An assessment of online learning materials on cumulative knowledge building in chemical reactions at Grade 10 through the lens of Legitimation Code Theory (LCT):

A case study of Mindset videos.

By

Tenson Jambaya

Student number: 1706882

Protocol Number 2022ECE007M

Supervisors: Dr Emmanuel Mushayikwa

Ms Nomfundo Radebe

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A research project submitted to the Faculty of Humanities, University of the Witwatersrand in partial fulfillment of the requirement for the degree of Masters in Education by combination of coursework and research report.

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ABSTRACT

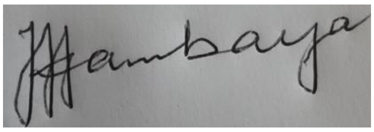
The Professional Teaching Standards (PTS) in South African schools have established cumulative knowledge building as the core of teachers' work. However, cumulative knowledge building is still an understudied field. The main aim of this research is to explore the effectiveness of Mindset videos as a teaching intervention to assist learners in grade 10, in order to develop adequate understanding of the concepts found in the topic of chemical reactions in Chemistry. Legitimation Code Theory (LCT) was used as a conceptual framework, with a specific focus on Semantic Density (SD) and Semantic Gravity (SG). The study employed a qualitative case study approach as this study used non-numerical data of the Mindset videos on chemical reactions which was interpreted and analysed in terms of how some chemical reactions concepts were taught. It also adopted a case study exploratory research design, a method established to explore a phenomenon that has not been researched or adequately explained before like the LCT and Mindset videos. Pre-recorded Mindset video observations served as the primary data collection method whereby two Mindset videos were observed and transcribed. The research sampling used in this study is a purposive sampling method. This is because the researcher understands the case explored in this study and therefore it is crucial to handpick the sample matching characteristics required for this research topic. The researcher had to pick two Mindset videos on chemical reactions purposively as the aim was to study the Mindset (and not any other types of videos) on chemical reactions to study them and make conclusions about the findings. In this study, data analysis involved observing two electronic documents, the two Mindset videos and interpreting them to answer the three research questions. Thus, document analysis, a form of qualitative research that uses a systematic procedure to analyse documentary evidence and answer specific research questions, was the approach to data analysis. The study's main findings revealed that Mindset videos are presented in a way that is accessible to learners and may reduce abstractness of concepts especially in the topic of chemical reactions. In this way, the Mindset videos are as good as conventional teaching, but they have the advantage of being supplementary to classroom teaching. After a grade 10 learner has been taught chemical reactions at school, s/he can supplement this with a Mindset video on the same topic. The Mindset videos are also helpful during learner non-contact times such as the COVID 19 lockdowns where learners were supposed to learn at home thereby contributing significantly to cumulative knowledge building.

Possible future studies on this study could include studying the effect of Mindset on learners who watch them as supplementary to the contact lessons on using performance tests. The other possible future study may include comparison of Mindset on chemical reactions as online methods in comparison to contact lessons on the same topic of chemical reactions. Can also compare effectiveness of Mindset videos and other companies produced videos on chemical reactions.

Key words: Professional Teaching Standards, cumulative knowledge building, Legitimation code theory, semantic gravity (SG), semantic density (SD), semantic ranges, COVID 19, online sessions.

DECLARATION

I, **TENSON JAMBAYA (1706882),** declare that this research study is my work. It has not been submitted before for any other degree or examination in any other university. All the work taken directly from other works has been cited accordingly and the full list of references has been provided. I fully understand that the University of the Witwatersrand will take disciplinary action against me if evidence suggests that this is not my own unaided work or that I failed to acknowledge the sources of the ideas or words in my writing.



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ABBREVIATIONS AND ACRONYMS

FET	Further Education and Training
CAPS	National Curriculum and Assessment Policy Statement
NSC	National Senior Certificate
ATP	Annual Teaching Plan
DoE	Department of Education
DBE	Department of Basic Education
SACE	South African Council for Educators
PTs	Professional Teaching Standards
COVID 19	Coronavirus Disease 2019
LCT	Legitimation Code Theory
SG	Semantic Gravity
SD	Semantic Density
SG−	Weak semantic gravity
SG+++	Stronger semantic gravity
SD−	Weak semantic density
SD+++	Stronger semantic density

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CHAPTER 1: INTRODUCTION AND OVERVIEW OF THE STUDY

1.1 Introduction and background

South Africa's education system and many other across the world, was disturbed in the year 2020 by the Coronavirus (COVID-19) pandemic. According to Mhlanga and Moloi (2020), learning in South Africa and the rest of the world came to a standstill due to lockdown regulations intended to reduce the spread of COVID-19. COVID-19 brought major challenges to the traditional education system which comprised of face-to-face lessons and daily attendance. Firstly, teachers with co-morbidities had to work from home. This was because international research had shown that individuals with certain co-morbidities (those with underlying medical conditions (such as cardiovascular disease, diabetes, chronic respiratory disease, and cancer)) were at higher risk of COVID-19 mortality (Spaull & Van der Berg, 2020). As a result, some schools were desperately understaffed.

Secondly, according to DBE Guidelines for schools on maintaining hygiene during the Covid-19 pandemic (2020), learners were supposed to keep a distance of at least 1.5 meters from others and where possible avoid gatherings and contact activities outside of the classroom such as contact sports, assemblies, and queuing at tuck-shops or for school feeding programme meals. This led to the rotational attendance of learners in schools due to the lack of sufficient space to cater for all the learners at once, especially in public schools where classroom overcrowding is already commonplace. According to DBE School Recovery Plan, in Response to Covid-19 (June 2020), the rotational attendance model had three possible forms as follows:

i) Rotate bi-weekly

The school population is divided into two groups. The first group attends school for the first two weeks in the month and thereafter the group remains at home for the remaining two weeks in the month, while the second group now attends school. This arrangement allows for a maximum of 50% of the remaining school population to attend school at a time, thus allowing for social/physical distancing to be accommodated.

ii) Rotate according to specific days in a week

In the second option, the school population is divided into two groups, with the first group attending school on three days of the week, followed by the second group attending school on two days of the week. This is then alternated with the first group attending school on two days of the week and the second group attending school on three days of the week.

iii) Platoon system

In the third option, the school population is divided into two with the first half of the school population attending school in the morning and the second half attending school in the afternoon. This is commonly referred to as the platooning system. It is aptly used in schools where space is limited.

Lastly, according to DBE Circular S7 of 2020, rotational attendance led to a loss of teaching time. According to Circular No. S2 of 2020 to mitigate the impact of the COVID-19 lockdown, the Department of Basic Education (DBE) working in collaboration with Provincial Education Departments (PEDs) together with teacher unions had to put together a school recovery plan which entailed the recovery of lost time, reorganization and trimming of the curriculum content and Annual Teaching Plan (ATP). The trimming of the ATP subsequently led to the reduction of assessment tasks to create more time for teaching and learning as stipulated in circulars S7 of 2020 and S17 of 2021, which articulated the following:

(i) The weighting of SBA is increased from 25% to 60% and the examination component is decreased from 75% to 40% resulting in a 60:40 split as opposed to the current 25:75 split.

(ii) The full-scale examinations in Grades 10 and 11 should be replaced by a controlled test.

This negatively impacted schooling and most schools in South Africa and worldwide, were encouraged to do online lessons to supplement to the traditional face-to-face teaching and learning.

Barak and Usher (2019) have pointed out that 'online learning' refers to any form of learning in which individuals are not physically present in a traditional classroom setting. Croxton (2014) noted that online learning holds great appeal to many students because it offers flexibility in participation, ease of access, and convenience. Appana (2008) indicated that online learning is any learning experience or environment that relies upon the Internet/World Wide Web (WWW or Web) as the primary delivery mode of presentation. Al-Benna (2020) in support of the idea of teaching moving online (virtual learning) went on to specify that this is conducted on platforms such as Skype, Zoom, and Microsoft Teams as well as industry-sponsored webinars, podcasts, and videos. According to Oberne (2017), one effort to promote an online community is through instructor-delivered videos. Instructors often post-introductory or weekly videos to engage their students in online courses. This shows that videos can act as an online method of giving instructions to learners. Online videos have been used as teaching interventions to enhance the teaching and learning of Chemistry. Benedict and Pence (2012) noted that videos can be accessed by learners to visualize elements from Chemistry manuals. This is because chemistry is an abstract subject that requires students to operate on three levels of thought which are the macro, the micro, and the symbolic levels (Chinaka, 2021). Learners generally have challenges or difficulties in understanding abstract and complex Chemical concepts (Jaber and BouJaoude (2012).

Online videos may help learners visualise the abstract content of Chemistry, in addition, they can see some chemical reactions which the teacher cannot do- due to a result of lack of resources. Online instructional videos are becoming increasingly common within education (Cooper, Higgins and Beckmann, 2017). There is however no study that the researcher has found that has attempted to assess the effectiveness of online videos like Mindset, in terms of knowledge building in the topic of chemical reactions at the grade 10 learning level in South Africa. Mindset videos are critical to study because they are the most broadcasted lessons on national television in South Africa, accessing millions of learners daily.

It is upon this background that the researcher sought to explore and assess the cumulative knowledge building practices of online learning materials in chemical reactions in Grade 10. Cumulative knowledge building is of paramount importance in physical sciences (Jackson, Rey and Járosi, 2017). Cumulative knowledge-building refers to learning practices that extends previous knowledge and integrates it with knowledge produced in different contexts and at different points in time (Maton, 2014). Clarence (2017) noted that students' ability to build knowledge and transfer it within and between contexts is crucial to cumulative learning and to academic success. Walton and Rusznyak (2020) contend that knowledge building is important in the process of learning because it allows teachers to integrate existing ideas from the learners with new knowledge. This makes learning meaningful and valuable to learners as they can relate to previously learnt knowledge.

An understanding of how teachers build knowledge using the semantics dimension of Legitimation Code Theory (LCT) (Maton, 2014) in online lessons on chemical reactions remains core to this research. According to Maton (2014), LCT is a practical framework that offers a potentially fruitful framework for exploring and shaping academic language and learning practices. It is a practical theory that offers an array of concepts that are used in empirical research to provide explanations of substantive problems (Howard and Maton (2011)). According to the LCT, any knowledge in chemistry has a specific vocabulary which precipitates into short phrases of complex ideas. Teaching an abstract, complex topic effectively may require the use of knowledge at lower cognitive levels (Chinaka, 2021).

