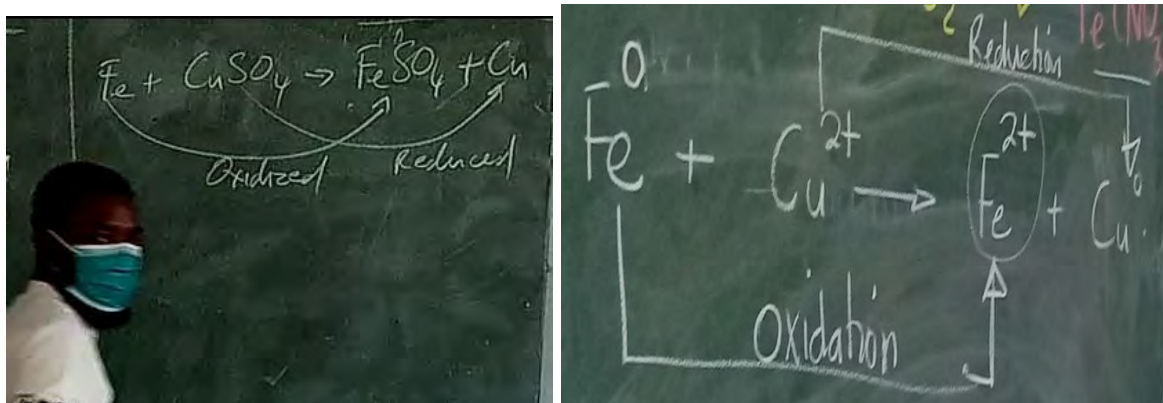
<b>Four different models of redox reactions</b>	<b>Definitions of oxidation and reduction in terms of those models</b>
1. Oxygen	Reduction is the loss of oxygen Oxidation is the gain of oxygen
2. Electron	Reduction is the gain of electrons Oxidation is the loss of electron
3. Hydrogen	Reduction is the gain of hydrogen Oxidation is the loss of hydrogen
4. Oxidation number	Reduction is a decrease in oxidation numbers Oxidation is an increase in oxidation numbers

#### **4.3.4 Representations including analogies**

This refers to how learning content should be presented so that it carries meaning to the learners. This can be achieved using teaching aids that teachers consider having the potential to support teaching content. These representations could be illustrations, metaphors, demonstrations, experiments, analogies, models or stimulations (Mavhunga & Rollnick, 2013; Mavhunga et al., 2016). Chemistry concepts or knowledge can be represented at multiple representation levels, also known as a chemistry triplet (Talanquer, 2011) or triplet relationship (Gilbert & Treagust, 2009). These multiple representation levels are the macroscopic, submicroscopic and symbolic levels (Johnstone, 1991).

The finding of this study revealed that both teachers used the chalkboard to write down either equations or summaries. I observed that no hands-on practical activities were carried out, as espoused by Asheela et al. (2021), and no models were used. Instead, teachers tended to focus more on the symbolic level followed by the submicroscopic level, and no macroscopic level was shown in their lesson presentation. Both teachers, in their presentations, showed that they are more knowledgeable at the symbolic and submicroscopic levels compared to macroscopic levels of representation. However, this finding differed from previous researchers. They stated

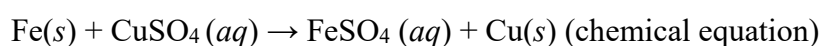
that the electrochemistry topic, which also includes redox reactions, deals mainly with macroscopic and submicroscopic levels (Garnett & Treagust, 1992; Sanger & Greenbowe, 1997). This showed that these teachers differed slightly from the standard teaching practice on this topic.

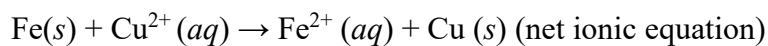


**Figure 4.11: Snapshots of the chemical equation by T2 and ionic equation by T1 of redox reactions (symbolic level)**

Regarding the snapshot above, I observed that teachers had ideas of the common equation they could use to represent all the multiple representation levels in redox reactions. The example that both teachers used is the reaction between iron and copper (II) sulfate solution. They could have carried out hands-on practical activities and learners could make some observations at the end of the reaction. The learners could have observed how, for example, a brown solid is deposited and how the blue solution changes to greenish. That observation represents the macroscopic level. However, no experiment was carried out. Hence, there was no evidence of the macroscopic level being taught during any of the lesson observations. Jaber and BouJaoude (2012) point out that failure to understand chemistry at multiple representation levels could lead to alternative conceptions and prevent students from learning and appreciating chemistry.

In addition, based on the snapshot above, for the learners to understand what happens in the reactions, teachers worked at the submicroscopic and symbolic levels, whereby they explained the type of particles that took part in the reaction. In the example of displacement reactions, for instance, an iron metal which is all in the elemental form will displace  $\text{Cu}^{2+}$  ions from its salt solution (submicroscopic). The reaction can be represented by the following chemical and ionic equation (symbolic).





If teachers do not explain what happens in the reaction by writing chemical and ionic equations, the learners will find it difficult to understand since the macroscopic level was omitted. In this regard, Li and Arshad (2014) posit that if a teacher fails to explain chemistry concepts at multiple representation levels, it may lead to misconceptions.

#### **4.3.5 Conceptual teaching strategies**

Conceptual teaching strategies refer to the teaching strategies derived from the considerations made from other components and exclude general teaching strategies (Mavhunga et al., 2016).

After independence in 1990, the Namibian education system went through major policy reform. This was a political initiative aimed at redressing the existing inequalities in access to education. As a way of guaranteeing social justice and democracy, an LCE approach was adopted (MoE, 1993). According to the MoE (1993), LCE is an educational approach that positions the learner at the centre of teaching. This implies that in lessons, the emphasis is on the learners' interests, active participation and prior knowledge. Concurring, Sedlacek and Sedova (2017) in their study revealed that participation patterns in the class are "context-dependent", for instance, participation was higher in open discussion than in teacher-led classroom talk (p. 106).

Moreover, LCE teaching methods such as group work are prescribed within this paradigm. This is in contrast to traditional teaching strategies such as the lecture method. In the same vein, the teacher is viewed as a learning facilitator rather than a mere transmitter of knowledge.

From my observation, I noted that the two teachers had different pedagogical knowledge when mediating learning of redox reactions. T2 tried to use the learner-centred approach to mediate the learning of redox reactions. For instance, he demonstrated the ability to teach learners and expose them to democratic learning, where learners' roles were considered (McLeod, 2014). I also noted that he demonstrated his role as a mediator in learning. For example, he engaged learners in activities, assisted learners, elicited learners' prior knowledge, and acknowledged learners' contributions. However, even though he tried various teaching methods, his intention of using a learner-centred approach was only partially fulfilled.

In contrast, I observed that in both classes there were no social interactions between learners (Vygotsky, 1978). This could be because of COVID-19 since learners were seated one metre apart. Similarly, in the semi-structured interview, T2 commented that “*now the time of COVID-19 it is very difficult to talk from learner to learner*”. On the other hand, I noted that T1’s teaching style was more of the lecture method. He dominated the whole lesson and learners only had to agree with what was presented to them. This finding is supported by Blonder and Maalok-Naaman (2019) who state that many teachers adhere to traditional instructional strategies.

T2’s method of teaching contradicts Nyambe’s view (2008) which argued that LCE is supposed to foster successful learning for all learners by taking their existing knowledge, skills, interests and understanding derived from their previous experiences in and out of school. However, Nyambe (2008) suggests that LCE has not been successfully implemented in Namibia. In the study, he found that teachers had difficulty interpreting and practicing the learner-centred approach. This was evident in the T1 class. Factors such as lack of skills and limited resources were some constraining factors. As a solution, Nyambe (2008) proposes a gradual transition from teacher-centred to learner-centred methods.

#### **4.4 Data Presentation and Discussion from Stimulated Recall Interviews**

The SRIs aimed to gain clarity using the TSPCK themes of the observations. Before the SRIs, 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 of the lessons I observed of each teacher. The videos allowed these teachers to remember the events as they happened during the lessons and to justify 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 SRIs were audio recorded and later transcribed verbatim (Cohen et al., 2018). The data presented here, therefore, is based on audio transcriptions.

#### 4.4.1 Stimulated recall interviews with T1

The first question I asked T1 was about the prior knowledge that learners get from previous lessons or grades and the community.

*For the learners in Grade 11, I can only say maybe they had acquired prior knowledge when they studied ionic equations when they did ionic bonding because it also involves the transfer of electrons but within the community, I don't think they have acquired such knowledge.*

T2 explained why it is necessary to refer learners to ionic bonding:

*I think is beneficial because it shows that whenever you are going to explain redox in terms of transfer of electrons then that has to do with the formation of ions where are the electrons coming from? Where are these electrons going? Meaning one of the species within the redox reaction one should lose those electrons and one should gain those electrons. So, for them to understand better I think it is necessary for one to take them back to ionic bonding, just to remind them that these two are closely related topics in terms of electron transfer.*

From the two excerpts above, it can be deduced that this teacher understands why prior knowledge is important to the learners. This resonates with Roschelle (1995), who states that learning should proceed from prior knowledge. That is why the Namibian curriculum (MoE, 2016) emphasises the use of everyday knowledge and experience.

It seems T1 expected learners to have prior knowledge of redox reactions, but strictly only from the previous topic they had covered, such as ionic bonding. From my experience as a chemistry teacher, there are many topics where learners can extract their prior knowledge not only from ionic bonding. Moreover, T1 failed to recognise the prior knowledge that learners might have from their community because he commented that there is a lack of everyday knowledge from the community.

The prior knowledge guides the teachers in identifying what pre-concepts learners have regarding the topic. This is significant as Mavhunga and Rollnick (2013) allude that considering the interrelated links between concepts and sequencing them enables learners to move towards what is required to be taught.

Furthermore, I asked T1 why he used the main equation in the extraction of iron to teach reduction and oxidation and he explained that: *“It is what is required by the syllabus to show redox reaction using examples of the extraction of metals, especially the extraction of iron, zinc, and copper, just to mention those”*.

As I looked at this response, T1 seemed to understand what the learners need to know about redox reactions. This shows that T1 understands and is able to interpret the syllabus. Doing so will help him pass the right information to the learners during the mediation. T1 further acknowledged that language seems to hinder teaching and learning and commented:

*One aspect is also the language barrier we have so many of our learners who do not understand the medium of instruction very well, interpret and cannot express themselves in the medium of instruction which is English ... sometimes you will be forced at some point to explain it in vernacular just for their sake.*

From the response above, we have to note that most learners in Namibia are taught in English, which is a second language to them and their teachers. Also, communication in the classroom is based on the meaning of thousands of words that are exchanged between teachers and learners. However, this communication will only be fruitful if the involved parties understand one another.

T1 further explained that sometimes he code-switches. Code-switching aims to connect comprehension gaps and make salient information and instructions understandable. As a researcher, I believe that allowing learners to express themselves in their home language gives them a space to share their prior knowledge that they cannot explain in English.

On how he reduces the challenges that are still faced by learners, T1 explained that: *“I give as much activity as I can and assess these learners... give a lot of work, whatever method one uses whether they use assignment, class activity or group tasks”*.

Even though T1 claimed to give enough activities for assessment to eliminate challenges that learners still face, it was evident that during the lesson presentation, only one activity was given to the learners. Activities given to learners were not adequate to aid the learners' understanding of the topic of redox reactions. This affects the learners' conceptual understanding. Also, however, he could not give work to the learners to do in groups; this was due to COVID-19 regulations.

On what seems to be easy to the learners, T1 commented, “*Defining oxidation and reduction in terms of oxygen, they don’t struggle at all*”. The oxygen model of redox reactions seems to be the only model the learners understand well. T1’s learners were given questions to define oxidation and reduction in terms of electrons, but most explained it in terms of oxygen. This seems to correspond with Barke (2012). He proposed that only one model of the electron transfer model of oxidation-reduction reactions should be taught at one time. He further added that the oxygen model of learning oxidation-reduction reactions should be avoided. This is because learners prefer the oxygen transfer model and then conceptualise the redox reaction in terms of the oxygen transfer model.

#### **4.4.2 Stimulated recall interviews with T2**

The first question I asked T2 was to explain why he introduced the topic of redox reactions by stating learning objectives. On this, he explained that “*before we start the lesson, learners need to know what we are going to talk about and what is expected of them from that certain lesson*”.

Looking at this response, it was clear that T2 understands the importance of using the syllabus when mediating learning. This means that a syllabus is the main tool for teachers when teaching. Moreover, by using a syllabus, a teacher can manage the class effectively, and the learners can achieve the goals in the learning process. Similarly, Wahyuni (2022) asserts that a syllabus is a great tool for teaching as the learners know what will be taught in the class. The content of the chemistry syllabus in the Namibian curriculum (MoE, 2019) is sequenced, where the syllabus presents the topic, the general objectives, specific objectives, and the practical activities, approaches, or demonstrations are also recommended. This helps the teacher to interpret the syllabus easily and pass the proper subject CK to the learners.

On prior knowledge, T2 commented that “*learners have a clue because we already did chemical reactions, the bonding part we have already discussed, and the formation of compound*”. Looking at this response, it was clear that T2 understands the links between topics, and he expects that learners must be able to remember prior knowledge from the previous chapters or topics. However, T2 acknowledged that he was not sure if learners have prior knowledge about redox reactions that they might have acquired from the community.

On what seems to be easy to the learners, T2 thought that the “*definition of oxidation and reduction in terms of oxygen and electrons*” was easy. This corroborates with the view of T1 because he explained that “*defining oxidation and reduction in terms of oxygen, they don’t*

*struggle at all*". From my own teaching experience, I can also attest that learners do not struggle with the definition of oxidation and reduction in terms of oxygen.

However, learners faced challenges, too; T2 explained that some *learners "have difficulties in writing chemical formulas, especially those that involve the polyatomic ions"*. T2 further explained that many have challenges in writing correct chemical formulas which have caused them to struggle with the *"writing of half equations because sometimes they will not even know where to start"*. As I listened to his response, it seemed that T2 understood that learners need to know how to write the chemical formula, which will help them write half-reactions. This corroborates Kambeyo's (2021) study which explains that failing to write the correct chemical formula will result in an incorrect chemical equation and being able to balance it.

#### **4.5 Chapter Summary**

In this chapter, I presented, analysed and discussed the data generated from semi-structured interviews, lesson observations, and SRIs. These data-generating methods were employed in order to answer research questions one and two in this study. I started this chapter with the datasets generated from the semi-structured interviews followed by lesson observations and ended with those generated from SRIs. In the next chapter, I present a summary of the findings, recommendations, and conclusion.

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## CHAPTER FIVE: SUMMARY OF FINDINGS, RECOMMENDATIONS, AND CONCLUSIONS

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### 5.1 Introduction

As alluded to earlier, the study was motivated by my personal experience as a chemistry and physical science teacher. I wanted to gain insights into how other experienced teachers help their learners make sense of the abstract topic of redox reactions. Firstly, it was necessary for me to understand these teachers' experiences and pedagogical insights on how they mediate learning on this topic. The study thus reported on how two selected chemistry teachers mediate the learning of the topic of redox reactions in the Namibian context, which is one of the perceived difficult topics in the NSSCO Chemistry syllabus.

This chapter presents a summary of my findings, followed by recommendations emerging from the findings. The limitations of the study are discussed and possible areas for future research. The chapter ends with the overall conclusion of the study.

### 5.2 Overview of the Study

My study aimed to explore how Grade 11 Chemistry teachers mediate learning on the topic of redox reactions. Data were gathered using semi-structured interviews, lesson observations, and SRIs. A qualitative approach was used to achieve this goal, informed by Shulman's (1986) PCK theory and Mavhunga and Rollnick's (2013) TSPCK theory. An inductive-deductive approach was used to analyse the qualitative data. The analysed data were then discussed in relation to the following research questions:

1. What enables and/or constrains Grade 11 Chemistry teachers when mediating learning of redox reactions?
2. How do Grade 11 Chemistry teachers mediate learning of redox reactions in their classrooms?

To answer these research questions, I used various data-gathering techniques. For research question 1, semi-structured interviews were used to determine teachers' experiences, understanding and pedagogical insights on the mediation of redox reactions. Semi-structured interviews allowed me to get in-depth data from the two teachers who participated in this study. For research question 2, I used lesson observations and SRIs to gather data. The data generated from research questions 1 and 2 were presented, analysed and discussed in Chapter Four of this thesis. I now discuss the summary of my findings in relation to my two research questions below.

### **5.3 Summary of Findings**

Shulman (1987) identifies PCK as one of the seven knowledge categories teachers must possess to mediate learning. He explains that PCK describes how teachers present and formulate subject content to make it understandable. That is, how concepts are presented during lessons to suit the abilities and interests of learners. During the first phase, information was gathered on what enables or constrains teachers when mediating redox reactions.

#### **5.3.1 What enables and/or constrains Grade 11 Chemistry teachers when mediating learning of redox reactions?**

The study revealed that some teachers still use the traditional lecturing method, which is more one-way communication, so this does not enhance learners' understanding of the concepts. Teachers should develop a strong SCK and PCK to have the best strategies in place to mediate learning on redox reactions. This is in line with Shulman (1986), who asserts that strong PCK would empower teachers to make a subject comprehensible to their learners in how they present the content.

Further, teachers revealed that there are some challenges which they normally experience which hinder the understanding of the learners. The prerequisite knowledge learners are expected to have before learning the topic is limited, while teachers also had limited knowledge of integrating prior knowledge. Skamp (2009) asserts that, especially in subjects demanding higher cognitive understanding, the teacher should identify relevant prior knowledge for teaching this specific topic. Similarly, Rennie (2011) raises a concern that teachers will have to shape their CK to bring real-life experiences into the science classroom for effective mediation of learning.

Furthermore, the medium of instruction in Namibian schools is English. However, this is not the home language for most teachers and learners. The language barrier is one of the constraining factors that can affect learners' long-term academic performance (Elsworth, 2013). The participants made successful use of simple language through explanations. However, they did not give the learners sufficient language support by allowing for extended learner talk; this could be due to COVID-19 regulations. Lemke (2001) suggests that learners' language proficiency develops as they converse during the lesson. Learners experience problems associated with language because of this omission. Thus, the language of teaching and language had a negative impact on learners' understanding of chemistry concepts (Kibirige & Masemola, 2014).

The study further indicates that the two teachers gave a limited number of activities to aid the learners' understanding of the topic of redox reactions. Consequently, the observations showed that both teachers did not conduct hands-on experiments with learners in the classroom as science is supposed to be taught. In this research, I have learnt that the use of practical work during the teaching of redox reactions depends on the science teacher and how these practicals are designed. This affects the learners' conceptual understanding of scientific concepts like redox reactions.

Additionally, there were challenges that learners faced that hinder teachers from mediating redox reactions effectively. Learners found it difficult to define oxidation and reduction in a given equation when oxygen is not involved. Some learners had problems explaining the transfer of electrons and could not explain where electrons were going and coming from. Other learners struggled with oxidising and reducing agents and explaining which ones are oxidised and which are reduced. Lastly, others were challenged by the increase and decrease in oxidation number. These challenges are consistent with the findings by authors such as Gan et al. (2018), Hunter et al. (2019) and Masykuri et al. (2019). T1 admitted that this topic is a challenge to both learners and teachers.

### **5.3.2 How do Grade 11 Chemistry teachers mediate learning of redox reactions in their classrooms?**

During lesson observations, it was revealed that the two teachers have sufficient PCK on the topic of redox reactions. The PCK guided teachers to mediate suitable content for the learners. The knowledge areas of TSPCK which emerged from observations are learners' prior knowledge, curricular saliency, what is difficult to understand, representations, and conceptual teaching strategies. These TSPCK areas are explained below.

#### ***5.3.2.1 Learners' prior knowledge***

From the observations, it emerged that these teachers used similar means of eliciting learners' prior knowledge through questions and answers and referring to what learners previously learnt in ionic bonding and chemical reactions. They probed learners through questions to find out their level of understanding of the topic. In the semi-structured interviews, teachers stated the preliminary concepts that they expected their learners to know. However, it was evident from the lesson presentations that teachers omitted some possible preconceptions that learners needed regarding redox reactions. Instead, the teachers assumed that learners would recall what was taught from the previous grades or topics about ionic bonding and chemical reactions. It turned out that the prior knowledge of redox reactions that learners were supposed to have, was limited. The teachers ended up giving learners leading questions. It was also observed that prior knowledge integration was limited throughout the lessons. Yet, Roschelle (1995) avers that prior knowledge should be integrated during teaching and learning for meaningful learning to take place.

#### ***5.3.2.2 Curricular saliency***

The lesson observations revealed that the two teachers made efforts to identify the main ideas on redox reactions. For instance, the teachers could connect redox reactions to chemical reactions and ionic bonding. This was evident as they tried to explain concepts from simple to complex. The fact that the teachers were able to use examples from other chemistry topics such as ionic bonding and chemical reactions was a strong point in this regard. Also, this clearly showed how those preliminary concepts were related to redox reactions. It might enable learners to see the sequence and understand what is being taught and what is expected from them later (Mavhunga & Rollnick, 2013).

### ***5.3.2.3 What is difficult to understand?***

From the observation, it was evident that teachers in this study understood what makes redox reactions challenging to understand. It was also evident that learners failed to understand the topic of redox reactions because some failed to answer questions that they were given at the end of the lesson presentation. Although a thorough explanation was given of the differences between the four models of redox reactions, learners still struggled with the definition of reduction and oxidation in terms of electrons, hydrogen, and oxidation numbers. This difficulty is due to the many definitions of redox reactions, as Silverstein (2011) reported. Mediation was mostly done through explanations, which I feel was insufficient to determine the level of understanding of what was taught. In addition, the assessment tasks given to learners to assess their understanding of redox reactions were also inadequate.

### ***5.3.2.4 Representations***

This TSPCK component is about how teachers explain science concepts using different mediation styles. Even though teachers tried to explain concepts by asking different questions and examples, the questions were not enough to strengthen the teachers' explanations and scaffold learners' understanding. The use of representations was limited to the submicroscopic and symbolic levels only, while the macroscopic level was omitted in all the lesson presentations observed. Li and Arshad (2014) posit that if a teacher fails to explain chemistry concepts at multiple representation levels, it may lead to misconceptions.

Moreover, it was evident that no experiments or practical activities were carried out to enhance or uplift learners' understanding. Asheela et al. (2021) posit that hands-on practical activities motivate learners to learn science concepts better.

### ***5.3.2.5 Conceptual teaching strategies***

These are the strategies that teachers use to mediate learning. Even though Namibia adopted a learner-centred approach, this study revealed that the two teachers who were involved in this study still use the traditional teaching method instead of the learner-centred one. This finding is in agreement with Nyambe (2012), who revealed that the LCE had not been successfully implemented.

The findings indicated that T2 attempted to practise a learner-centred approach while teaching redox reactions. However, the intention of using a learner-centred approach was only partially fulfilled. In addition, T2 used the question-and-answer method and activities to help the learners grasp the lesson content on redox reactions.

The teacher's use of different teaching strategies is vital in the classroom where a learner-centred approach is being practiced striving towards learning the concepts related to redox reactions with understanding (Nyambe, 2008). Concurring, studies have revealed that open-ended classroom discussions can promote critical thinking (Anagnostopoulos et al., 2008) and the quality of learners' talk in terms of elaborate utterances and arguments (Sedlacek and Sedova, 2017).

However, the study further revealed that T1 used traditional teaching methods throughout his lessons. He dominated the whole lesson, and learners only had to agree with what was presented to them. He posed a few leading questions to learners, and learners quickly answered them. This finding is supported by Easa and Blonder (2022), who state that many teachers still adhere to traditional instructional strategies.

Moreover, T1 made successful use of language through his explanations. Just like T2, he also used the question-and-answer method and activities. Teacher-learner interactions were limited as they did not engage learners to learn through a variety of interactions. This might be due to the fact that these teachers practised more of a traditional method than a learner-centred way of teaching. However, Lemke (2001) posits that teachers and learners need a balance of interaction and talking time.

Moreover, the teachers talked more than the learners, which opposed the suggestion of Lemke (2001) that learners should be given more opportunities to talk for them to develop the language of science. Similarly, if learners do not frequently talk during teaching and learning, it might affect the conceptual teaching strategies of the teacher (Mavhunga et al., 2016).

Apart from the TSPCK components, these research findings revealed that language is one of the constraining factors that hinder the effective mediation of redox reactions.

## 5.4 Recommendations

Based on this study's findings and discussions, some emerging issues need to be addressed. These recommendations aim to alleviate some problems encountered when mediating redox reaction concepts. These are as follows:

- Findings revealed that hands-on practical activities are neglected when teaching this topic. Asheela et al. (2021) reiterate that teachers need to use hands-on practical activities and emphasise the concepts 'to be innovative' and 'to be critical' during classroom teaching of redox reactions.
- Teachers need to use a variety of learner-centred teaching approaches such as group work and peer tutoring. This would reduce their reliance on traditional teaching methods such as the lecture method.
- I recommend that teachers should try by all means to get easily accessible resources and use them to carry out hands-on practical activities, as emphasised by Asheela et al. (2021).
- Schools should establish science clubs where learners could be encouraged to take part in discussions and interactions to improve their language proficiency as well as higher cognitive development as proposed by Vygotsky (1978).
- Further, teachers need to use the examiners' reports as resources when planning their lessons.