1.2 Rationale of the study

Use of online videos as a method of giving instructions to learners has been in existence for a long time, but the insurgency of covid-19 has made its use in schools of paramount importance. Some of the videos used are from private organisations like Mindset, which is going to be used in this research, and some are prepared by the South African government through its Department of Basic Education (DBE) which are aired on the public television, South African Broadcasting Corporation (SABC) TV. According to Cooper, Higgins and Beckmann (2017) online instructional videos are becoming increasingly common within education. The researcher looked at the use of Mindset videos on chemical reactions for Grade 10 with the aim of finding their effectiveness on teaching the topic of chemical reactions to the grade 10 learners. Looking at what has been done so far regarding online learning in physical sciences under the topic of chemical reactions, it remained vital to conduct a study that looked deeper into the insights of knowledge building practices in teaching the topic of chemical reactions in online lessons videos. This is because the grade 12 learners have shown to have difficulties in answering almost all questions that are based on chemical reactions as indicated by the NSC Diagnostic Report Part 1 (DBE,2020). Presumably, the intervention at this lower grade may help the learners to understand the topic of chemical reactions and hence the motive to research on effectiveness of Mindset videos on this topic.

1.3 Problem statement

Chemical reactions have been chosen for studying knowledge building in videos because it is one of the basic science topics that is core to other chemistry topics and the Grade 10 content has been chosen because this is where the topic is introduced. It has also been chosen because it is a topic that has been found to be very demanding in Matric. Therefore, the research needed to consider if Mindset videos can be instrumental in helping learners understand and hence build knowledge on this topic at the lower Grade 10 level.

The South African Council for Education (SACE) along with the Professional Teaching Standards (PTSs) suggests that knowledge building is the core of the teachers' work. Cumulative knowledge-building refers to learning that expands and connects prior knowledge with knowledge generated in different contexts and at different times (Maton, 2014). Knowledge building on the topic of chemical reactions at the Grade 12 level is still challenging, as most learners have difficulties in writing chemical equations for reactions, many wrote incorrect reactants (Sulphuric acid instead of Nitric acid), others wrote the incorrect products and many still have problems in chemical/compound formula writing (NSC Diagnostic Report Part 1: DBE, 2020). This could be because of poor learning experience due to a lack of teaching and learning materials, specifically in schools in rural areas (Gardiner, 2008; Mlachila & Moeketsi, 2019; Zenda, 2020). According to Rootman-le Grange and Retief (2018), chemistry has a hierarchical knowledge structure, which denotes that an understanding of certain primary concepts is a prerequisite for being able to understand more advanced concepts. A subject such as Chemistry, where the content is already complex and abstract, has a direct impact on the learners' ability to learn new concepts. It is therefore crucial that an effort is made to make explicit the connectedness of concepts and the hierarchical knowledge structure of chemistry to support students' learning of the subject (Rootman-le Grange and Retief, 2018). Although knowledge building remains at the core of the teachers' work as stipulated by the South African Council for Education (SACE), it is often understudied even though it plays a huge role in teaching and learning. Studies conducted by Maton (2013) and Scardamia and Bereiter (2020) revealed the importance of knowledge building in teaching, however little research have been done on knowledge building especially on the topic of chemical reactions using Mindset videos.

Hansch, Hillers, McConachie, Newman, Schildhauer and Schmidt (2015) note that video content plays a central role in online learning, as it is typically the main form of content delivery leading to knowledge building. Hansch et al. (2015) went on to say that many questions regarding the effective use of video in learning remain unanswered. Therefore, the aim of this research project is to assess the effectiveness of the use of Mindset videos on cumulative knowledge building on the topic of chemical reactions using the Legitimation Code Theory. It sought to explore the effectiveness of Mindset videos as supplementary/adscititious resources to enrich the learning experiences for learners in grade 10 to develop an adequate understanding of the concepts found in the topic of chemical reactions in Chemistry. We have not yet come across any study in the South African context which has looked at this area. Therefore, not much is known about the effectiveness of Mindset videos in enhancing the learning of the topic of chemical reactions from the LCT perspective.

1.4 Objectives of the study

The specific objectives of the study can be summarized as follows:

a. To gain insight of how effective Mindset videos are on the teaching of chemical reactions to Grade 10 learners using LCT and how the concepts of chemical reaction and equations are developed in online videos.
b. To describe how the teacher reduces the complexity and abstractness of the concepts of chemical reactions and equations when teaching online.

1.5 Research Questions

Using the semantic dimension of the LCT, this study seeks to answer the following research questions:

Main/Primary research question:

How effective are Mindset videos on the teaching of chemical reactions to grade 10 learners?

Secondary/Sub-research questions:

1. How are the concepts of chemical reactions and equations developed in online videos?

2. How does the teacher reduce the complexity and abstractness of the concepts of chemical reactions and equations when teaching online?

1.6 Significance of the study

This study will contribute to an understanding of the knowledge-building processes of online learning using the concepts of Semantic gravity and Semantic density. This is significant considering the increase in the number of online schools and at the same time the increase in online videos. An understanding of knowledge-building processes using the semantic gravity and semantic density by science teachers is critical because it enables them to change a body of knowledge into more understandable, more accessible, and more relevant forms that can be integrated with new knowledge and is transferable to different contexts during the lessons they teach. This study, therefore, is of importance to teachers, and educators alike. The findings of this study can provide the Department of Education knowledge needed for the professional development of in-service teachers, on how they can create videos with content that is accessible and relevant to learners. At the same time, the findings of this study are useful to higher education institutions (HEIs) involved in training pre-service because of the need to train their teachers on how to make online videos so that they can use them as interventions.

1.7 The structure of the report

This report consists of five chapters. The first chapter contains the introduction of this research report which is on the assessment of online learning materials on cumulative knowledge building in chemical reactions at Grade 10 through the lens of Legitimation Code Theory based on a case study of Mindset videos. In the introduction, the background upon which the research was started, the challenge of the Covid-19 and online lessons is stipulated. The problem statement mainly based on Matric learners' failure rate on the topic of chemical reactions was also stated and followed by the objectives of the study. The main research question supported by two sub-research questions were also stated. This was followed by significance of this study and where the study may be of great help to the new era of online learning taking place all over the world.

Chapter two focuses on the literature review and conceptual/theoretical framework, where the insight of great authorities of online lessons and videos and authorities on the teaching of chemical reactions were consulted and quoted. The conceptual/theoretical framework used is the Legitimate Code theory which assisted in the process of data collection by revealing the cumulative knowledge building practices used in the Mindset videos using semantic waves.

Chapter three focuses on the research methodology, where the research paradigm, the constructivist/interpretive paradigm which focuses on human interpretations of the social world was adapted and supported by the qualitative research approach since the report is on a case study of Mindset videos. A case study exploratory research design was chosen as the research design for the report. Chapter three ends with data collection and also shows the validity and reliability of the report findings.

Chapter four is mainly about presentation of findings and discussions to answer the research questions. Translational devices on Semantic gravity and Semantic density were used in the presentation of the findings. Graphs were drawn as a way of presenting the findings on each of the research questions.

Chapter five is about discussion of findings and conclusion. A summary of findings on each research question was given followed by the discussion of the findings. The conclusion where the videos were generally recommended for use was given as well as implications of the findings and limitations of the study.

1.8 Summary of Chapter 1

This chapter managed to introduce the topic of this study entitled, 'The assessment of online learning materials on cumulative knowledge building in chemical reactions at Grade 10'. It goes on to include the background of the study where the study has been necessitated by the high failure rate of Matric learners on the topic of chemical reactions. Research questions are part of this chapter, a chapter concluded by the significance of the study, which is mainly to contribute to an understanding of the knowledge building processes on online learning using the concepts of Semantic gravity and Semantic density.

CHAPTER 2: LITERATURE REVIEW AND CONCEPTUAL/THEORETICAL FRAMEWORK

The aim of this chapter is to identify what has been done in the field of online learning, to locate any knowledge gaps. A literature review was conducted on the following concepts: online videos (on chemical reactions in science), chemical reactions as a topic in Grade 10 chemistry as well as cumulative knowledge building and semantics. The theoretical framework of this study is also going to be discussed in this chapter.

2.1 Background on chemical reactions

Many researchers have done a lot of research on the topic of chemical reactions research. Some of such researchers are Jaber and BouJaoude, (2012). The purpose of their research was threefold:

(i) to identify the difficulties that Grade 10 students in a Lebanese school have that hinder their conceptual understanding at the micro–macro–symbolic interface in chemistry,

(ii) to investigate the effect of a macro–micro–symbolic teaching approach on students' relational understanding of chemical reactions, and

(iii) to characterize students' conceptual profiles regarding their understanding of chemical reactions in terms of macro, micro, symbolic levels, and the relations among them, at the end of the teaching sequence.

So, this research was mainly to help Grade 10 learners in Lebanon to understand chemical reactions in their microscopic and macroscopic state. In this research the researcher also discussed this as one of the ways of methods used to study chemical reactions.

Weinrich, and Talanquer (2016) also came out with their own study. The central goal of this study was to analyse the complexity of students' explanations about how and why chemical reactions happen in terms of the types of causal connections students built between expressed concepts and ideas. A central goal in chemistry education is to help students understand why and how chemical reactions happen. These studies have revealed that many students struggle to understand the concept of chemical substance (Yan and Talanquer,(2015) and tend to rely on surface macroscopic features of reactants and products rather than on submicroscopic models of matter to predict the outcomes of chemical reactions (Barthlow and Watson, 2014). The central goal of our investigation was to explore the different modes of reasoning expressed by students with different levels of training in chemistry when thinking about chemical reactions selected to produce a targeted product. Linear causal reasoning was the major mode of reasoning found as well as relational reasoning when thinking about chemical reactions.