## 5.5 Limitations of the Study

This study only sampled two Grade 11 Chemistry teachers. Therefore, the data findings cannot be generalised to represent all teachers due to the sample size. However, I gained valuable insights into how the teachers mediated learning on the topic of redox reactions. It is recognised, however, that my presence in the classroom and videotaping during observations might change the way teachers and learners usually interact. In a way, this might have affected the results of my study.

## 5.6 Areas for Future Research

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

- A similar investigation could be conducted with a larger sample size to get a broader understanding of how teachers mediate learning of the redox reactions.
- An interventionist study could be conducted on supporting teachers' knowledge and mediation of learning of redox reactions.
- A study could be conducted on learners' perceptions and experiences of being taught and learning redox reactions.
- Research could be conducted on the value of hands-on practical activities, using easily accessible resources when mediating learning of redox reactions.
- Research could be conducted on the effectiveness and elicitation of learners' prior everyday knowledge as proposed by Kuhlane (2011).
- There is a need for future research on how language as a constraining factor hinders the effective mediation of redox reactions.

## 5.7 Personal Reflections

As human beings, we are constantly learning, and learning covers everything we do in life. I believe that critical learning comes in as we encounter problems and difficult questions daily. This kind of learning elevates us to become greater living beings because, as we are learning, we gain knowledge and skills. Also, we gain the ability and flexibility to adapt to different situations in the environment in which we find ourselves.

This is a journey that I will never forget, and it is remarkable. I joined Rhodes University in 2017 when I enrolled for my Honours degree (in Science Education). Academic writing and analysing literature were the most challenging, but with all the guidance and assistance from my supervisors and other lecturers, I managed to pull through.

In my second year of BEd Honours, learning was a mind opener in the sense that, I came to understand how one can become innovative by carrying out hands-on practical activities using the easily accessible resources and indigenous knowledge to mediate learning as it was presented by Eva Asheela. In addition to that, I also came to learn the procedure of conducting hands-on practical activities. As a Chemistry and Physical Science teacher, I began to

understand the value of hands-on practical activities, learners' prior knowledge as well as language in the mediation of the learning process. Furthermore, I started to appreciate Shulman's (1986) work on PCK. It dawned on me that strong subject CK does indeed precede PCK as reiterated by Shulman (1986). Shulman's (1986) and Mavhunga and Rollnick's (2013) seminal work helped me understand that teachers can possess subject CK, but transferring it to learners can be a challenge. Herein lies the importance of TSPCK (Mavhunga & Rollnick, 2013).

The research design course I attended in March 2019 at Rhodes University, Grahamstown motivated me to take up the research challenges. The course was an eye-opener for me and it strengthened my understanding of the research process. The experienced scholars who gave their presentations on the research design course were so open that they shared how they came up with their proposals and how they managed to complete their research studies. Despite being fed with that relevant information, I realised that my biggest challenge was to find a topic which was researchable and relevant. I was still not sure about the subject of study. Since then, various presentations during the contact sessions on different learning areas and assistance from my supervisors and teammates helped me how to decide on my topic.

Before the research journey began my proposal had to be approved. Afterwards, the practical implication became a reality, and the data generation process started in 2020. Due to the surgical procedure that I went through, I could not complete my study on time and this caused me to put my study on hold for 2021. Since the entire process of this research had its 'ups and downs', a roller coaster journey, I needed to be resilient so that I could complete what I had started.

Moreover, this journey opened my eyes to the world of research and the new ideas generated by the study. In October 2022, I came across a phrase: "If research does not benefit the community by extending the quality of life for those in the community, it must not be done" (Louis, 2008, p. 131). This phrase prompted me to think deeply about my research and I was left with a question: Will my research work benefit the community? Since this research was just an exploration of how teachers mediate learning, I thought that in the future, I could use my findings to conduct an interventionist study on supporting teachers' knowledge mediation of teaching and learning on the topic of redox reactions.

Lastly, by taking this MEd journey I learnt from the words of an African humanist philosophy phrase “*Umntu Nguntu Ngabantu*” which simply means a human being is a human because of other beings. I would like to thank my supervisors Prof. Kenneth Ngcoza and Ms Joyce Sewry for their kind and caring hearts in assisting me in shaping this work and the MEd master’s group as I could not have made it on my own without their moral support. It was not an easy journey as it was very bumpy, but I am happy to announce out loud that it is our oneness that made it possible. As our great African leader Nelson Mandela once said: “*It always seems impossible, until it is done*”. And here we are, **IT IS DONE BY GOD’S GRACE!**

## **5.8 Chapter Summary**

In this study, it was also established that the incorporation of learners’ prior knowledge is limited. Also, curriculum saliency, knowledge of resources, and conceptual teaching strategies still need to be strengthened. Moreover, the study revealed that teachers still practice traditional methods of pedagogy rather than a learner-centred approach which has been emphasised in teaching and learning. However, teachers could improve their PCK by employing more learner-centred instructional strategies. This study finally suggests a need for continuing PD – this creates opportunities for teachers to learn from one another which enhances their classroom effectiveness. In addition, these platforms will help them expand on their subject CK and PCK to make use of different teaching styles as they scaffold learners in the process of making sense of, in particular, abstract science concepts.

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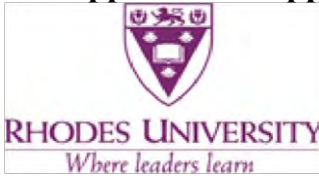
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## Appendices

### Appendix A: Approval Letter from Ethics Committee



**Human Ethics Sub-Committee**  
**Rhodes University Ethical Standards Committee**  
PO Box 94, Makhanda, 6149 South Africa  
Email: [ethics-committee@ru.ac.za](mailto:ethics-committee@ru.ac.za)

[www.ru.ac.za/research/research/ethics](http://www.ru.ac.za/research/research/ethics)  
NHREC Registration No. REC-241114-045

15 September 2020  
Prof Kenneth Ngcoza  
Review Reference: 2020-1206-3486  
Email: [kngcoza@ru.ac.za](mailto:kngcoza@ru.ac.za)

Dear Prof Ngcoza

**Re:** Exploring how Grade 10 Chemistry teachers mediate learning of redox reactions in their classrooms

**Principal Investigator:** Prof Kenneth Ngcoza  
**Collaborators:** Ms. Junilla Iindombo

This letter confirms that the above research proposal has been reviewed by the Rhodes University Human Ethics Committee (RU-HEC) and APPROVED. Gatekeeper/Permission letters have been received and considered by the Chair.

Please note that this approval is valid for 1 year upon issued date. Kindly ensure that the Ethical Standards Committee is notified should any substantive change(s) be made, for whatever reason, during the research process.

Sincerely,



**Prof Arthur Webb**  
**Chair: Rhodes University Human Ethics Committee, RU-HEC**  
*cc: Mr. Siyanda Manqele, Ethics Coordinator*

## Appendix B: Approval Letters from the Regional Directors



REPUBLIC OF NAMIBIA

OSHANA REGIONAL COUNCIL  
DIRECTORATE OF EDUCATION, ARTS AND CULTURE  
ASPIRING TO EXCELLENCE IN EDUCATION FOR ALL

Tel: 065 - 229800/25

Fax: 065 - 229834

Private Bag 5518

Oshakati

Enquiries: Hileni M Amukana

Ref. 13/2/9/1

Ms Junilla Inamudhimbwa Iindombo

P.O. Box 218

Oshakati

Email, [jiindombo@gmail.com](mailto:jiindombo@gmail.com)

### SUBJECT: PERMISSION TO CONDUCT A RESEARCH IN OSHANA REGION

Your letter dated 03 September 2020 on the above caption bears reference.

Kindly be informed that permission is hereby granted to conduct research study at Oshakati Secondary School in Oshakati Circuit, Oshana Region.

This permission is subject to the following strict conditions; (i) There should be minimal or no interruption on normal working schedule (ii) Ethical issues of confidentiality and anonymity should be respected and retained throughout this activity i.e. Voluntary participation, and consent from participants

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

Furthermore, we humbly request you to share your research findings with the Directorate of Education, Arts and Culture, Oshana Region. You may contact Ms. Nuunyango-George, the Acting Deputy Director; Programs and Quality Assurance (PQA) for the provision of summary of your research findings.

We wish you the best in conducting your study.

Yours sincerely,

**HILENI M. AMUKANA**  
REGIONAL DIRECTOR



Cc: Inspector of Education, Oshakati Circuit

All Official Correspondence must be addressed to 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: Felisa Nambala  
Our Ref: 12/3/10/1

Harelbecke Street, Greenwell Complex Building  
Private Bag, 88005  
Eenhana


25 August 2020

To: Ms. Junilla Inamudhimbwa Iindombo  
Email: jhiindombo@gmail.com

**SUBJECT: PERMISSION TO CONDUCT AN EDUCATIONAL RESEARCH**

1. Receipt of your letter on the above stated subject is hereby acknowledged.
2. The request has been evaluated and found to have merit.
3. Kindly be informed that permission to collect data 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 school Principal of Shituwa SS 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,

  
Isak Hamatwi 25/08/2020 2 5 'AUG 2020  
Director



## Appendix C: Letter to School Principals

J.I. Iindombo  
P.O.Box 218  
Oshakati

The Principal  
X Secondary School

Dear Sir,

### REQUEST FOR PERMISSION TO CONDUCT RESEARCH

I, Junilla Inamudhimbwa Iindombo (student number 1718177), am a part time registered Master's student in the Department of education at Rhodes University, Grahamstown, South Africa and a Physical Science and Chemistry teacher at S.I. Gobs Secondary school, Omaruru circuit in Erongo region.

The study's objectives are to work with selected teachers (Grade 11 Chemistry teachers) to explore how they mediate learning of redox reactions and to find out what enables or constrains them to mediate learning of the redox reaction. The topic of my study is to *explore how Grade 11 chemistry teachers mediate learning of redox reactions in their classrooms*: A case study.

I am hereby seeking permission to conduct the research mentioned above study with one of your senior secondary chemistry teachers. His participation involves the following; I wish to observe your teacher in the three lessons and interviews (semi-structured interview and stimulated recall interview) before and after the observations in his free time. My critical friend will video your teacher during (three) lesson presentations. I will ensure the school, learners and the teacher (participant) that everything will be treated confidentially, and the participant reserves the right to withdraw. I intend to publish the research results as a thesis, research report, conference proceedings, journal articles and book chapters. However, confidentiality and anonymity of records will be maintained, and names and identities will not be revealed to anyone who has not been involved in the research.

I attach the following documents to this letter: (a) A copy of approval from the regional director of Education, Arts and Culture office. (b) A copy of an ethical clearance certificate issued by the University. (c) A copy of the research instruments which I intend to use in my research.

Should you require any further information, please do not hesitate to contact my supervisors or me. Our contact details are as follows:

Junilla Inamudhimbwa Iindombo (researcher) Email address ([jhiindombo@gmail.com](mailto:jhiindombo@gmail.com))  
My supervisor is Prof K.M. Ngcoza at Rhodes University, Email address ([k.ngcoza@ru.ac.za](mailto:k.ngcoza@ru.ac.za))  
My co-supervisor is Mrs Joyce Sewry at Rhodes University, email address ([j.sewry@ru.ac.za](mailto:j.sewry@ru.ac.za))  
The Rhodes University Ethics coordinator is Mr Siyanda Manqele, email address ([s.manqele@ru.ac.za](mailto:s.manqele@ru.ac.za))

Upon completion of the study, I will provide you with feedback and make a copy of my thesis available if so desired. Your permission to conduct this study will be greatly appreciated.

Yours sincerely



Junilla Inamudhimbwa Iindombo

## Appendix D: Letter to the Participants (Teachers)

J.I. Iindombo  
P.O.Box 218  
Oshakati

The Participants  
..... Secondary School  
Oshakati

Dear participants,

### REQUEST TO PARTICIPATE IN AN EDUCATIONAL RESEARCH STUDY

I, Junilla Inamudhimbwa Iindombo, (student number 17I8177) am a part time registered Master's student in the Department of education at Rhodes University, Grahamstown, South Africa and a Physical Science and Chemistry teacher at S.I.!Gobs Secondary school, Omaruru circuit in Erongo region.

The objectives of the study is to explore how Grade 11 chemistry teachers mediate learning of redox reactions and to find out what enables or constrains them to mediate learning of the redox reaction. The topic of my study is to *explore how Grade 11 chemistry teachers mediate learning of redox reactions in their classrooms*: A case study.

Your participation involves the following, I wish to; (a) interview you (semi-structured interview) to find out what enables and/or constrains you when mediating redox reactions, (b) observe you in each of the three lessons and (c) interview (stimulated recall interview) after the observations in your free time. My critical friend will videotape during (three) lesson presentations. I intends to publish the research results in the form of a thesis, research report, conference proceedings, journal articles and book chapters. However, confidentiality and anonymity of records will be maintained and that names and identity will not be revealed to anyone who has not been involved in the conduct of the research. Kindly be informed that you are voluntary participating in this study thus you can withdraw at any time if you wish.