Different researchers took their time to research on chemical reactions, this researcher is going to research on the same topic of chemical reactions, concentrating on the effectiveness of the Mindset videos as very little if any of such research has ever been done.

2.2 Approaches to teaching chemistry (in general) and Chemical Reactions in particular

The topic of chemical reactions is under the strand Chemical change (DBE Grade 10 Recovery Annual Teaching Plan (ATP) (2021) which is a strand under chemistry. According to Barthlow and Watson (2014), chemistry is a branch of science that should be taught with student- centred activities, because it contains many abstract concepts which are difficult to be grasped by learners. Therefore, hands on activities, audio-visual aids and demonstrations should often be used in teaching abstract concepts such as chemical reactions as knowledge building occur when ‘’experiential knowledge is extracted from the context in which it was produced and then conceptualised so that the knowledge is applicable beyond the specific context in which it was created’’ (Walton & Rusznyak, 2020, p, 23). These hands-on activities, audio-visual aids and demonstrations should help in cumulative knowledge building. Ensuring that learners are constructing or reconstructing correct frameworks for their new scientific knowledge during the instruction is critical to their learning (ÖZMEN and Alipaşa (2003)). The chemical reaction topic in grade 10 includes the following sub-topics: chemical word and symbol equations, balanced chemical equations, use of (s), (l), (g) and (aq.) indicating phases and conservation of atoms and mass as well as law of constant composition (DBE National Recovery ATP (2021)). According to Øyehaug and Holt (2013) chemical reaction is an example of chemical change as opposed to change of state of matter (like melting), dissolution which are examples of physical changes.

To be able to teach this topic, Rootman-le Grange and Retief (2018) suggested, that chemistry has a hierarchical knowledge structure, which means that an understanding of certain primary concepts is a prerequisite for one to be able to understand more advanced concepts. Learners' ability to learn new concepts in a subject such as chemistry which already has complex and abstract content is negatively affected. It is therefore crucial that effort is made to make explicit the connectedness of concepts and the hierarchical knowledge structure of chemistry to support learners' learning of the subject (Rootman-le Grange and Retief (2018)).

A review of literature has revealed a few other studies in the South African context on the teaching and learning of chemical reactions, (Maake (2019), Kibirige & Maake, (2021)). The two studies focussed on the effect of guided discovery instructional strategy on grade nine learners' performance in chemical reactions. This study established that Guided Discovery Instructional Strategy (GDIS) improved learners' conceptual understanding regarding chemical reactions. Guided Discovery Instructional Strategy is generally defined as instruction in which learners construct essential information for themselves with minimum guidance from the teacher (Shieh & Yu, 2016). The teacher acts as a facilitator while the learner does the learning with guidance from the teacher. This approach is based on the constructivist theory which believes in designing activities where learners are actively learning to gain knowledge rather than transmitting knowledge (Kibirige & Maake, 2021). Learners construct knowledge themselves with the help or guidance of the teacher. The benefits and weaknesses (disadvantages) are discussed.

2.3 Types of approaches to teaching chemistry, particularly chemical reactions

2.3.1 Guided discovery

Studies indicated that traditional teaching strategies are less effective with learner performance Elfaki, Abdulraheem and Abdulrahim (2019). According to research, teachers normally use direct instruction to teach chemical reactions, where learners are provided with information that fully explains the concepts and procedures that learners are required to learn (Clark, Kirschner, & Sweller, 2012). In this teaching strategy, the teacher presents well defined knowledge and skills and explicitly guides the learning process. Learners are required to memorise what the teacher says rather than allowed to discover ideas (Mayer, 2004). Yet, there is evidence from the literature that learners use their experiences to create the understanding that makes sense to them rather than delivering knowledge to them in already organised forms (Eggen & Kauchak, 2012, p. 124), a teaching strategy called guided discovery method.

According to Maake (2019), who did research on the effect of guided-discovery instructional strategy on learner performance in chemical reactions in grade 9 in Mankweng circuit, Limpopo, South Africa, the benefits of using guided discovery to learners include an intrinsic need to learn science. Learners are motivated to move beyond knowledge and comprehension and into application and analysis. In addition, guided discovery increases intellectual potency by enhancing the learner's ability to organize and classify information (Akimbobola & Afolabi, 2010; Mirasi, Osodo & Kibirige, 2013). Information becomes embedded in the cognitive structures of leaners. This information can be retrieved later on in the learner's memory as s/he answers questions say in an examination. Amor and Maaloul (2016) indicated that learners taught through guided discovery develop confidence and construct their creativity skills, to familiarize themselves with the world. Creativity is encouraged when learners are actively involved (Maake (2019)). The learners also become responsible in self-learning and keep what they have learned (Gholamian, 2013). However, there are also shortcomings or difficulties in using the method (Maake, (2019)). It is not easy to learn by yourself as a learner and the method is time consuming as compared to lecture or exposition method. A few studies show that some learners resist active learning (Seidel & Tanner, 2013). Guided discovery which is based on the constructivism is the best approach of teaching chemical reactions as it agrees with the learning theory (constructivism) adopted by the LCT framework. According to Jaber and BouJaoude (2012) in light of this framework (LCT), learning is viewed as the active process of meaning making in the mind of the learner, against a background of prior knowledge and experiences. During this process, teachers have a pivotal role in helping students gradually integrate and reconstruct the conceptual structure of the academic discipline under study, such as chemistry. The Mindset videos are supposed to provide this guided discovery approach to help learners to construct their own knowledge.

2.3.2 Macro-micro-symbolic approach

The other study in a different context was done by Jaber and BouJaoude (2012) who focused on the macro–micro–symbolic teaching to promote relational understanding of chemical reactions. Before discussing this study, explaining the terms macro-, micro- and symbolic representations is important. According to Adesoji and Omilani (2012) macroscopic representations describe bulk properties of tangible and visible phenomena in the everyday experiences of learners when observing changes in the properties of matter (e.g., colour changes, pH of aqueous solutions, and the formation of gases and precipitates in chemical reactions). Shwartz, Dori and Treagust (2013) described macroscopic level as one which deals with the sensory/visible phenomena such as how solid salt dissolves in water. Microscopic (or molecular) representations provides explanations at the particulate level in which matter is composed of atoms, molecules and ions (Chandrasegaran et. *al.,* (20007)). Hanson (2017) described the third representation, symbolic (or iconic) representations, as that which involves the use of chemical symbols, formulas and equations, as well as molecular structure drawings, diagrams, models and computer animations to symbolise matter. This multi-levelled way of thinking can be represented by the corners of a triangle, as illustrated in Figure 3,

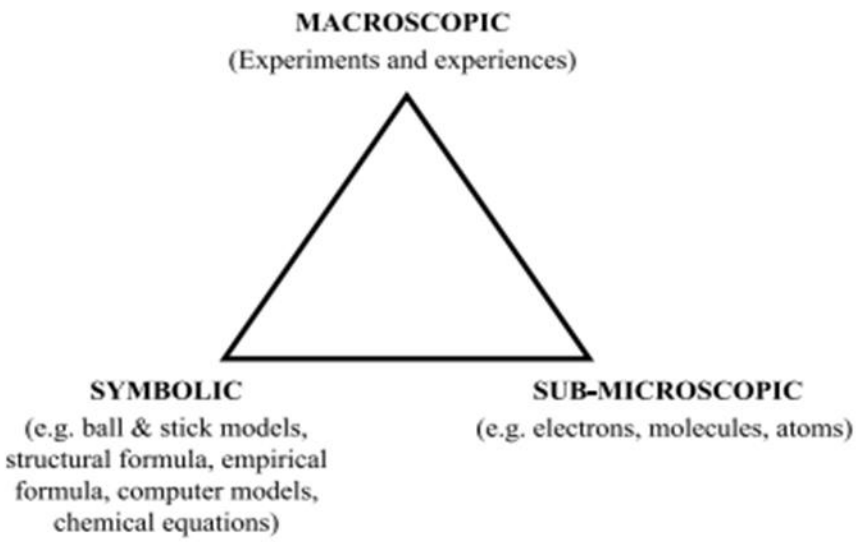


Figure 1 The three representational levels in chemistry (Johnstone, 1991 in Jaber and BouJaoude (2012)).

The purpose of the Jaber and BouJaoude (2012) study was threefold:

(i) to identify the difficulties that Grade 10 learners in a Lebanese school have that hinder their conceptual understanding at the micro–macro–symbolic interface in chemistry.

(ii) to investigate the effect of a macro–micro–symbolic teaching approach on learners' relational understanding of chemical reactions, and,

(iii) to characterize learners' conceptual profiles regarding their understanding of chemical reactions in terms of macro, micro, symbolic levels and the relations among them, at the end of the teaching sequence.

The outcomes of this study according to Jaber and BouJaoude (2012) were:

(i) Most learners were able to interpret chemical reaction at the macroscopic level, for example 'a black solid is formed'.

(ii) Major impediment to conceptual understanding can be attributed to learners' inappropriate application of macroscopic reasoning to explain phenomena at the microscopic abstract level. For example, interpreting the decrease in the size of the metal sheet as a result of the shrinking of the molecules.

(iii) Learners tended to exhibit difficulties in understanding the epistemic nature of models. Rather than viewing models as human constructions that illustrate abstract concepts (symbolic and microscopic), learners tended to perceive models as exact copies of reality. Learners seemed to consider models as the source of 'truth' rather than as tools to enable a simplified representation of reality and as tools for reasoning.

(iv) Learners' relational understanding can be fostered by an explicit teaching of the nature of chemical knowledge in terms of macro, micro, and symbolic realms and the relations among them. The macro–micro–symbolic teaching of chemical reactions provided learners with an alternate framework for their ontological knowledge to construe chemical change as an emergent process. By modifying learners' ontological knowledge, the macro–micro–symbolic teaching approach fosters conceptual and relational understanding by learners.

So, when a teacher is teaching chemical reactions to the learners, s/he should first make learners understand the three levels, the macro, the micro, and the symbolic especially when talking about atoms, elements, molecules and compounds. This will help learners to understand the topic with depth.