I attach the following documents to this letter: (a) A copy of approval from the office of the regional director of Education, Arts and Culture. (b) A copy of an ethical clearance certificate issued by the University. (c) A copy of the research instruments which I intend using in my research.

Should you require any further information, please do not hesitate to contact me or my supervisors. Our contact details are as follows:

Junilla Inamudhimbwa Iindombo (researcher) Email address ([jhiindombo@gmail.com](mailto:jhiindombo@gmail.com))

My supervisor is Prof K.M. Ngcoza at Rhodes University, Email address ([k.ngcoza@ru.ac.za](mailto:k.ngcoza@ru.ac.za))

My co-supervisor is Mrs Joyce Sewry at Rhodes University, email address ([j.sewry@ru.ac.za](mailto:j.sewry@ru.ac.za))

The Rhodes University Ethics coordinator is Mr Siyanda Manqele, email address ([s.manqele@ru.ac.za](mailto:s.manqele@ru.ac.za))

Upon completion of the study, I undertake to provide you with feedback and make available a copy of my thesis if so desired. Your permission to conduct this study will be greatly appreciated.

Yours sincerely



Junilla Inamudhimbwa Iindombo

## **INFORMED CONSENT DECLARATION (Participant)**

Project Title: Exploring how Grade 11 Chemistry teachers mediate learning of redox reactions in their classrooms: A case study

Junilla Inamudhimbwa Iindombo from the Department of Education, Rhodes University has requested my permission to participate in the above-mentioned research project.

I am aware that:

1. The purpose of the research project is to investigate how Grade 11 Chemistry teachers mediate learning of redox reactions in their classrooms
2. Rhodes University has given ethical clearance to this research project and I have seen the clearance certificate. [Certificate number]
3. By participating in this research project, I will be contributing towards gaining knowledge and more insight about redox reactions including the four models of reduction-oxidation reaction (oxygen, hydrogen, electrons and oxidation state). I expect the use of four models (electron, hydrogen, oxygen and oxidation number) as a modelling tool to increase and improve my pedagogical content knowledge and enhance learners' understanding about redox reaction. I also expect this study to increase the number of chemistry teachers using the four model of redox reactions for teaching and learning purposes.
4. I will participate in the project and by participating, semi-structured interview will be about attitude and pedagogical insight when mediating redox reactions. I will teach two lessons that will be video recorded for observation purposes. Thereafter a stimulated recall interview will be about the lesson observed
5. My participation is entirely voluntary and should I at any stage wish to withdraw from participating further, I may do so without any negative consequences.
6. I will not be compensated for participating in the research.
7. There may be risks associated with my participation in the project. I am aware that:
  - a. The following risks are associated with my participation: I may work after normal working hours without compensation as the lesson presentation are expected to be longer than normal teaching time of a lesson.
  - b. The following steps have been taken to prevent the risks: The lesson presentation is planned to be taught during double lessons (80 minutes).
  - c. There is a 40% chance of the risk materialising.
8. I understand that the study will involve taking video and voice recordings of my teaching and responses to interviews.
9. The researcher intends to publish the research results in the form of a thesis, research report, conference proceedings, journal articles and book chapters. However, confidentiality and anonymity of records will be maintained and that my name and identity will not be revealed to anyone who has not been involved in the conduct of the research.
10. I will receive feedback in the form of a 'summary of the key findings' regarding the results obtained during the study.
11. Any further questions that I might have concerning the research or my participation will be answered by: Junilla Inamudhimbwa Iindombo, (researcher) Cell: 0812139087, Email: [jhiindombo@gmail.com](mailto:jhiindombo@gmail.com).

12. By signing this informed consent declaration, I am not waiving any legal claims, rights or remedies.

13. A copy of this informed consent declaration will be given to me, and the original will be kept on record.

I, ..... have read the above information / confirm that the above information has been explained to me in a language that I understand and I am aware of this document's contents. I have asked all questions that I wished to ask and these have been answered to my satisfaction. I fully understand what is expected of me during the research. I have not been pressurised in any way and I voluntarily agree to participate in the above-mentioned project.

.....

.....

**Participants signature**

**Witness**

**Date**

## Appendix E: Letters to the Parents

**J.I. Lindombo**

P.O.Box 218  
Oshakati

Dear Parents /Guardian

### **REQUEST TO PARTICIPATE IN AN EDUCATIONAL RESEARCH STUDY**

I, Junilla Inamudhimbwa Lindombo, (student number 17I8177) am a part time registered Master's student in the Department of education at Rhodes University, Grahamstown, South Africa and a Physical Science and Chemistry teacher at S.I.!Gobs Secondary school, Omaruru circuit in Erongo region.

The objectives of the study is to explore how Grade 10 chemistry teachers mediate learning of redox reactions and to find out what enables or constrains them to mediate learning of the redox reaction. The topic of my study is to *explore how Grade 10 chemistry teachers mediate learning of redox reactions in their classrooms*: A case study.

I am hereby seeking your permission for your child to be part of my study. Your child will participate in the research by being part of the classroom where the researcher will be observing and video recording your child's teacher teaching chemistry to your child's class. By participating in this research your child will be contributing towards teachers gaining knowledge and more insight about mediation of redox reactions including the four models of redox reactions (oxygen, electron, hydrogen and oxidation states). As a result of this study, the use of four models of redox reactions is expected to increase and improve teachers' knowledge of teaching redox reactions. This research is also expected to increase the number of chemistry teachers using four model of redox reactions for teaching and learning purposes as well as enhancing learners understanding.

I wish to; (a) interview the chemistry teacher (semi-structured interview) to find out what enables and/or constrains her when mediating redox reactions, (b) observe the teacher in each of the three lessons and (c) interview (stimulated recall interview) after the observations in their free time. My critical friend will videotape during (three) lesson presentations.

I intends to publish the research results in the form of a thesis, research report, conference proceedings, journal articles and book chapters. However, confidentiality and anonymity of records will be maintained and that names and identity will not be revealed to anyone who has not been involved in the conduct of the research. Kindly be informed that you can refuse your child from participating if you do not want him/her to take part and that nothing will happen to you or your child if you refuse participating in this study thus your child can withdraw at any time if they wish.

I attach the following documents to this letter: (a) A copy of approval from the office of the regional director of Education, Arts and Culture. (b) A copy of approval from the office of the Principal. (c) A copy of an ethical clearance certificate issued by the University. (d) A copy of the research instruments which I intend using in my research.

Should you require any further information, please do not hesitate to contact me or my supervisors. Our contact details are as follows:

Junilla Inamudhimbwa Iindombo (researcher) Email address ([jhiindombo@gmail.com](mailto:jhiindombo@gmail.com))

My supervisor is Prof K.M. Ngcoza at Rhodes University, Email address ([k.ngcoza@ru.ac.za](mailto:k.ngcoza@ru.ac.za))

My co-supervisor is Mrs Joyce Sewry at Rhodes University, email address ([j.sewry@ru.ac.za](mailto:j.sewry@ru.ac.za))

The Rhodes University Ethics coordinator is Mr Siyanda Manqele, email address ([s.manqele@ru.ac.za](mailto:s.manqele@ru.ac.za))

Upon completion of the study, I undertake to provide you with feedback and make available a copy of my thesis if so desired.

Your permission to conduct this study will be greatly appreciated.

Yours sincerely



Junilla Inamudhimbwa Iindombo

## Appendix F: Semi-structured Interview

**Research question 1:** What enables or constrains Grade 10 Chemistry teachers when mediating learning of redox reactions? [Semi-structured interview]

Question	Purpose
1. What are your views and experiences of the topic of redox reactions?	To get some insight of teacher perception and experience of the topic of redox reaction.
2. How do you introduce the topic of redox reactions to your learners?  a) How do you make use of learners' previous experience (prior knowledge) when teaching the topic?  b) What prior knowledge are learners expected to have before starting with redox reactions topic?	To find out how teachers elicit learners' prior everyday knowledge when teaching redox reactions.  To get insight on whether the integration of learners' prior knowledge does influence learners understanding of redox reactions.  How teachers build on learners' prior knowledge.
3. What type of learning support materials do you use to support the teaching and learning process of redox reactions?	To find out the presentation including analogies, demonstration and any other learning support materials used apart from notes.
4. What teaching strategies do you use to make sure that learners are actively involved in the lesson?	To find out the teaching strategies that teachers employ to help learners to acquire curriculum knowledge.
5. How do you assess learners' understanding of redox reactions?	To find out teachers insight or knowledge about curriculum sequencing of topic.
6. What challenges do you experience when mediating learning of redox reactions?  a) How do you deal with these challenges?	To find out the pedagogical insight of the teachers when mediating redox reactions, as well as what makes the topic easy or difficult to understand.

Adapted from Kanime, 2015

## Appendix G: Semi-structured Interview with Teacher 1

**Interviewer:** What are your views and experiences of the topic of redox reactions?

**T1:** I think in most cases when we teach this topic, aah its one of the most difficult topic to teach especially in terms of learners understanding of the topic itself. Not necessary that the teacher doesn't understand but we still find it, in some cases where, teachers also find it challenging and also we have, I think problem in learners defining terms like oxidation number and them differentiating between oxidation number and ionic charge. And also a problem is defining oxidation and reduction in term of like electrons transfer and all that.

**Interviewer:** Apart from your experience how do you introduce this topic redox reaction to your learners?

**T1:** I'm....., for them to understand sometimes, you have to give example that are more related to real-life things that they experience, things like, How a battery works for instance, thing like extraction of metals, because probably they have done it in the previous grade chemical process like in living organism like photosynthesis those are all types of redox reaction, so they get that feeling that yes we are learning something that happens on a daily basis.

**Interviewer:** How do you make use of previous knowledge meaning the prior knowledge when teaching redox reaction? The knowledge they have acquired previous grade or the community where they are coming from?

**T1:** In that case, most of their prior knowledge when it comes to redox reaction, is just like said, how battery works, chemical process, photosynthesis, maybe rusting they see a nail iron rusting than you can explain that it is a type of redox reaction, when fuel burns and when they burn wood at home is a type of redox reaction And maybe on the topic of ionic bonding where the electrons being transferred between species and all that.

**Interviewer:** Just maybe to be more specific on what you said on the previous question what prior knowledge are learner expected to have before starting with redox reaction topic.

**T1:** They need to know about transfer of electrons, that is like metals they lose electrons to form positive ions, non-metals they gain electrons to form negative ions. They also need to

know types of reaction such as combustion reaction, decomposition reaction, yeah those types of reaction

**Interviewer:** OK, when teaching the topic redox reaction, what type of learning support material do you use to support the teaching and learning process of redox reaction?

**T1:** The learning support materials, that we can use are things like flip chart where you have already prepared, different types of reaction and you show them, using flip chart, maybe you use simple cell diagram where its already displayed on a flip chart maybe you can also make, when, this is one you find it might be difficult to do but it can be doable when you have, this you tube video that you can show to learners, especially in school were you don't have enough facilities like chemistry lab where they can do experiment, those are some of the learning material one can use.

**Interviewer:** OK is there anything extra special again learning support material apart from the one you have mentioned?

**T1:** When, saying special, in terms of like

**Interviewer:** Just to add on what you said, or the one that you usually use most?

**T1:** The one that is use in most cases like at the school where I have been in most cases we just use, textbook as a learning material that is the basic one that it is unfortunate that we have to learn how to work with it and at the end of the day make the learners understand the little learning material available to us.

**Interviewer:** OK, teaching strategies what teaching strategies do you use to make sure that, learners are actively involved in the lesson?

**T1:** When it comes to redox reaction learners really need to be actively involved because, we find it challenging to the learners. So, you can make use of assignments, simple assignments, group work, working in pairs, homework. You can make use of probes where they... You give them diagram and the possible answers and use ask them which one is do they agree, with and explain why? Just to make them work because it is a challenging topic. If you don't give them a lot work or activities on it at the end of the day, you will rush through and they will not understand the topic at all.

**Interviewer:** Apart from teaching strategies, as a teacher how do you assess learners understanding of redox reaction.

**T1:** I'm.. the assessment here can be done from their prior knowledge meaning that before we can even start maybe you can even you come up with an activity on ionic bonding where they show electrons transferred and all that because that is knowledge that they need to know for them to understand redox reaction. So, you can make a pre-assessment on the previous topic that is involved like transfer of electrons.

**Interviewer:** How do you ensure that learners are really involved in the lesson in those activity that you are giving them?

**T1:** The only way you can ensure they are they are involved is when you assess the work that you give to them and when you actively engage them in the lesson, make sure that they are asking question they are free to ask question because the most important thing in..... teaching is for learners to feel comfortable, so that they ask question where they do not understand so, that is very important.

**Interviewer:** OK, apart from making learners understand, are there challenges that you experience when mediating learning of redox reactions?

**T1:** Yes, as I previous mention, there are quite a lot of challenges... some of them is learners may not be able to really, define oxidation & reduction in a given equation when oxygen is not involved is one of the challenge there and also learners might be able to explain transfer of electrons as to where they are coming from and where they are going, so they, those are some of the challenges that we face when you are teaching redox reaction.

**Interviewer:** How do you deal with those challenges?

**T1:** When it comes to defining oxidation-reduction in terms of electrons transfer it is a....what do is before we define oxidation in term of oxygen loss & gain than we start with defining oxidation and reduction in terms of electrons transfer and in terms of increase of oxidation number and reduction in oxidation number. So, when they grasp that than it will be easier for them to grasp the concept of loss & gain of oxygen atom. Then I see that helps them in understanding of redox.

**Interviewer:** Thank you very much, the fact that you accepted this interview, I believe this information will really help me. Unless you have something to say.

**T1:** It is a great pleasure and I wish you all the best in your research project.

## Appendix H: Transcript Semi-structured Interview with Teacher 2

**Interviewer:** What are your views and experiences of the topic of redox reactions?

**T2:** It's a very short topic, from the look of things it looks very easy, yes when you look at it and it has few objectives one would think it is very easy. But now, experience side, most learners tend to fail especially when it comes to the half-reaction. I think maybe they confuse the word oxidation and reduction. So if they do not really master the definition of the two key words oxidation & reduction then, they tend to mix up the two.

**Interviewer:** Apart from your view and experience how do you introduce this topic redox reaction to your learners?

**T2:** What I normally do I try by all means to make them understand just the definition, for them to be able to identify the two reduction and oxidation because I tell them like redox, the word itself it is made up of **red** for reduction and **ox** from oxidation they need to understand that part first before we proceed with everything.

**Interviewer:** How do you make use of learners' prior knowledge, or previous experience when you are teaching this topic of redox reaction?

**T2:** When it comes to redox first of all they need to know the oxidation number or charges of elements themselves, because you find some learners they still confuse the oxidation numbers of metals and non-metals. Sometimes you find learners putting negative on a metal or sometimes the hydrogen itself and sometime they are putting positive and sometimes negative and so on. And also the, writing of balancing chemical equation because you will be dealing with equation there those two are very much important.

**Interviewer:** Apart from learners' previous knowledge, what prior knowledge are the learners expected to have before starting with redox reactions?

**T2:** What we will be doing is chemical equation, so they need to know the reactants & products in chemical equation.

**Interviewer:** What type of learning support material do you use to support the teaching and the learning process of redox reactions?

**T2:** I think with me .... Maybe I'm lucky because I'm in a town school with Internet and so on, I usually take my learners to the computer lab and show them some video and so on even, if they don't understand my lesson I usually even download a video of different person explaining the same content I explain in the class, and they have to listen to that person and then relate the two lessons and so on and they ask question, they usually go to the computer lab.

**Interviewer:** What teaching strategies do you use to make sure that learners are actively involved in the lesson of redox reactions?

**T2:** So, it's a..... I teach sometimes with handouts I give them hand out because I sometimes give them hand out then when I explain they already have their note with them ..... which I find, more convenient because the first year, I use to write on chalk board but they tend to be concentrating more on copying the notes, so giving them hands out, helps a bit because they will not be concentrating on writing and so on. Giving them more question post question or oral question like assessing them orally randomly and so on and give them homework and test and so on.

**Interviewer:** When it comes to assessment, how do you assess your learners to understand redox reactions?

**T2:** I have spoken oral assessment where, pose question in class and then It depend than from year to year, as sometime maybe, this year I give, I ask oral question during the lesson give them class activity, they have to finish before the lesson or maybe this year will you give a homework because it's a very short topic but they will still have to write a test on everything so, oral assessment during class and class activity and sometimes homework and tests.

**Interviewer:** How do you make sure that learners are involved during lesson?

**T2:** What I do when I teach, in the handout, there are question, there is a part of questions, I might give handout with question or write question on the chalk board then they have to solve those question within a limited time, I will then go around / walk around the classroom from learner to learner checking the one if they are answering them if they understand or not, if they don't understand then they have to ask question, it just that now time of COVID 19 it is very difficult to talk from learner to learner.

**Interviewer:** What challenges do you experience when mediating teaching of redox reactions?

**T2:** Challenges from my side when delivering, challenges are not really a lot from the side of a teacher because I find it as an easy topic maybe the challenges is coming from the side of the learners, don't want to grasp the content within a short period of time.

**Interviewer:** If challenges are coming from the learners, how do you deal with those challenges?

**T2:** What we do, we have a system where we teach after schools each subject teachers have their own days in a week for instance Monday can be for mathematics and physics that whole Monday during afternoon, physics & maths teachers stays behind with the learners either to give them activities or teach them but in most cases we give them more activities after school.

**Interviewer:** Thank you Mr.....this will really help me to finish my study. Unless you have something else that you would like to add.

**T2:** It is my pleasure, thank you also and I wish good luck in your research.

## Appendix I: Transcription of Teacher 1, Lesson 1

### Topic: Redox Reaction

Teacher : Good Afternoon

Learners : Good Afternoon Sir

Today we are going to talk about redox reaction.

I hope everyone has received the notes

Whenever we are talking about redox reaction there are some process redox reaction that take place on daily basis things like redox reaction, things like photosynthesis are redox reaction, so that's how you connect that to everyday life issue.

Now the term **redox** is divided into two, the first part is reduction and the second part is oxidation, all right. Now, reduction refer to the loss of oxygen from a compound, when a compound losses oxygen and this is reduction and when compound gain oxygen that's oxidation.

So they define **reduction as loss of oxygen atom** and we define **oxidation atom as gaining of oxygen atom or atoms**. Now if you look on that first page (summary or notes given to learners) under oxidation, it says gain of oxidation atom and also we can define reduction and oxidation in terms of electrons.

So, we are saying that reduction can also be defined as a gain of electrons and oxidation can also be defined as a loss of electrons. Now when we did chemical reaction we know that, electrons are transferred from one compound to another or during ionic bonding when we did ionic we know that metals loss electrons to form positive ions isn't? So, where are these electrons going in ionic bonding?

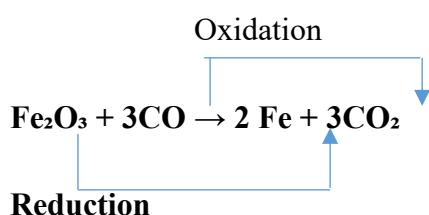
Those electrons are gained by the non-metals, so the non-metal ones, non-metals gains electrons to form what ions?

**Learners** replied negative ions

**Teacher** = negative ions (emphasise)

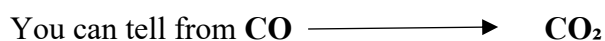
So, at the same time this is what is involved in redox reaction, okay. Electrons are being transferred from one species to another species. Now when electrons are being transferred there is an increase in what we call the ionic charge or in the oxidation number of an element.

Now we want to give the example of redox reaction. For instance, one of the example of redox reaction is the one we learned in, under extraction of metals, we say that like extraction of iron we say that, Haematite which is iron oxide reaction with carbon monoxide to produce Iron and carbon dioxide gas.



So this is a redox reaction.

Now from here you can tell that this  $\text{Fe}_2\text{O}_3$ , change from  $\text{Fe}_2\text{O}_3$  to  $\text{Fe}$  there is a reduction because this  $\text{Fe}_2\text{O}_3$  has lost its oxygen, so this step is a reduction.



This one is, what step that?

Learners replied **oxidation**

Teacher = oxidation step (emphasise)

Teacher asking, and why are we saying it is oxidation?

Learner replied Carbon monoxide has gained oxygen



So, that is why we are saying we need to relate this type of reaction to this that happen on daily basis, because the extraction of iron is very important, and most of metals that we use are made up Iron.

Now when it comes to transfer of electrons, we can explain oxidation and reduction in term of electron transfer, reduction in terms of electron transfer, now that brings us to ionic charge.

Now if we have to break this down, for instance  $\text{Fe}_2\text{O}_3$  here  $\text{Fe}_2\text{O}_3$  the oxidation number here of iron, we have  $\text{Fe}^{3+}$ , will there will be a formation of  $\text{Fe}$  and how many electrons?

Learners replied 3 electrons  $\text{Fe}^{3+} \rightarrow \text{Fe} + 3\text{e}^-$

So, it means that for reduction you can see that there is reduction in oxidation because this ionic charge or oxidation number has decrease from 3 to 0 there, that's reduction there. Reduction can also be defined in term of oxidation number, we can say **reduction is a decrease in the oxidation number**. So, that's happen in that process.

Now at the same time we sometimes if look in your note there is not part of our syllabus but I think it is something that you need to understand as well as, that oxidation can also be described in terms of hydrogen atom, where we are saying oxidation is loss of hydrogen atom.

This is, you can also say that oxidation is also refers as loss of hydrogen atom and **reduction can also be referred to as gain of hydrogen atoms**. But it is something you need to know, but if you look at the specific objective for our lesson in our syllabus it only requires us to define reduction and oxidation in terms of **oxygen loss or gain and in terms electron gain or electron loss** but you are not restricted not to know that.

Oxidation $\rightarrow$ loss of hydrogen atoms
--

Reduction $\rightarrow$ gain of hydrogen atoms
--

Because if you are going to do further chemistry than you have to know that.

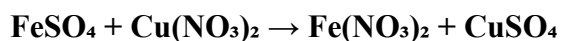
Now, sometimes in the syllabus there are, we are use the term ionic charge and oxidation number interchangeably but there is a slight difference, OK.

We might use it interchangeably when we are talking about ionic charge and oxidation number there is a slight difference. Now let's do a demonstration and example and see,

So, let use an example of a displacement reaction. Remember the displacement reaction that we did under reactivity series? Reactivity of metal, we looked at displacement reaction where a more reactive metal displaces a least reactive metal from its compound.

Now, let us say you have a compound of Iron sulfate reacting with copper nitrate now in this case because iron is more reactive than copper we know that from the reactivity series, iron is

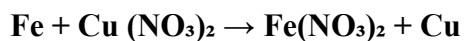
more reactive than copper, this Iron will come and displace copper therefore in this case we are going to form, we are going to form Iron nitrate plus copper sulfate.



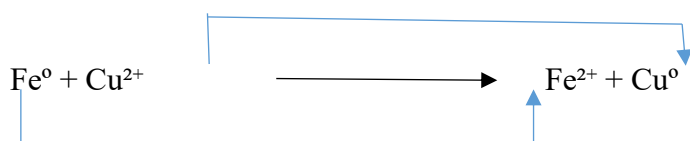
Now in this case if you are to write a half equation or ionic equation for this type of reaction then we are going to see that these are all aqueous solution.

So, we are going to see that here Iron has a charge of  $2^+$  in this compound  $\text{FeSO}_4$  and here copper has a charge of  $2^+$  in that compound  $\text{Cu(NO}_3)_2$  and you are going to form a neutral.....

Let me do this just Iron itself and here just copper

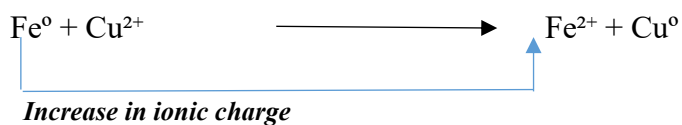


So now this iron here has a charge of zero ( $\text{Fe}^0$ ) because it is an element and that copper there has a charge of two plus ( $\text{Cu}^{2+}$ ) because it forms a compound therefore when Iron comes here to form this compound it will have  $\text{Fe}^{2+}$  and copper will have zero  $\text{Cu}^0$



Now in this case we can be able to identify where is oxidation taking place and where is reduction taking place.

So now you can see that here we are not focusing on oxygen even though you see that oxygen there is an ion in a form of nitrate ion, OK, therefore we can see that from zero to 2 there is an increase in ionic charge, so that increase in ionic charge.



## Transcription of Teacher 1, Lessons 2

### Topic: Oxidising and Reducing agents

Teacher : Good Afternoon

Learners : Good Afternoon Sir

Teacher : How are you?

Learners : We are fine

When we talked about oxidation and reduction reaction we said that one compound might loss oxygen and one compound might gain oxygen. So, in Oxidising agent, Oxidising agent, Oxidising and reducing are doing verbs, something, a compound that is doing, giving away oxygen.

An oxidising agent is a reactant that gives oxygen. Let us define it, we are saying: Oxidising agent gives away its oxygen atom or atoms. (writting on board )

Or in other words we say an oxidising agent is always reduced when it loses oxygen atom, “it have been reduced”.