The advantage of the macro–micro–symbolic teaching is that it helps learners to understand the abstract chemistry in general, and chemical reactions in particular, better as they would be understanding and knowing all the three levels/representations. Jaber and BouJaoude (2012) suggested that emphasizing the existence of three levels and the associations among them will facilitate transformations students need to perform better. The disadvantage is that it is quite difficult for most learners to understand these three levels and it is also time consuming to teach these levels as if it is part of chemistry chemical reactions content. According to Dori (2003) learners find it difficult to transfer from one level to another and chemistry teachers sometimes do not pay sufficient attention to explaining these transitions.

2.3.3 Computer simulation approach

Another approach used for teaching chemical reactions is computer simulations. According to Daaif, Zerraf, Tridane, Chbihi, Moutaabbid, Benmokhtar, and Belaaouad, (2019) computer simulations refer to a set of computer programs that run on computer and which are based on the implementation of models, theoretical or practical in experimentation to simulate a physical or chemical phenomenon. In the process of teaching and learning of science subject, especially the science of chemistry, computer simulations provide opportunities to create environments of learning such as support of visualization of scientific phenomena and data capture and representation (Daaif et. al (2019)). According to Salame and Makki (2021) interactive simulations are a powerful tool for scientific thinking. Salame and Makki (2021) further noted that interactive simulations are dynamic; can be highly interactive; they can scaffold inquiry; they can provide multiple representations; and they can be readily disseminated and incorporated into classroom settings. A worthwhile goal for science education is to develop simulation pedagogies that maximize student learning (Lindgren and Schwartz (2009)). Computer simulations help learners to understand because learners can see the graphical representations like two atoms of oxygen (O_2) shown to combine with four atoms of hydrogen (or two molecules of H_2 ($2H_2$) to form/produce water molecule with four hydrogen atoms and two oxygen atoms ($2H_2O$). The learners see the atoms in form of small, coloured balls combining forming a new substance. Computer simulations like any other teaching approach, has benefits and limitations.

Zendler and Greiner (2020) assert that computer simulation is advantageous, as it can help students to get routine work done without much effort as is the case with experimenting and can be used for illustrative purposes. This is not necessarily possible with a normal experiment due to time and cost (Zendler and Greiner (2020)). This shows that computer simulation is less time consuming, for example the time for showing the heating and cooling of water to produce a heating and cooling curve of water takes less time using computer simulation than doing the practical in the laboratory.

The other advantage according to Xie and Tinker (2006) is that computer simulation on chemical reactions can easily dispel the common learner misconception that a reaction ceases upon reaching equilibrium as students would be seeing the continuous making and breaking of bonds. Although each bond-making and bond-breaking event in the simulation can be set to be unidirectional with certain parameters, these events can combine in a simulation to result in chemical reactions that can proceed in both directions and exhibit a dynamic equilibrium (Xie and Tinker (2006)).

The user can easily start, stop, and examine frame-by-frame a simulation and can quickly change the starting conditions and parameters in computer simulation to get different results

(Xie and Tinker (2006)). This is supported by Fang and Guo (2016) who noted that learners can change the input parameters of the computer stimulation and animation module and immediately observe how computer animation and the values of variables change simultaneously. For example, in rate of reactions, the concentration of nitrogen or hydrogen can be changed in the Haber process to see the effect of change of concentration on the rate of reaction. Therefore, students not only see 'what' happens (via computer animation), but also understand 'why' and 'how' it happens (modelling) Fang and Guo (2016). Another advantage according to Chiu and Linn (2014) is that interactive computer simulation and visualization of chemical reactions at the atomic scale could help learners understand the connections between chemical reaction equations and atomic interactions. Observing chemical reactions as emergent behaviours from the time evolution of an atomic scale model is expected to help learners build intuitive, coherent, and predictive mental models of the atomic interactions that constitute chemical reactions (Yu and Chen (2012)).

According to Fang and Guo (2016) the computer simulation and animation (CSA) has a limitation in correcting persistent student misconceptions. This implies that the CSA cannot replace human teachers or tutors in teaching high-order thinking and reasoning, because human teachers or tutors can offer flexible methods of teaching (such as using metaphors and real-world demonstrations), where the CSA is limited in this aspect.

The other disadvantage is that in developing countries like South Africa, most schools and most learners cannot afford to have the computers to use for the simulation or do not have the full technological know-how on this computer simulations and hence its implementation is limited (Cook and Steinert (2013)).

In this study, computer simulations were used by the presenter when she was presenting on balancing of chemical equations. The presenter used blue balls of nitrogen and yellow balls of hydrogen and made sure that at the end the number of blue nitrogen balls on the right were equal to the number of the blue balls on the left. Equally so, the number of the yellow hydrogen balls on the right were made to be equal to those on the left. The presenter could move the balls and make them balance and move them to unbalance them and so on. This helps learners to understand balancing equations better, but the presenter must always be careful of some misconception brought about by different colours of atoms.

2.4 Online videos and online learning materials on Chemical reactions

Online videos provide a means for online learning. Online learning is any learning experience or environment that relies upon the Internet/World Wide Web (WWW or Web) as the primary delivery mode of communication and presentation (Appana, 2008). Ally (2008) defined online learning as the use of the Internet to access learning materials; to interact with the content, instructor, and other learners; and to obtain support during the learning process, in order to acquire knowledge, to construct personal meaning, and to grow from the learning experience. This implies that the learner is at a distance from the tutor or instructor, that the learner uses some form of technology (usually a computer) to access the learning materials and that the learner uses technology to interact with the tutor or instructor, content and with other learners.

According to Alexander, Truell & Zhao (2012), researchers have documented learners' experiences with online courses and found that several variables affect course completion. They went on to say other areas studied included predicting patterns of online student effort, performance, and success. They also suggested that implementing new online strategies, and assessing and evaluating course offerings needs to be ongoing as a continuation of research as well as designing and refining online course delivery methods. This study is going to look at the effectiveness of Mindset videos as an online method of learning to compliment other research on online learning. But first, the researcher is going to look at the advantages and disadvantages of online methods of learning.

According to Alexander, Truell & Zhao (2012) the advantages of online learning include the convenience factors; not having to pay attention to dress, to not worry about how to get to class (transport concerns), dealing with bad weather, and flexibility of allowing learners to work on the course at their own convenience. This may lead to "lifelong" learning opportunity (Appana, 2008:_Sit, Chung, Chow, & Wong (2005)). Online learning enabled learners to hold a higher level of accountability for their own learning and allowed for independent learning (King, Logan and Lohan (2019)). Another advantage of online learning is for the educator, not having to deal with other students disrupting classroom teaching. Alexander, et. al. (2012) also gave disadvantages of taking online courses with the lack of face-face interaction, namely an increasing likelihood of procrastinating, not understanding content, and lack of self-discipline for reading and learning. Other disadvantages also include misunderstanding assignment directions as well as using the computer for other non-related course activities, such as Facebook, WhatsApp, while working on the course. In developing countries like South Africa, the other disadvantage of online lessons is that the parents of the children can hardly get the technology needed like computers to use for the online lessons. Langmia (2006) asserts that not everyone in the third world has access to this resource and those who do, often lack the knowledge and ability use the technology.

In this study, the online method of teaching and learning is the use of online videos. Hansch, McConachie, Schmidt, Hillers, Newman and Schildhauer, (2015) note that video is an essential component of online learning. According to Jordan, Box, Eguren, Parker, Saraldi-Gallardo, Wolfe and Gallardo-Williams (2016), videos are widely used as a teaching tool in the organic chemistry classroom; and are rapidly growing in popularity in content provision and assessment due to the widespread use of technology. Videos are therefore used to provide content to learners as well as for assessment, as methods of instruction or as intervention (Holland, Smith, McCrossan, Adamson, Watt, & Penny (2013).

Hansch et. al (2015) noted that there are two video production styles that are featured prominently online (see Figures 1 and 2): the talking head style, where the instructor is recorded lecturing into the camera, and the tablet capture with voiceover style (e.g., Khan-Academy style).

Figure 2 Talking head style

[Source: Hansch et. al (2015)]

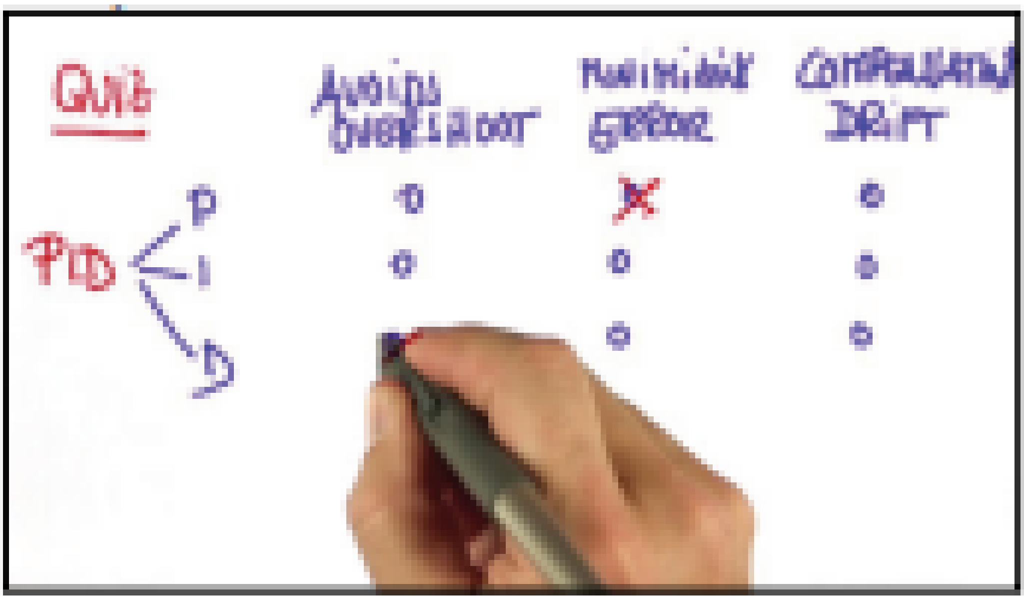


Figure 3 Tablet capture style

[*Source: Hansch et. al (2015)*]

This study focussed on Mindset videos which uses the talking head style in their presentation. This approach is employed because the talking head style has more advantages over the tablet capture style.

The advantages of talking head style are that it can be used to build a connection between the person on-camera and the viewer who is the learner. In addition, multiple camera angles are used for easier editing and to break monotony (Hansch et. al (2015)). Hew and Lo (2020) gave the following advantages of the above style: presentation materials (e.g., PPT file) could be reused, presentation of each slide could be recorded separately and in the event of re-shooting, all materials and scene could be restored easily. Other advantages of talking head style are that it harnesses learning motivation, increases learning performance, satisfies individual learning needs with different learning styles, and selects the most appropriate format to facilitate learning (Chen and Wu (2015)). According to Hansch et. al (2015), the disadvantage of talking head style is that although there will be connection between the presenter and the learner, the speaker's personality does not come across to the learner, that is, the learner knows nothing about the presenter's personality as is the case in a contact classroom.

The advantage of the tablet capture style, described as 'Chalk and talk' style made on a digital tablet is that it is relatively cheap and easy to produce, it makes learners benefit from seeing step-by-step how an instructor assembles or creates complicated ideas when writing on the board (Hansch et. al, 2015). According to Hansch et. al (2015) the disadvantage of the tablet capture style is that at times the handwriting is not legible to the learners.

According to Hansch et. al (2015) when used correctly, video can serve as a powerful teaching tool. Koumi (2006) describes three types of value that video is well placed to add in an educational context: (a) cognitive, (b) experiential, and (c) nurturing. Cognitive value includes visual strategies to assist learning, such as demonstrations of processes using animated graphics.

Provided that the video has been well designed pedagogically, the learning outcomes of the techniques and teaching functions in the cognition domain are outlined below:

- Aid synthetic, analytic and discrimination skills
- Help learners to share the teacher's imagery, particularly powerful in interspersing real life with animation of obscured motion.
- Concretise abstract processes.
- Illustrating abstract concepts with evocative real-world examples, hence making the concepts more tangible
- Modelling a process with tailored, simplified version, which scaffolds learning by showing only pertinent features
- Contrasting situations or processes to aid discrimination
- Pruning real-world processes by say, editing, thus bringing the duration within the viewer's concentration span
- Narrative power to create coherence and aids recall through its network of causal links and signposting (Koumi, 2014).

Koumi (2006) noted that experiential value provides vicarious experiences, allowing viewers to see something in a video that they might not be able to see in everyday life. Thomson, Bridgstock and Willems (2014) concur that the experiential value of video relates to vicarious learning, to show aspects of places and interactions between people. It may be easier, less resource intensive and more effective to take students on a video-based 'virtual field trip' to show them situated exemplars rather than to take them to visit a place of interest (Thomson et. al (2014)).

Nurturing value refers to video's power to motivate and connect with its audience through the affective domain (Koumi (2006)). Thomson et. al (2014) note that nurturing value refers to connecting with the audience in the affective domain. Videos can be used to increase motivation to learn through humour, entertainment, or inspiration (Thomson et. al (2014)). According to Koumi (2014) nurturing affective characteristics reveal that the ambition of the affective roles is to change a viewer's character, that is to effect enduring changes in a viewer's motivations and feelings, in this case the viewer, is the learner. If the learner is motivated by the video and likes it, the learner can concentrate and will acquire knowledge from the video.

The three types of value that videos add in an educational context including (a) cognitive, (b) experiential, and (c) nurturing (Koumi (2006)) discussed above are very important to this study. They underpin the framework of LCT. According to Maton (2009), the framework (LCT) provides tools to evaluate, amend or design curricula to provide the dimensions of cognition, experiential and nurturing in order to facilitate cumulative learning. The three types of value of videos help in the accumulation of knowledge because when learners experience the real world (vicariously but realistically) their study is grounded in context (Koumi, 2014). Jonassen (1991) argues that context provides 'episodic memory cues that make the acquired knowledge more memorable' (p. 37), thus enabling cumulative knowledge building.

Using videos as an online method of instruction or intervention has some advantages and disadvantages as revealed by different research.

2.4.1 Advantages of (online) video instruction

According to Bravo, Amante, Simo, Enache and Fernandez (2011), videos as an educational tool helps increase students' motivation in any discipline, in this study, in chemistry. Use of videos in chemistry lessons, specifically on chemical reactions, motivate learners as they see the macro-, micro- and symbolic stages of compounds and chemical reactions (Herga, Čagran and Dinevski (2016)). Jordan et. al (2016) note that there are many benefits of using a video as an instruction method or as an intervention method. These benefits include the ability to pause, speed up and slow down, and repeat portions of a video, learners can learn at a comfortable pace and may revisit the material on demand when needed. So, if a learner does not understand or did not hear well on a certain portion of a video, like on how to write a compound formula, s/he can pause, repeat it or revisit it some other time to understand it. Oh

(2021) called this free time management where learners have time for personal development and hobbies and can watch the class video anytime/anywhere. Attached to this is also an advantage of the learner controlling the class speed and therefore managing his or her learning by being able to repeat the lesson as many times as they want and controlling the learning speed (Oh, 2021). Cook and Steinert (2013) called this the advantage of convenience and flexibility. Another benefit as noted by Jordan et. al (2016) is that these videos could provide uniform access to information across very large programs or large groups of learners. All the learners who listen to one video will be accessing same type of well-pre-prepared information which forms part of cumulative knowledge. For example, if the video is teaching about balancing an equation, all the learners will listen to the same information on balancing equations.

2.4.2 Disadvantages of (online) video instruction

According to Pulukuri and Abrams (2020) the limitation of the use of online videos (over contact lessons) is that after a student answers a multiple-choice question incorrectly (in pre-prepared videos), they are immediately presented with the correct answer and automatic instructor feedback for all answer choices. This is unfortunate, because it does not allow students to try to self-correct before getting feedback as is the case with face-to-face lessons. The preferred option would be allowing students to retry answering a question that is answered incorrectly before feedback and the correct answer is given. Oh (2021) noted that it is hard for learners to concentrate. Learners in high school still need to be helped to concentrate on schoolwork, so when they learn on their own using videos, they can easily lose interest and do not concentrate on the work being emphasised. Associated with this disadvantage, Oh (2021) noted another disadvantage of difficulty in management of the time for learning. The learner may say s/he will listen to the video later and then realise later that either s/he forgot or there is no time to watch the video. Cook and Steinert (2013) identified the following problems for online instruction:

i) increased isolation (especially if the learners are accustomed to meeting face-to-face),
ii) communication problems with the presenters, technical problems,
iii) lack of comfort with the technology as some learners are not technologically gifted and last, but not least,
iv) costly software development where there is need for financial support to get the videos.

Considering research on online videos, Hansch et. *al.*, (2015) noted that there is scant research on the effectiveness of video instruction as a pedagogical tool for online learning from a LCT perspective. Hansch et. al., (2015) continued to note that most research to date has focused on educational multimedia from a cognitive sciences perspective, and little of this research has been verified in a natural educational setting (i.e., outside of a research lab). According to Hansch et. al., (2015), there is therefore a need for future research that focuses on measuring gains in competency and/or skills that arise from watching videos explicitly designed to teach. The videos to be used in this study are Mindset videos which are reposited and can be accessed on YouTube. This researcher has not yet come across any study that has specifically looked at evaluating Mindset online videos and yet a greater population of learners have access to these Mindset videos by virtue of them being broadcast on the national TV. It remains unclear as to the degree to which researchers have researched on the effectiveness of the videos as a mode of instruction or as a mode of intervention in making abstract concepts to become accessible to the learners. This researcher, therefore, investigated the effectiveness of Mindset videos as an intervention mode using the LCT semantic waves codes of semantic gravity and density profiles to see their effectiveness of these videos in transforming the concepts in chemical reaction into formats accessible to learners.

2.5 Mindset Videos

Mindset videos are produced by Mindset Learn Xtra an Educational consultant based in Randburg, South Africa, which supports teachers and learners in accessing and delivering the school curriculum. The producers claim that they provide learners with high quality video lessons and supporting lesson notes. All the lessons are CAPS aligned and cover key aspects of the curriculum, providing overviews and summaries of difficult and important sections. During examination time they give special support revision programmes. Learn Xtra lessons are broadcast on DSTV 319 and on Openview HD 201 and anyone can watch them for free of charge. They are also made available on YouTubeChannel Mindset Learn, where this researcher accessed them and on their website: learn.mindset.co.co.za/xtra/lessons free of charge. The source of most of the above information is from their website. (learn.mindset.co.za/xtra/lessons; http://learn.mindset.co.za). They claim that they use some of the best teachers in South Africa for their Mindset videos who present live lessons which are recorded and broadcasted later on the stated channels. Physical science is one of the 11 subjects that they offer, besides teacher development programmes that they also offer.

2.6 Online learning materials

According to Evgeniou and Loizou (2012) the development of effective online learning materials should be based on proven and sound learning theories. Behaviorist, cognitivist, and constructivist theories have contributed in different ways to the design of online materials. Ally, 2008 suggested that the behaviorists' strategies can be used to teach the what (facts); cognitive strategies can be used to teach the how (processes and principles); and constructivist strategies can be used to teach the why (higher-level thinking that promotes personal meaning and situated and contextual learning. line learning materials should include activities for the different styles, so that learners can select appropriate activities based on their preferred learning style.

Learners gain significant learning benefits from audiovisual or computer media, the reason for those benefits is not the medium of instruction, but the instructional strategies built into the learning materials (Abdulrahaman, Faruk, Oloyede, Surajudeen-Bakinde, Olawoyin, Mejabi and Azeez, 2020). Delen and Liew (2016) adds that online learning materials must be designed properly, with the learners and learning in focus, and that adequate support must be provided.

Generally, in chemistry and particularly in chemical reactions, a lot of practical or experiments are done, for example to show how magnesium react with oxygen, so materials in form of apparatus and chemicals are needed and are used by the presenter. Simulations using computers are also used often in chemistry online lessons. So, the computer is the main online material on which almost all other materials depend on or are broadcasted. According to Zhang (2017), the computer can even be used to replace the work part of teachers and help teachers to impart knowledge and skills to the students and provide services for students' learning through the interaction between student and the computer.