- Oxidising agent is reduced

And, a reducing agent receives or accepts oxygen atom or atoms.

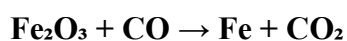
A reducing agent is a substance or reactants that receives oxygen. Then, we say that a reducing agent is oxidised, because it has reducing oxygen, then its oxidised.

So, don't get confused between oxidised agent and when you are saying a substance is reduced or a reducing agent and when you are saying a substance is oxidised

Are we together?

Learners responded yes

Alright, Now and let us now look at the example from the equation that we give, the equation of iron reduction or extraction of Iron.



Now between this two reactant  $\text{Fe}_2\text{O}_3$  and  $\text{CO}$ , remember that an oxidising and reducing agent should be one of the reactant is not a product but should be one of the reactant, OK Here between  $\text{Fe}_2\text{O}_3$  and  $\text{CO}$  which one is giving oxygen?

Learners replied Iron oxide

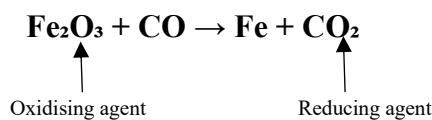
So, this one  $\text{Fe}_2\text{O}_3$  there is our oxidising agent because is the one which is giving oxygen Where is it giving its oxygen to?

Learners answer carbon monoxide

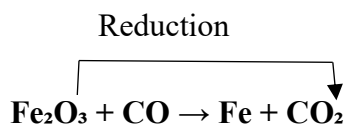
So, the carbon monoxide is our reducing agent in this case. So, some people whenever they are asked to identify oxidising and reducing agent they end up mentioning products which is not the case.

A reducing and oxidising agent should always be one either one of the reactants. Are we together?

Learners, yes



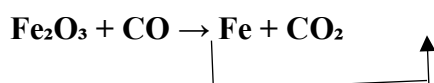
And you should know that, if you are able to identify and oxidising agent, than you are also able to identify which one is reduction from there to there



The oxidising agent is the reactant under the reduction step.

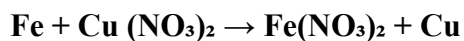
While

A reducing agent is the reactant under oxidation step



Therefore  $\text{Fe}_2\text{O}_3$  is our oxidising agent and  $\text{CO}$  is our reducing agent.

There something goes when we have to, when we are dealing with equations where we are identifying oxidation in terms of ionic charge by the example we did previously we said that,.. you **have iron plus copper nitrate to give you Iron nitrate plus copper.**

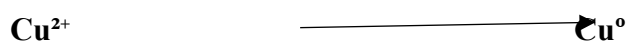


We can still identify the oxidising agent and reducing agent, we said that from here

$\text{Fe}^0$  but here  $\text{Fe}(\text{NO}_3)_2$  the ionic charge is 2. So, we are saying that from here to there is oxidation meaning that this one is our reducing?

Learners answer..... Agent

So, This is our reducing agent and this oxidation of ionic charge here is  $2^+$  and it goes there and its zero



Therefore Copper nitrate  $\text{Cu}(\text{NO}_3)_2$  is our oxidising agent.

So, is not an equation can come chemically equation can come where you have to identify oxidation and reduction step but you are not going to identify that by looking at the transfer of election, OK, and that is one of the example.

Now, we have to.... there is something extra here where we are going to say, because you are going to do is further under balancing of equation and writing of ionic equation an equation like this  $\text{Fe} + \text{Cu}(\text{NO}_3)_2 \rightarrow \text{Fe}(\text{NO}_3)_2 + \text{Cu}$  involve reduction and oxidation right so you are, you can be required to write a half equation, half equation for oxidation & reduction.

Now, here we know that from there  $\text{Fe}$  to there  $\text{Fe}(\text{NO}_3)_2$  there is increase in oxidation number.

**$\text{Fe}$   $\text{Fe}(\text{NO}_3)_2$  from  $2^+$  to 0** this is our oxidation step. So, if you are asked to write a half equation for that one,

What is happening to the oxidation number?, it is increase right?

Learners: yes

**Fe** which is a solid in that case, what happen to the iron? It will lose electrons right? All metals lose electrons to form ions.

The electrons that are lost are always on the right side of the equation.

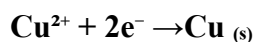
So it will be  $\text{Fe}_{(s)} \rightarrow \text{Fe}^{2+} + 2\text{e}^{-}$  to show those electrons that are lost.

So, this is a half equation for oxidation  $\text{Fe}_{(s)} \rightarrow \text{Fe}^{2+} + 2\text{e}^{-}$

Now, for reduction there is gain, gaining of electrons, this copper here gained electrons to form **(Cu)**. So you have  $\text{Cu}^{2+}$  it has gained electron that are lost there  $\text{Fe}_{(s)} \rightarrow \text{Fe}^{2+} + 2\text{e}^{-}$

So, where are they going to be gained by copper, so copper will gain those electrons to form copper solid  $\text{Cu}^{2+} + 2\text{e}^{-} \rightarrow \text{Cu}_{(s)}$

**So these are what we call half equation**



So, half equation we will be able.... you will be required to write half equation for oxidation and reduction, but that is a lesson for another day when you will do ionic equation. OK, is there any question, any question?

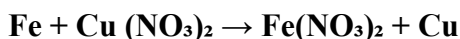
Now, if there is no question I need you to do a recap of what you really need to know here, a recap of what you need to need to know in this topic

Let us recap quickly.

**Recap :**

**Firstly:** Define oxidation and reduction both in terms of oxygen or electron loss or gain, that is the first thing you need to know

**Secondly:** Identify redox reaction in terms of ionic charge e.g the example that we did here



When there is an increase in ionic charge that is oxidation, and when there is a decrease in ionic charge that is reduction.

**Lastly** we must be able to identify oxidation step and reduction step looking at extractions of metals, the extraction of metal we did, we did extraction iron, extraction of copper, extraction of zinc and extraction of aluminium.

But we gave example of extraction of copper, I mean Iron, rather just of all the other example of extraction of metal you should be able to identify from those equation which one is oxidation and which one is reduction step.

OK, then there is two activity that, I gave you, first activity and second activity class activity that you just have to answer to see if understood.

Thank you....

Learners, doing the activity

Teacher.....let us do the first activity and you will come to the 2<sup>nd</sup> activity later.

## Appendix J: Transcription of Teacher 2, Lesson 1

### Topic: Redox Reaction

Teacher : Good Afternoon

Learners : Good Afternoon Sir

Teacher : How are you?

Learners : We are fine

So, Today we are going to talk about redox reactions.

Definition of redox reaction reads as follows:

**Redox reaction are oxidation or reduction reaction in which electron are transferred.**

So, in this unit you will learn about reaction where oxygen is involved, you will consider whether oxygen is lost or gain during certain reaction.

We only have one section which is redox. We have three lesson objectives but today we are only going to cover the first one, we are only going to cover the first lesson objective. Are we together?

Learners : yes

It reads as follow, at the end of this unit you should be able to define oxidation and reduction in terms of oxygen gain, loss and in terms of transfer of electrons, It simply means after this lesson now all of you should be able to define what oxidation is and what reduction is in terms of two things one is oxygen gain and loss and the other one is the transfer of electrons

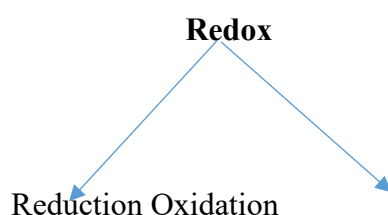
Are we together?

Learners: yes

Good, if we are together than its fine....

So first of all, I want us to break down this word **Redox**

So whenever you come across this word redox reaction it simply means **red** for reduction and **ox** for oxidation.



To say redox is formed by two word **oxidation and reduction**

Teacher: Are we together there?

Learners: yes

Our lesson objective also state that we will talk about oxidation and reduction in terms of oxygen gain and in term of oxygen loss and also in term of electrons transfer OK.

It simply means, when we talk about oxygen gain and oxygen loss we are simply talking about the compound lossing oxygen, from a certain element. Are we together?

Teacher: Who can remember what electron transfer is from previous chemistry topics?

Electrons transfer? Anyone?

Can remember what electron transfer is all about

Which element maybe do transfer electrons?

Anyone?

Learners: Metals transfer electrons

Teacher : How is it going to transfer?

Learners: Metal looses electrons to non-metals

OK, now we have to look at the definition because the lesson objective says we must be able to define.

Teacher : who can give the definition of reduction?

Learners: refers to the loss of oxygen and the gain of electrons.

It means when we are going to talk about reduction reaction, we will be talking about a reaction whereby oxygen will be lost and then electrons will be gained.

Are we together?

Learners : yes

Teacher: how now? How?

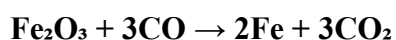
So, when we are talking about Reduction reaction, I will give you an example. We have an example here you guys did an extraction of metals right?

Learners: Yes

Whereby you say, one of the main method to extract a metal from its ore is reduction with carbon, which all happens in a blast furnace, Are we together?

Learners: yes

We have an example, here of an ore whereby this example:



What is happening here is that, reduction is used in industry to extract metals from their ores. So, in the blast furnace Iron oxide is reduced whereby it loses oxygen to Iron by the gas carbon monoxide.

Let us quickly check what happened here, I now want to explain the loss of oxygen and gain of electrons in this equation.

First of all as you can see here:  $\mathbf{Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2}$

For you to understand every step you need to check the number of oxygen atoms on both reactants.

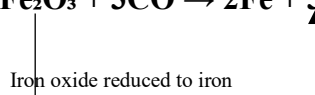
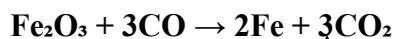
Teacher: Are we together?

Learners: Yes

**Fe<sub>2</sub>O<sub>3</sub>** there are three oxygen atom and CO there is one oxygen atom.

Now, when you look at the reactant Iron was bonded to three oxygen but now in product it doesn't have oxygen atom. **Fe<sub>2</sub>O<sub>3</sub>** the oxygen was taken away by carbon monoxide.

It means Iron oxide (**Fe<sub>2</sub>O<sub>3</sub>**) is reduced to Iron (**Fe**)

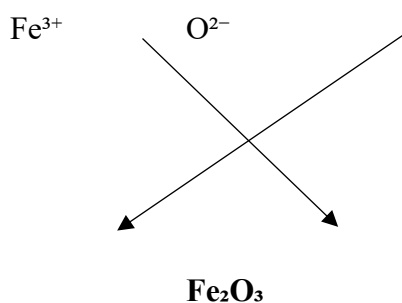


**Fe<sub>2</sub>O<sub>3</sub>** has lost its oxygen.

And also the gain of electron.

In **Fe<sub>2</sub>O<sub>3</sub>** what happen is .....

Fe(III) Do you understand where the Fe(III) is coming from?



When carbon monoxide takes this oxygen from **Fe<sub>2</sub>O<sub>3</sub>** Iron itself will gain three electrons to form Iron atoms **Fe<sup>3+</sup> + 3e<sup>-</sup> → Fe<sub>(s)</sub>**

### **Oxidation**

Teacher: Who can give me a definition of oxidation?

Learners : is the gain of oxygen atoms and loss of elements.

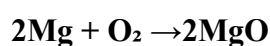
Again I am going to give you an equation where we will be tackling the loss of electrons and gaining of oxygen

Teacher: Are we together there?

Learners: Yes

Let us quickly look at this example:

- When magnesium burn it combine with oxygen in this reaction, magnesium has gained oxygen



- Now, how is the gaining of oxygen  
At first Mg was alone isn't?

Learners : yes

But here MgO has gained an oxygen atom.

Let us look at loss of electrons



Magnesium was alone but after bonding with oxygen magnesium will now loss two electrons.  
Those two electrons will go to oxygen atom.

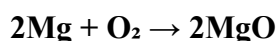
**Teachers:** Are we together?

**Learners:** Yes

**Teacher:** Are you sure? You guys are not sure



So, now this means magnesium is oxidised because it is given oxygen atoms.

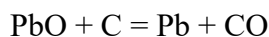


Teacher: Are we together? Let me give you another example.

Now here you are going to tell me which one is oxidised and which one is reduced. Because now we talk of oxidation whereby an element is given oxygen atom or it loses electrons and then reduction whereby oxygen atom is taken away from a certain compound or certain metal.

Teacher: Are we together?

Now, example :



Now from that equation, because it says we have redox reaction is a reaction whereby we have a reduction and oxidation at the same time.

Firstly we spoke of reduction and then oxidation, now I am giving you an example whereby everything both reduction and oxidation are happening.

Tell me which one are object, element is oxidised & which one is reduced or just explain what happens in this example?



What happens at A B C D in terms of oxidation and reduction?