2.7 Theoretical Framework

The theoretical framework used in this study is the Legitimation Code Theory (LCT) (Maton, 2014) which assisted in the process of data collection by revealing the cumulative knowledge building practices used in the Mindset videos. Accordingly, the theoretical framework is the foundation from which all knowledge for a research study is constructed, (Osanloo, and Grant (2016). Osanloo, and Grant (2016) further suggest that the theoretical framework serves as the structure and support for the rationale for the study, the problem statement, the purpose, the significance, and the research questions. This means it is an anchor for the data collection methods and data analysis. A theoretical framework serves as the guide on which to build and support one's study (Osanloo, and Grant (2016)).

This theory's principal foundation framework is Bernstein's code theory (Moore, 2013), it builds upon Basil Bernstein and Pierre Bourdieu's work (Walton & Rusznyak (2020)). According to Maton, Hood, and Shay (2013), LCT is a practical framework that is being used to explore a host of issues, practices and contexts in education. Maton (2014) concurs when suggesting that LCT offers a potentially fruitful framework for exploring and shaping academic language and learning practices. It is a practical theory that offers an array of concepts that are used in empirical research to provide explanations of substantive problems like test scores in Chemistry (Maton, 2014). LCT is a social realist framework that offers a multidimensional conceptual toolkit to assess, but also shape practice (Maton 2013, 2014). Moreover, in pedagogy, the framework provides tools to evaluate, amend or design curricula to facilitate cumulative learning (Maton 2009). This is also supported by Clarence (2016) who said LCT offers an accessible framework with strong explanatory power in terms of its ability to conceptualise disciplines in terms of both knowledge and knowers. The tools that it offers can assist both academic development practitioners and disciplinary educators, working collaboratively, to analyse and change pedagogical practice in higher education.

The five dimensions of LCT namely specialisation, semantics, autonomy, temporality, and density (Clarence, 2016), offer different concepts to analyse the underlying organizing principles of practices and then present these as legitimation codes. This study is going to employ the semantics dimension of LCT, which considers social fields of practice as semantic structures (as both conceptual and as an analytical tool). In this case, the organizing principles are presented as semantic codes, comprising semantic gravity and semantic density. Semantic dimension is chosen over the other dimensions for this study because it gives the opportunity to understand how the teachers change complex body of knowledge to simple forms that learners, the focus of this study can understand, enabling cumulative knowledge building. To analyse this cumulative knowledge, the semantic dimension of LCT using the semantic gravity and semantic density will be used.

According to Clarence (2016, p.126), "semantics contends that if we can understand the conditions necessary for cumulative knowledge-building in different disciplinary contexts, we can more ably move learners between abstracted and contextualised meanings. Mouton (2020) agrees with Clarence's assertion by saying that all teachers strive towards facilitating cumulative knowledge building for our learners. Mouton (2020) noted that learners are able to build on their previous knowledge, make the connections between their new and past knowledge and transfer this knowledge across a range of contexts. Knowledge building occur when ‘’experiential knowledge is extracted from the context in which it was produced and then conceptualised so that the knowledge is applicable beyond the specific context in which it was created’’ (Walton & Rusznyak, 2020, p, 23). To understand how knowledge builds, semantic gravity (SG) and semantic density (SD), the two semantic codes are used. These two semantic codes can provide teachers with important insight of what new knowledge learners are struggling with, why pedagogy matters, and how they need to connect it with prior knowledge to make new meanings.

Semantic gravity (SG) refers to the degree to which meaning relates to its context or it speaks to the context dependence or independence of meanings (Maton, 2014). Walton and Rusznyak (2019) concur that ssemantic gravity (SG) describes the degree into which teachers take abstract concepts and bring them closer to learner’s everyday lives or real –world situations. Semantic gravity may be relatively stronger (+) or weaker (−) along a continuum of strengths. The stronger the semantic gravity (SG+), the more meaning is dependent or is tied on its context and the meaning would therefore be concrete; the weaker the semantic gravity (SG−), the less dependent meaning is on its context (Botyczoko, 2020). A concept that is used abstractly or in a decontextualised way would exhibit weaker semantic gravity (SG−), because it is removed from any context in which it would find application (Clarence, 2016). This means a concept which is used in a more contextualised space exhibits stronger semantic gravity as every concept needs to be attached to a context to make sense. In practice, semantic gravity can be strengthened by moving from more abstract meaning to more general, concrete, contextualized meaning and in the same way weakened by doing the opposite. According to Clarence (2013), when teaching and learning leans too much towards weaker or stronger semantic gravity to the exclusion of the other, the potential to accumulate knowledge and transfer it between and through contexts is impeded.

For example, if we look at the topic of chemical reactions, aspects such as valency; that is the number of bonds an atom can form is an abstract concept. When a teacher uses concrete examples or everyday examples to teach this concept, the examples have a stronger semantic gravity because the ability to express meaning within that context would be understood. In this study, semantic gravity was categorized into four strengths: SG+++, SG++, SG+ and SG−. The strongest semantic gravity is represented by SG+++, while the weakest is represented by SG−.

Semantic density (SD), on the other hand, refers to the degree of condensation or “packing up” of meaning within socio-cultural practices, whether these comprise symbols, terms, concepts, phrases, expressions, gestures, clothing, etc. The concept of semantic density describes the degree into which the teacher changes knowledge from complex to more simple forms that learners can understand (Walton and Rusznyak, 2020). Semantic density may be relatively stronger (+) or weaker (−) along a continuum of strengths. The stronger the semantic density (SD+), the more meanings are condensed or packed into a concept; the weaker the semantic density (SD−), the less meanings are condensed. Maton and Doran (2017) comment that to make the semantic density weaker a complex concept should be simplified and made more understandable by using common words and everyday examples.

For an example on the topic of chemical reactions, the concept of valency is condensed and requires subject specialists’ knowledge to understand. Hugo (2014) argues that complex concepts must be broken down into their specific elements and once understood, they must be incorporated with other concepts to explain a higher process. Hugo (2014) adds that when a teacher “unpacks” a concept, semantic density weakens; but, when she “packs” the concept up and uses it as a whole to understand complex ideas, semantic density increases.

The more meanings are related, the stronger the SD. In this study semantic density was categorized into four strengths: SD+++, SD++, SD+ and SD−. The strongest semantic density is represented by SD+++ and the weakest with SD− .

Thus, during semantic waves profiling, meaning was lifted out of gravity by abstracting away from concrete meaning, and then brought back again to concrete and simpler meaning, thus the strengthening and weakening of both semantic gravity and semantic density (Mouton (2020)). This brings about the decontextualization and recontextualization of knowledge over time, thereby leading to knowledge building in two directions (Maton, 2014a). The diagram below (figure 4) shows the relationship between semantic density and semantic gravity:

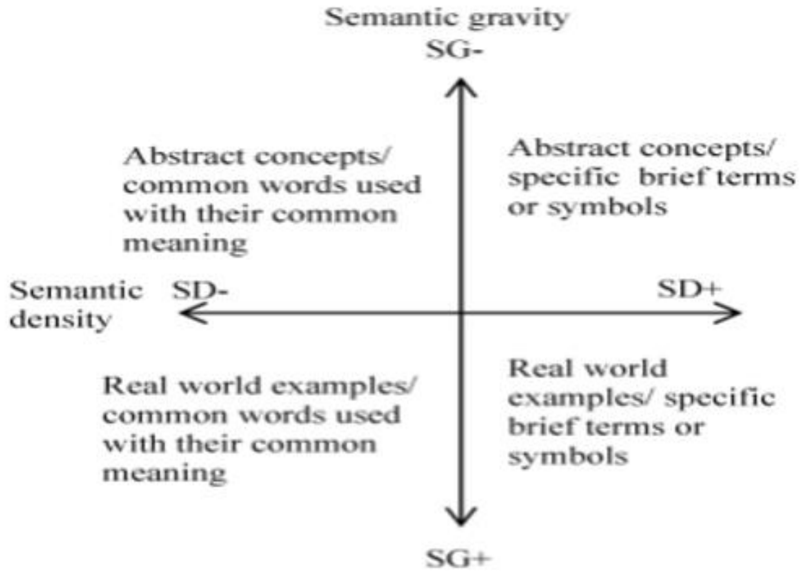


Figure 4 Shows the relationship between semantic density and semantic gravity (Maton, 2011)

The upper left quadrant shows meanings that are abstract and context dependent (indicating that both semantic density and semantic gravity are weak), while the upper right quadrant shows the meaning that has strong semantic density and weak semantic gravity. The lower right quadrant's meanings have both semantic density and semantic gravity being strong, and last but not least, the lower left quadrant's meanings have weak semantic density and strong semantic gravity. Complimentary to the above diagram is the following diagram (figure 5) showing the four semantic codes, namely the rhizomatic code, the worldly code, the prosaic code and the rarefied code (Maton 2014a).

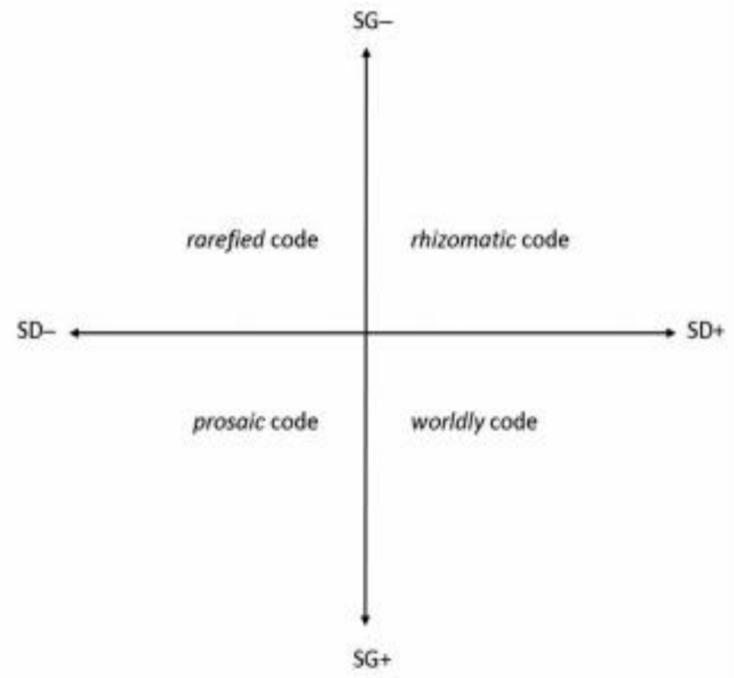


Figure 5 The Semantic plane used in Legitimation Code Theory (Maton 2014a). (Semantic gravity (SG) is displayed on the vertical axis and semantic density (SD) on the horizontal axis).

The rhizomatic code (SG−, SD+) is where meaning is relatively context independent, but complex. In the worldly code (SG+, SD+), meaning is still complex but relatively context dependent and more concrete. The prosaic code (SG+, SD−) represents meaning that is less complex and simpler, but context dependent. The rarefied code (SG−, SD−) is where meaning is relatively simple but context independent and thus more abstract. Practice can display code shifts with movement between more abstract and more contextualized meaning, as well as between simpler and more complex meaning (Maton 2014a).

Likewise semantic waves codes: semantic gravity and density were used for analysing the effectiveness of online Mindset videos on chemical reactions in terms of cumulative knowledge. This was done by analysing cumulative knowledge building semantic profiles like the one below (Maton, 2014).

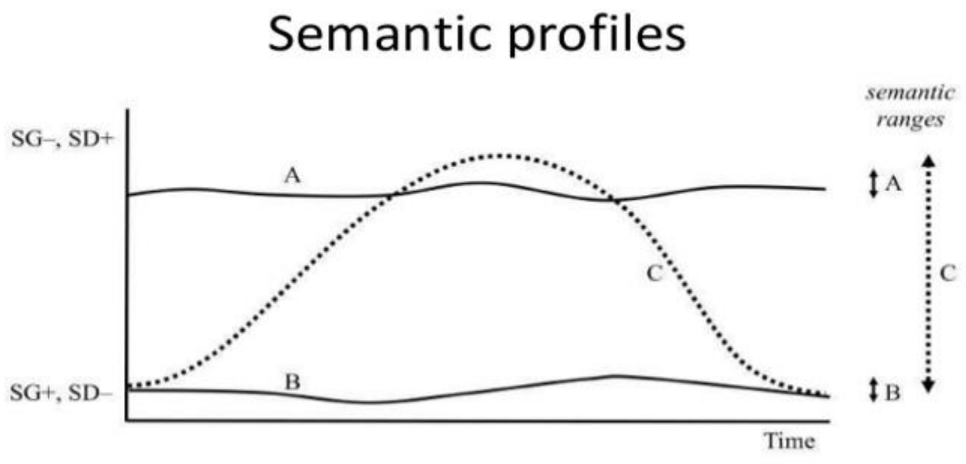


Figure 6 Showing semantic profile (Maton, 2014)

Key:

A – high semantic flat-line (theoretical and abstract)

B – low semantic flat-line (practical and simple)

C – semantic wave (weakening and strengthening of context and density and a larger semantic range)

The semantic wave profiles of the Mindset videos were plotted and analysed after transcription. It is important to note that semantic profile shows how knowledge is built over given time. A high semantic flat-line shows that concepts remain unpacked and complex for learners to understand, a low semantic flat-line shows that learning of a concept is too simple and when teaching happens in this form no learning occurs (Walton and Rusznyak, 2020). When we look at the semantic waves, we realize that the teacher moves between practical and simple to theoretical and abstract over time.

Maton (2013) noted that semantic waves represent the pulse of cumulative knowledge building that involve the shifts in context-dependent, simplified meanings and decontextualized, condensed meanings. In the business of teaching, teachers should create waves. In simple terms, semantic waves refer to the upward and downward shifts in semantic profiles that characterize classroom practice (Msusa, 2019). According to Msusa (2019) a semantic wave may be characterized by a downward movement on one end, which is essentially the "unpacking" of technical terms, concepts or definitions into more familiar common-sense language for learners. This can also be described as movement from context-independent symbols whose meanings are relatively abstract. On the other end the inverse upward movement is a "repacking" process, where engagement with the knowledge is now grappled with using terms and concepts as well as application of theories in own voice. As Maton (2013) discusses, the concept of semantic waves can be used in a variety of ways as a tool to trace changes in knowledge through time. Another diagram from Maton, 2013 showing the unpacking and repacking of concepts teaching by a teacher:

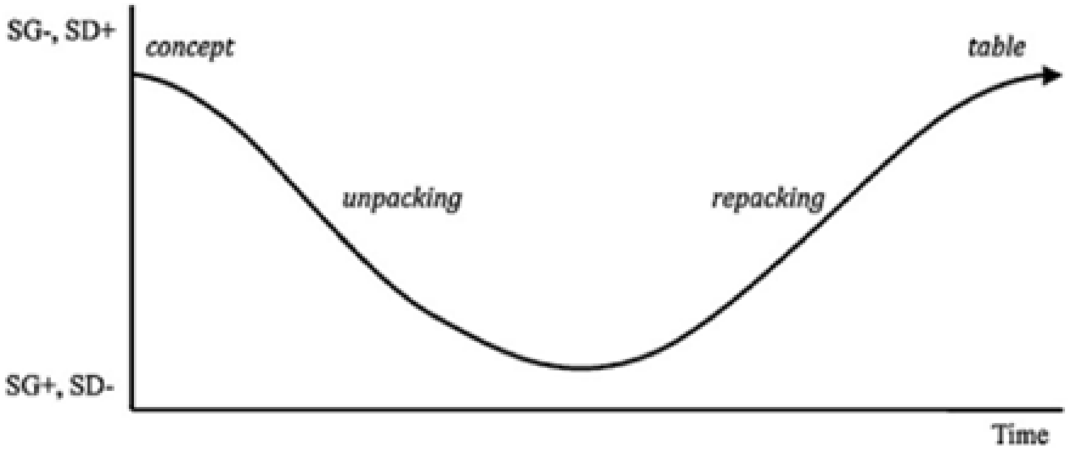


Figure 7 Showing semantic wave (Maton, 2013)

A teacher may use non-technical terms to explain concepts in an understandable way, this indicate a less complex or simple scientific meaning and in semantics this is weak semantic density (SD -). The teacher may then repack to a more complex and condense level of explanation using technical terms and this strengthens semantic density to a stronger semantic density (SD +), upward escalator. Conversely when a teacher repacks using non-technical and with reference to general situation there is weakening in the degree of complexity to a weaker semantic density (SD -). A continuous wave indicates potential for knowledge building (Walton & Rusznyak, 2020).

There are instances where knowledge may be too closely linked to particular contexts and too fragmented to build on prior knowledge either. According to Maton (2013) such practices describe high stakes profiles which are characterized by knowledge that is segmented. Maton (2013) further argues that high stakes profiles present potential problems for the building of cumulative knowledge, since knowledge is characterized by relatively strong semantic gravity and relatively weak semantic density.

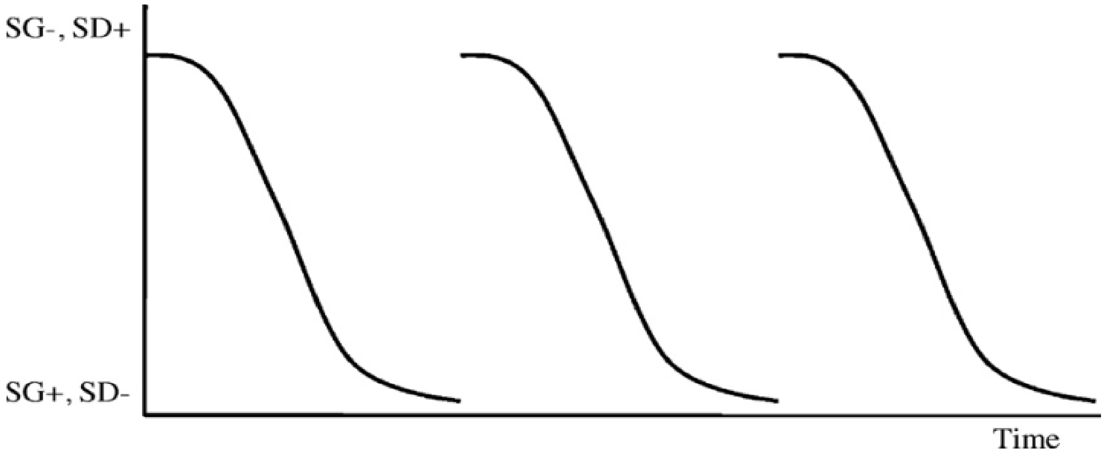


Figure 8 Shows an example of a high-stake profile (down escalators) (Maton, 2013

2.8 Cumulative Knowledge building

According to Maton (2009), cumulative knowledge building is a form of learning in which new knowledge builds on and incorporates previous knowledge. Maton (2014) adds that cumulative knowledge-building extends previous knowledge and integrates it with knowledge produced in different contexts and at different points in time This can happen when experiential knowledge is extracted from the context in which it was produced and then conceptualised so that the knowledge is applicable beyond the specific context in which it was created (Walton and Rusznyak (2020)). The abstracted concepts can then be drawn on to yield relevant and useful insights in future or changing situations (Maton 2014).

Constructivists, according to Maton (2013), view 'knowledge' as mental processes and states of consciousness that reside within the learner. This shows that knowledge can be cognitively constructed. Knowledge is revealed as socially constructed (Maton, 2013). Clarence (2016) identifies disciplinary knowledge which is knowledge of the disciplines or of the subjects, and this is the knowledge that the researcher will concentrate on in the online videos to be analysed. Bernstein (2000) identified two types of knowledge, the horizontal discourse or everyday knowledge and vertical discourse or educational knowledge. Horizontal discourse entails a set of strategies which are local, segmentally organized, context specific and dependent, for maximizing encounters with persons and habitats while vertical discourse comprises specialized symbolic structures of explicit knowledge where meaning is related to other meanings (Bernstein, 2000). Maton (2013) argues that educational knowledge which is learnt is typically embodied in written forms such as textbooks and is accessed through reading. It is also the knowledge that learners must display in their assessments mostly in writing tasks.