Learners: At **A** Lead oxide is reduced to became lead

At **B** Carbon is oxidised to become carbon monoxide

Teacher: Good

Are you getting that one? As you can see here, as you are looking at A PbO lead is reduced to Pb while carbon is oxidised from carbon to form CO

Teacher: Are we together?

### ***Class work***

*When Zinc Oxide combines with Carbon, Zinc Oxide loses oxygen to form Zinc.*

*(a) Write a complete balanced equation*

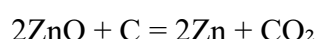
- (b) Show the half equation of Zn as it gain electrons  
 (c) Show the half equation of carbon as it loses electrons.

Teacher: I am coming around with a red pen

**A task was done in class and learners books where marked. Learners were given chances. Teachers know his learners name.**

Can I have someone to write the balanced chemical equation on the chalk board.

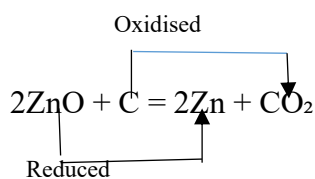
Learners answer



Who is agreeing with that answer? How many of you agree with that answers

**Learners raised their hands to show that they agree with the answer written on board.**

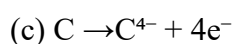
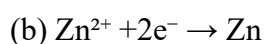
As you can see Zinc Oxide is reduced to Zn and C is oxidised to CO<sub>2</sub>.



I will give you two minute to answer letter **b** & **c**. Teacher walk around marking learners work.

As he was moving around the class teacher noted that learner were failing although examples were still on chalk board.

Teacher: You guys are failing something which is on the chalk board.



Teacher: Now close the book

Teacher: Someone close the chalk board

Before we go, I have to check if you have mastered this topic

- Our lesson objective says, the end of this unit you should be able to define oxidation and reductions in terms of oxygen gain or loss and in terms of transfer of electrons.

Teacher: Good, Who can define for me what oxidation is?

Learners replied that Oxidation is gain of oxygen atom and loss of electron

Learners replied that Reduction is a loss of oxygen and gain of electron

OK, who don't understand, tomorrow morning when you come you will write a quiz.

Are we together? There is a quiz tomorrow morning for everything we did today.

Teacher: This is all for today...

### **Teacher 1: 2<sup>nd</sup> Lesson about Redox Reaction**

Teacher: How are you?

Learners: We are fine Sir

Our lesson objective for today is:

1. Identify redox reaction by changes in ionic charges
2. Identify reducing and oxidising agents

#### Redox reaction by changes in ionic charge

Ionic charge is the measure of the number of electron lost or gained.

As you can see from the periodic table all metal, what happen, do they loss or gain?

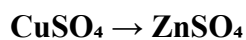
Learners: Metals loss electrons

Non-metal gain electrons

Examples:  $\text{Zn} + \text{CuSO}_4 \rightarrow \text{ZnSO}_4 + \text{Cu}$

**NB:** First check if the equation is balanced.

Now, when we talk about redox reactions by change in ionic charge we are only concern as to what is happening between



The metals only, we are not concerned about non-metal.

Are we together?

Learners: Yes sir

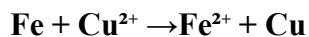
As you can see here we have:  $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$

Now, want us to quickly do another example we are going to do it step by step. Now we are going to look at how reaction like what like happen it to zinc copper there, but we are going to look at all this step.

### Half oxidation and reduction reactions

We are only going to look at oxidation and reduction part. **Zn** is oxidised to become **ZnSO<sub>4</sub>** while **CuSO<sub>4</sub>** is reduced to become **Cu**.

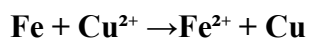
Example of our chemical equation will be a **redox reaction**:



If you look at these two equation they are almost the same.

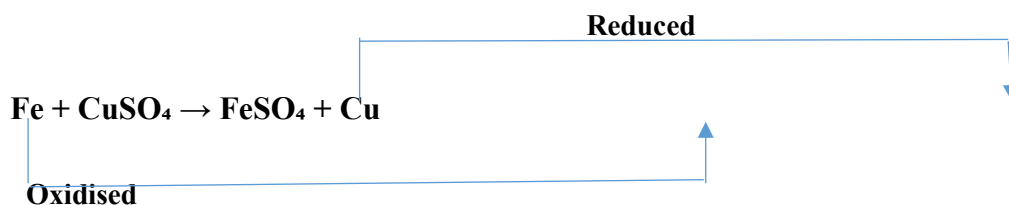
Now let us look at oxidation half-reaction.

Which one is oxidised?



If you look here Iron

Let us assume the equation was like this



Now oxidation half-reaction will be like this:  $\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$

Iron has to transfer 2 electrons.

Let us look at **Reduction half-reaction**.

$\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$  transferred 2 electrons to sulfate

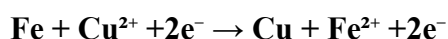
Now for you to have your full redox reaction now you have to add these half equation together to come up with your full redox reaction.

Add the half-reaction together to get full redox reaction.



If you add these two half equation what are you getting?

**NB:** We write the neutral equation First.



This is the final redox reaction, very easy neee.....?

If you know the half, reaction in each metal, you just add them together to get full redox reaction. In other words iron oxidised when something is oxidised, it loses electrons.

Fe – lose 2 electrons

Cu – gain its electrons

Then we are done with that part.

**For today, now let us look at the last objective identify oxidising and reducing agents.**

We said **Iron** is oxidised

**Copper** is reduced

Let us quickly check

Oxidising and reducing agent

What is oxidising agent and what is reducing agent?

Oxidising agents: are substances that causes oxidation in the substances they react with by giving oxygen or by receiving electrons that are lost.

Example of oxidising agents:

- Oxygen
- Potassium permanganate
- Potassium dichromate
- Chlorine

These are not the only one, but are common:

Reducing agents: Are substances that causes reduction by taking away oxygen or by giving electrons

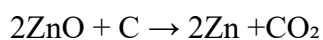
Example of common reducing agent:

- Hydrogen
- Carbon monoxide
- Hydrogen sulfide

For example, we have an example in a textbook here it says.

For example in the extraction of Zinc oxide to produce Zinc metals the zinc oxide give oxide to carbon therefore it is oxidising agent while carbon on the other hand is the reducing agent because it takes oxygen away from zinc oxide.

Example: Identify the reducing agent and the oxidising agent from the equation below.



From the definition of oxidising agent and reducing agent which one is

Learners: Oxidising agent – Zinc Oxide

Reducing agent – Carbon

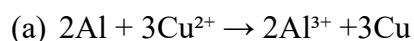
Which one is taking way oxygen?

Read the definition first and from there you will be able to identify them.

OK, I have a class work for you but it will deal with reducing and oxidising agent where oxygen is not present. Because you guys are more on oxygen. Any question before we proceed to class work?

### **Class work**

Determine which element is oxidised and which element is reduced in the following reaction.



Which one is (i) Oxidised?

(ii) Reduced?

If you are done, call me then I will mark your work.

Class work means everything is done in class and you finish it here.

Good people time is up, we will continue again tomorrow, but before we close off want one of you to give us a feedback of the class work.

How many of you get it like this?

Learners: Raised their hands

Teacher: she is correct

Teacher: Clap hands for her

**In other words it is easier to indicate from the reaction.** Let us stick to the name of element lets ignore the number of mole.

Leena you were the first to be marked.

I can see that our lesson objective for today were met.

**Thank you very much, we will meet again tomorrow.**

## Appendix K: Components of TSPCK

COMPONENTS	DESCRIPTION	LP - - (Weak)	LP <sup>-</sup> (Moderate)	LP <sup>+</sup> (Strong)	LP <sup>++</sup> (Very)
<b>Learner Prior Knowledge L(PK)</b>	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 rephrases explanations using one other component of TSPCK interactively.	Identifies misconception; provides standardized definition; phrases explanations using one other component; confronts and confirms accuracy of drawing on component interactively.
		CS <sup>-</sup> (Weak)	CS <sup>-</sup> (Moderate)	CS <sup>+</sup> (Strong)	CS <sup>++</sup> (Very)

<p><b>Curricular Saliency (CS)</b></p>	<p>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</p>	<p>Identified concepts are a mix of Big ideas and subordinate ideas; identified precepts are far from topic; sequencing of no value due to mixed concepts; reasons given are generic benefit of education.</p>	<p>Identifies at least 3 Big ideas; identified precepts 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.</p>	<p>Identifies at least 3 Big ideas; subordinate concepts correctly identified for all Big ideas; identifies precepts 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.</p>	<p>Identifies subordinate concepts identified explanatory precept topic and sequence with reasons importance reference scaffolding development TSPCK components makes topic</p>
	<p>of pre-concepts needed prior to teaching a topic</p>				
		<p><b>WDU<sup>-</sup> (Weak)</b></p>	<p><b>WDU<sup>-</sup> (Moderate)</b></p>	<p><b>WDU<sup>+</sup> (Strong)</b></p>	<p><b>WDU<sup>++</sup> (Very Strong)</b></p>
<p><b>What is Difficult to Understand (WDU)</b></p>	<p>Refers to gatekeeping concepts which are difficult to understand often because they cause conflict with previously established understanding</p>	<p>Identifies broad topics without specifying the subordinate subconcepts that are problematic</p>	<p>Identifies specific concepts but provides broad generic reasons such as abstract concepts.</p>	<p>Identifies specific concepts leading to learner difficulty; reasons given relate to one other TSPCK component.</p>	<p>Identifies subordinate concepts with reasons gatekeeping TSPCK components prior knowledge curricular</p>
		<p><b>RP<sup>-</sup> (Weak)</b></p>	<p><b>RP<sup>-</sup> (Moderate)</b></p>	<p><b>RP<sup>+</sup> (Strong)</b></p>	<p><b>RP<sup>++</sup> (Very Strong)</b></p>

<b>Representations (RP)</b>	Refers to a combination of representations	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 symbolic and submicroscopic representations to enforce
	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 aspects with other TSPCK, e.g., aspect of the representation prior knowledge
		<b>CST<sup>-</sup> (Weak)</b>	<b>CST<sup>-</sup> (Moderate)</b>	<b>CST<sup>+</sup> (Strong)</b>	<b>CST<sup>++</sup> (Very Strong)</b>
<b>Conceptual Teaching Strategies (CTS)</b>	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 knowledge confrontation of misconceptions; at least two curricular sequencing, discussing important aspects of the macroscopic representation submicroscopic to enable

## Appendix L: Stimulated Recall Interviews for Teacher 1

### Lesson 1

**Interviewer:** When you introduced your lesson you gave an explanation that redox reaction is standing for two words. One is reduction and another is oxidation. How do you define redox?

**T1:** Transfer of oxygen between two compound or molecules or substance, oxygen transferring from one compound to another or transfer of oxygen either electrons are lost or electrons are gained as well as can be defined in terms of transfer of hydrogen atom from one compound to another.

**Interviewer:** This topic of redox reaction do you think learners have prior knowledge about redox reaction they might have acquired from previous grade or from the community where they are coming from?

**T1:** For the learners in grade 11, I can only say maybe they have acquired prior knowledge when they studied ionic equation. When they did ionic bonding because it also involve transfer of electrons. Within the community I don't think they have acquired such knowledge.

**Interviewer:** Why was it necessary to take the learners back to ionic bonding where you say metals give away their electrons and become positive charged while non-metals gain electrons and become negatively charged. Why do you think it is beneficial to the learners to recap that part of chemical reactions?

**T1:** I think it is beneficial because it shows that whenever you are going to explain redox in terms of transfer of electrons then that has to do with the formation of ions. Where are the electrons coming from? Where are this electrons going? Meaning one of the species within the redox reaction one should lose those electrons and one should gain those electrons. So for them (learners) to understand better, I think it is necessary for one to take them back just to ionic bonding just to remind them that these two are closely related topic in terms of electrons transfer.

**Interviewer:** You used the main equation in the extraction of iron, why do you think this was suitable equation to determine or to get reduction and oxidation?

**T1:** It is what is required by the syllabus, to show redox reaction using examples of extraction of metals, especially extraction of iron, extraction of zinc and extraction of copper just to mention those. The curriculum require us as teacher to use those example to show reduction and oxidation because for the learners to understand that they are learning the process that is used for the extraction of metals which is useful and use them on daily basis.

**Interviewer:** You indicated that the syllabus does not require learners to know oxidation and reduction in terms of hydrogen. Why do you think it was necessary for the learners to know that part of hydrogen?

**T1:** I think it is necessary because we have those learners who are going to continue doing chemistry in the future and it is not something which is difficult is just in the same vain as explaining redox in terms of oxygen and in terms of electrons, so when they find the definition of redox but only referring to hydrogen they must not think it is wrong, that is why I think it is necessary for them to know that.

**Interviewer:** When you gave an example of a reaction where oxidation and reduction is taking place, don't you think maybe it was necessary to give more example?

**T1:** It is necessary to give more different example on the same topic but as I have said, the moment the learners get the concept then that it should not limit them to just that example that you gave them. Another example of reduction of copper than they should be able to answer that at the same time when you this redox reactions involving extraction, sometimes you reserve some question for assessment instead of giving them all them as example during lessons.

**Interviewer:** You said in the syllabus they have used the term ionic charge or oxidation number. You also said somehow they are used interchangeably but they are not the same. So what is the different between ionic charge and oxidation number?

**T1:** The different is in writing, when writing ionic charge you write the magnitude of the charge first followed by the charge while oxidation number you write the charge followed by the magnitude of the charge. The confusion is always there but the curriculum does not really put strict measure as penalize learners when they write it differently let me say they start with the

size of the charge or they start with the charge. So learners don't get penalized for that, that is the current curriculum that we are dealing with but I think at higher level I am not certain they penalize and at high level they are also required to calculate the oxidation number because the ionic charge there the overall charge of either single ion or a poly atomic ion. But if you are given a polyatomic ion each and every atoms of a specific elements in that ion has its own oxidation number that can be calculated.

**Interviewer:** This topic of redox reaction, for you to make sure your learners understand the topic well, how do you go about it, where do you start? What do the learners need to know before tackling this oxidation, reduction, How do go about it just to make sure learners understand what redox reactions are?

**T1:** These when you approach a topic because you have to define the term when they understand the definition of the term than you give an example in this case we use reduction of iron. For them to see that if you start for instance with  $\text{Fe}_2\text{O}_3$  and ending up with iron metal then they can see that the oxygen that was on  $\text{Fe}_2\text{O}_3$  has been lost than you explain to them that, that is reduction. For them to see that carbon from carbon monoxide to carbon dioxide, there is an increase in oxygen and the will really understand that that is oxidation. Meaning carbon monoxide gained oxygen so that is one aspect.

Another aspect is, for them to understand that when you have loss of electrons and that is oxidation and when you have gain of electrons that is reduction, now that one if you want to understand even further then you have to go to half equation likely for this curriculum it allows learners to know half-reaction. If you teach them half-reaction then I think they will understand better, they will see that this ion has lost or gain an electrons and they know that whenever there is a loss of an electrons that is oxidation. So write those half equation, you teach them those half-reaction because have done them already in electrochemistry so by the time you will come to redox it will be much easier. Also the curriculum is designed in such a way that it helps learners to understand the previous topic, the flow of topic is constructed in such a manner that the information flows and does not go back.

**Interviewer:** Reactivity series. Why do you say iron is more reactive than copper?

**T1:** The reactivity is done in such a way that different metals are put under the same condition or they are reacted with the same reagent so the reactivity series is formulated based on

observation. So, if you have two metals and you react them with an acid then what tell you what metal is more reactive is how fast the production of gas, let me say hydrogen gas is produced per unit. The faster the production of hydrogen in that case it means that, that metal is more reactive than the other one, where there is a slow production of hydrogen gas. So we just put them in the same condition and do the observation from there you see able to conclude.

## Lesson 2

**Interviewer:** Oxidising agent always gives away oxygen atoms or we can say it is always reduced. Can you give me an example?

**T1:** Equation of extraction of iron, in that equation we have iron oxide reacting with carbon monoxide to form iron and carbon dioxide. Now in that case from the definition of oxidising agent is a reactant that gives oxygen because it is doing something. What it is doing it gives out oxygen atom. So in that case  $\text{Fe}_2\text{O}_3$  is the one that is giving out its oxygen, so that is why we refer to it as oxidising agent and oxidising agent in turns become reduced.

**Interviewer:** When you are saying oxidising agent is a substance that gives away oxygen and its being reduced while reducing agent is a substance that receive oxygen and its being oxidised. Is this definition suitable in terms of electrons?

**T1:** Both terms in terms of electrons transferred and also in terms of oxygen because if you have for instance  $\text{Fe}_2\text{O}_3$  the oxidation number or ionic charge of iron in this compound is three  $3^+$ . Now for this  $\text{Fe}_2\text{O}_3$  is an oxidising agent which is reduced. Here you have a reduction in oxidation number of 3 to 0 meaning it has lost 3 electrons to form metal which is neutral. Therefore we say either the definition covers in terms of oxygen or in terms of electrons transfer or in terms of hydrogen and oxidation number.

**Interviewer:** Is half equation part of the syllabus? Do learners find it easy to write it down?

**T1:** Yes, it is part of the syllabus. Not at all because they, the problem is with learners what I have realised is that they don't know which side of the equation to put electrons especially when they are lost, because you tell them that whenever the electrons are lost then they have to be on the right side of the equation and whenever they are gained they have to be on the left

side of the equation. So you find a lot of mixed up when it comes to half equation and especially to balancing those half equation because the number of electrons gained and lost must be the same. So you find a learners they write the reduction half equation with different number of electrons to the oxidation half equation and the number of electrons need to be the same. So that in the challenge and other thing is that they are finding it difficult to grasp how to determine the ionic charge of a certain ion even the main group element they find it challenging let alone the transition elements it is quite challenging because, I personally feel like there is a huge gap in the level of the content of the curriculum to the level of the learners understanding from the previous grade. I think there is huge gap from the junior grade to the senior grade off course we know we are in this time where the curriculum is just changing its always a challenge when there is a change. But we hope that as time go our learners will get used to the curriculum maybe they will be able to understand better.

**Interviewer:** In this topic of redox reactions, apart from writing half equation is there any other thing that you consider to be difficult to the learners?

**T1:** Whenever you are doing redox reaction the learners tend to mix up when question ask them to define oxidation and reduction in terms of electrons transfer that where they mix up, they say gaining of electrons is oxidation and losing of electrons is reduction. But that one I don't think is something difficult is just that probably the understanding where they attach that to oxygen which are totally two different thing. The other thing is determining of oxidising and reducing agent this is where teachers have to empasise that an oxidising agent or reducing agent is either one of the reactant but you find learners saying or indicating a product that this is an oxidising agent and this is a reducing agent. So I am not sure if that is something difficult is just also a mixed up or just the level of understanding but those are the things we face on every time we are dealing with.

**Interviewer:** How do you handle the challenges that learners face to make sure that they do understand?

**T1:** One, not only in chemistry, sometimes learners do not understand as such but one aspect is also language a barrier. We have so many of our learners who are or cannot understand the medium of instruction very well and interpret it very well. Also they cannot express themselves in the medium of instruction which is English in this case. that could be, I think is one of the

main as to why learners sometimes find things difficult because they failed to understand these terms in their own vernacular language such as reduced, oxidised, reducing agent, oxidising agent. The other things in that aspect sometimes you have to / you will be forced to explain it in vernacular language just for their sake.

The other challenges that we face is the understanding otherwise we just, I tackle them in such a way that I give as much activity as I can and assess these learners just to see where they stand with the content of the topic but most of the time you just have to do with assessment, give a lot of work, whatever method one uses whether they use assignment, class activity or group task.

**Interviewer:** Apart from those difficulties is there any part of redox reactions, where learners do not struggle at all?

**T1:** Yes, like defining oxidation and reduction in terms of oxygen they don't struggle at all.

**Interviewer:** All in all what can you say about redox reactions? Is it an easy topic or difficult topic? How do you rate it?

**T1:** Is quite a challenge, you know in our classes we have different types of learners and I happen to teach learners that are below average who are average and who are way above average. For an above average learner whatever you explain they understand. For an average learner what you are explaining some for a below average learner a little bit a challenging but all in all most of the learners or a lot of them that I taught a lot of them are the below average learners. And quite also a considerable number learners and few are above average learners. So if I have to put those statistics into consideration I would say out of 10 I will rate it 5/10.

**Interviewer:** Thank you very much, I really appreciate it, I have learned a lot from this!

## Appendix M: Stimulated Recall Interviews for Teacher 2

### Lesson 1

**Interviewer:** Why is it necessary to start or introduce the lesson by stating lesson objectives?

**T2:** Before we start the lesson, learners need to know what we are going to talk about and what is expected of them from that certain lesson.

**Interviewer:** Do you think learners had a clue about losing and gaining electrons?

**T2:** They have a clue because we already did chemical reactions, the bonding part we have already talked about it, as well as formation of compound where by I explained how a certain compound is formed. Example this involve simple ions such as metal that transfer or losses electrons to non-metals. Also whereby we have complex ions such as sulfate ions whereby you have more than one elements.

**Interviewer:** Do you think learners have prior knowledge from the community where they are coming from or from the previous grade, apart from the previous lesson of chemical reactions about redox reactions?

**T2:** Previous grade yes, because physical science is like or was more like a repetition of everything like you will do periodic table from grade 8, 9, 10 and now grade 11. Is just that maybe from the community I'm not sure.

**Interviewer:** Why do you prefer to use this equation ( $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ ) to explain which compound is reduced and which one is oxidised?

**T2:** The equation itself is a redox reactions where by both oxidation and reduction are taking place at the same time. I wanted them to see, let me say if this compound is being reduced, what happens to oxygen atoms? They will now find that oxygen atom to the compound which is reacting with the first one. Also, when it comes to electrons gained I wanted them to understand that when you are saying an elements has lost an electrons, it is simply because

there is an ionic bonding happening. Let me say it has transferred, for instance if you are to draw an ionic bond then you can see that this certain electrons from the metal to the non-metals.

**Interviewer:** Do learners face challenges when writing half equations?

**T2:** Yes, very big one, I even noticed from the previous examination, some of them will write it correctly but some failed to get, to put which side the electrons will be and which side the ion will be because, the electrons is supposed to be on the side of the ion and on the other side will be a natural element itself. Now that one I think they tend to confuse it and when it comes to balancing them also troubles them.

**Interviewer:** Which part of redox reactions seems easy to the learners?

**T2:** Yes, especially when it comes to definition of oxidation and reduction in terms of oxygen and electrons.

**Interviewer:** Do your learners have problems writing chemical formulas?

**T2:** Yes, but not the simple ones like the one with one element in the ion they are easier to them. But polyatomic ions some, or most of them will get it but there is always those few individual that are struggling.

**Interviewer:** If learners have challenges writing chemical equations, what impact does it have on writing half equations?

**T2:** it has a big negative impact because sometimes they will not even know where to start.

**Interviewer:** When you are presenting the topic of redox reactions in the class how do you start and how do you end your lesson?

**T2:** First of all I have to give them the learning objectives, for them to know what is expected of them, that is what I always start with. Then we start with defining and the prior knowledge now came in when I was asking them what happen here when metal losses and when oxygen gained electrons. The ending part now in most cases I end with a small classwork activity, just to check if most of my learners have grasp the content I taught them for that specific day.

**Interviewer:** Which teaching strategies suit your learners to understand redox reactions better?

**T2:** What I did here I know most learners struggle when it comes to reactions but then that is why I opted to write on the chalk board, so they have to see what is happening, when I am saying this one is losing, then I am showing it on the chalkboard, then them they have to copy it in their book so that tomorrow when it comes in the test, they will know.

## **Lesson 2**

**Interviewer:** What were you expecting learners to know about the reducing and the oxidising agent?

**T2:** So, I actually wanted them or expected from them to know, when you are now talking about reducing agent in general English now is like something that is reducing the other thing. There should be a specific agent now maybe an atom or elements that will reduce the other one. Or take oxygen atom from the other element.

**Interviewer:** If learners have problems of writing half equation, what about net ionic equation?

**T2:** There are always those who will pass it in every class there is always those individuals, but again you will find the one who will not get it at all. Some struggle from half equation to net ionic equation.

**Interviewer:** Since learners struggle with this equation, how do make sure that all learners are at the same level of understanding?

**T2:** What I do is, let me say I give a class activity and realise that there are certain individuals who are not getting it right, because there is always that person where you want to mark and is always not done, sometime the person have not started, or maybe only wrote down the question, that is already a sign that they are struggling. I always have lesson in the afternoon studies or during evening studies just to repeat again the topic they are struggling with.

**Interviewer:** I have noticed that you gave multiple example to your learners as you were teaching. What is the advantages of using multiple reaction when you are teaching this topic of redox reactions?

**T2:** I think the first one is exposure, it exposes the learners to different reactions and it also help the learners because there are those learners who just memorises.

**Interviewer:** In conclusion, what will you say about redox reaction, is it an easy or difficult topic?

**T2:** To me, is very short and easy especially it contains a lot of definition such as of reduction, oxidation, reducing agent and oxidising agent, Which means that most of the learners will get something on definitions because they don't really struggle with them.

The part of calculations or reactions is the one that is a bit troubling the learners. Overall it is a moderate topic because it contain some easy parts and some difficult part that trouble the learners, but not all. But it is a very good topic.

**Interviewer:** Thank you so much!