It is important to note that teachers facilitate knowledge building, and they foster on the cumulative building of knowledge to avoid the issue of knowledge segmentation (Maton, 2014). For the sake of clarification, segmental knowledge building refers to learning in which new concepts or skills are acquired alongside existing knowledge rather than being built on top of it (Maton, 2009). Maton (2013) asserts that knowledge is segmented when it is so tightly bound to its context that it is only relevant within that context. Teachers must know and understand the subject matter that they teach to learners, that is they should have high pedagogical content knowledge to facilitate knowledge building for the learners (Maton, 2014).

To understand how knowledge builds over time we use a conceptual tool called semantics which mainly consists of two semantic codes called semantic gravity and semantic density which will be used to analyse the Mindset videos. Teachers should combine ideas with stronger semantic density with ideas that has stronger semantic gravity for cumulative knowledge building to occur in teaching and learning (Walton & Rusznyak, 2019) this creates a semantic wave with a bigger range. Maton (2013) adds that cumulative knowledge-building is defined by the big semantic ranges which range from knowledge with stronger semantic gravity to knowledge with stronger semantic density. The semantic wave is crucial for both cumulative and progressive learning (Maton, 2011).

2.9 Translational device

The study used an LCT translation device to evaluate the lessons and identify the shifts in a form of semantic gravity which explored the shift in the context of the ideas taught about how they change over time. According to Maton and Doran (2017), the translation device is a means for translating the higher-order concept of semantic gravity. The study looked at the semantic density to understand the shift in the complexity of knowledge and how these shifts took place during the lessons. The shift in semantic density and semantic gravity allowed this study to understand how the shifts in context and complexity of knowledge connect different forms of knowledge (Maton, 2020). Chapter 3 provides a detailed outline of the adopted transitional device used in this study.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The previous chapter of the study introduced the reader to the literature and the conceptual toolkits that guided the study. This chapter, on the other hand, makes known the paradigm guiding this study to provide a clear understanding of how the topic was unpacked. In this section, the researcher is also presenting the research design, research instrument, research methodology, and research participants chosen. LCT has been chosen as the central conceptual and analytical framework and applied to this study not only because of the rigor that the conceptual framework enables in research and the depth of its "explanatory power" (Maton, 2013a), but also because of its relevance as an analytical and organizing framework for organizing, exploring and analyzing data (Clarence, 2013). Lastly, the ethical considerations for this study were also indicated.

3.2 Restating the objectives of the study.

The primary objective of the study was to gain insight into the effectiveness of Mindset videos as adscititious/supplementary resources to enrich the learning of chemical reactions to grade 10 learners. The literature review section pointed out that online sessions are described as learning and teaching that assumes that the teacher and learners are apart in space and that this distance is bridged by the use of technological tools (Ananga & Biney, 2017), in this case, the Mindset videos. To achieve this objective, the following research questions were asked:

1. How are the concepts of chemical reactions and equations developed in online videos?

2. How does the teacher reduce the complexity and abstractness of the concepts of chemical reactions and equations when teaching online?

The following section discusses the research paradigm, research approach, and design before the chapter moves on to describe the data that was gathered.

3.3 Research paradigm

Every research is guided by a paradigm (Hatch, 2002). In educational research, the term paradigm is used to describe a researcher's 'worldview' (Mackenzie & Knipe, 2006). Kivunja, and Kuyini (2017) concur that a paradigm constitutes the abstract beliefs and principles that shape how a researcher sees the world, and how s/he interprets and acts within that world. This study is premised on the constructivist/interpretive paradigm which focuses on human interpretations of the social world, and the significance of both the participants' and the researchers' interpretation and understanding of the phenomenon under study (Ritchie &

Lewis, 2013). It views reality and meaning making as socially constructed and it holds that people make their own sense of social realities. Interpretivism was deemed the most appropriate paradigm for this undertaking, as it is concerned with revealing multiple realities as opposed to searching for one objective reality (Guest, Namey & Mitchell, 2013). With respect to ontology, the interpretive paradigm assumes that there is no single objective/ reality or truth. Reality is created by individuals in groups. Reality is socially constructed ((Bogdan & Biklen, 1998) in Kivunja and Kuyini (2017)). Epistemology deals with the relationship between the knower and what is known. As for its epistemology, the interpretivist/constructivist researchers view the world as constructed, interpreted, and experienced by people in their interactions with each other and with the wider social systems (Maxwell, 2006; Bogdan & Biklen, 1992). According to this paradigm, the nature of inquiry in this study is interpretive and the purpose is to understand the phenomenon of video instruction with the intention of not generalizing the findings to a wider population (Farzanfar, 2005). The researcher was non-manipulative, unobtrusive, and non-controlling (Tuli, 2010).

3.4 Research approach

There are three major types of research approaches: qualitative, quantitative, and mixed methods approach in educational research (Creswell, 2012; McMillan, 2012). The qualitative research approach is concerned with providing a naturalistic observation that translates into a detailed description of the phenomenon under study while quantitative research is concerned with measuring and testing general laws (Auerbach & Silverstein, 2003). The mixed method approach is a unique approach as it combines both qualitative and quantitative approaches (Creswell, 2012). In this study, a qualitative approach within the interpretivism philosophy was deemed appropriate as the researcher was not concerned with testing any hypotheses. Interpretivist research focuses on understanding a process or phenomenon. Such research is intended to understand and interpret social meanings.

Qualitative research is a type of social science research that uses non-numerical data to interpret and analyse peoples' experiences and actions, (Crossman, 2018). Another perspective is given by Strauss and Corbin (1990) who define qualitative research, as; "any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification" (Strauss and Corbin, 1990, p. 17). It is any research carried in uncontrived settings where the "phenomenon of interest unfold naturally" (Patton, 2001, p. 39 in Golafshani, 2003). The definition of qualitative research was further clarified by Maxwell (2013) who advocates that qualitative research works with meanings, motives, aspirations, beliefs, values and attitudes, which corresponds to a deeper space of relationships, processes and phenomena that cannot be reduced to the operationalization of variables. It is out of this understanding of the definition of qualitative approach that this study used it as non-numerical data of the Mindset videos on chemical reactions was interpreted and analysed in terms of how some chemical reactions concepts were taught. The participants in the videos were teachers presenting. The presentations were transcribed. The development of the concepts as well as the reduction of the complexity and abstractness were plotted as semantic wave profiles of semantic gravity and density.

Qualitative research has been chosen because of the advantages that it has in such type of study which has no numerical variables. According to Starman (2013), qualitative research is characterized by an interpretative paradigm, which emphasizes subjective experiences and the meanings they have for an individual. Queirós, Faria, and Almeida (2017) concur that qualitative research provides detailed information about individuals or situations under study. Another characteristic of qualitative research is its idiographic approach (Starman (2013)), that is the study stay limited to the phenomenon under study. This can either be an advantage or disadvantage depending on the context of the study. The disadvantages of qualitative research include the idea that it is hard to generalize the results of a study (Queirós et. al (2017)). Starman (2013) added that the subjective views of a researcher on a particular situation play a vital part in the study results. This means the researcher's viewpoint may affect the results that the researcher gets.

3.5 Research design

There are many types of research designs that one can choose to carry out in a study. This study adopted a case study exploratory research design. Exploratory research is a method established to explore a phenomenon that has not been researched or adequately explained before (Ferrer Conill, R. (2016). Its primary goal is to notify us about where we may get a modest bit of information. Its purpose is to discover the what and the why of a subject under investigation. It is a type of research design that is responsible for finding the reasons behind the events through the establishment of cause-effect relationships (Lwakatare, L. E., Kuvaja, P., & Oivo, M. (2016); Rowley, J. (2002)).

This research employed an exploratory case study of Mindset videos on chemical reactions. The research questions in this study include the "what" and the "how", thus case studies may be used to explain causal links between the data and the questions (Babbie & Mouton, 2010).

This is the reason why the case study was chosen as the design. In this study, two Mindset videos on the teaching of the topic of chemical reactions and equations for Grade 10 learners were studied. These videos were found /downloaded from YouTube. According to Dooley (2002), case study research emphasizes detailed contextual analysis of a limited number of events or conditions and their relationships. Dooley (2002) went on to say the researcher who embarks on case study research is usually interested in a specific phenomenon and wishes to understand it completely, by not controlling variables but rather by observing all of the variables and their interacting relationships. Case study research can employ various data collection processes such as participant observation, document analysis, surveys, questionnaires, interviews, and others. The power of case study research is the ability to use all methodologies within the data-collection process and to compare within the case and across the case for research validity (Dooley (2002)). According to Queirós et. al (2017), the advantages of case studies are to provide detailed information about individuals, offer a good opportunity for innovation and change current theoretical assumptions. However, case studies have disadvantages as well, which include difficulty to establish cause-effect connections, hard to generalize from a small number of case studies, and ethical issues, especially confidentiality. (Queirós et. al (2017)).

3.6 Data collection and analysis

3.6.1 Collection

Data for this study was collected from the observation of Mindset videos. Two videos of pre-recorded online Mindset video lessons for Grade 10 were used as documents to collect the data. These electronic documents were downloaded from you-tube. They were considered be useful by the researcher to uncover insights, developing theory, and gaining a greater understanding of the phenomenon of online teaching. These videos qualify to be classified as documents because they contain information created or recorded without the influence of the researcher and for a purpose other than the research study. The Mindset videos are on the topic of chemical reactions, a topic on which this study is based on. Only two Mindset videos were chosen because the researcher could not access the other previously recorded videos. Mindset videos were chosen because they are broadcasted on the national/public TV channel, South Africa Broadcasting Corporation (SABC) and according to Stats SA, 82.2% of households in South Africa have access to a television set. We, therefore, assumed that a larger portion of learners have a greater chance of seeing/viewing Mindset lessons on the SABC channel as well as the Mindset channel. The ability to repeatedly view moments in a lesson allow a researcher to note trends, themes and patterns, which are helpful aspect of characterising knowledge in terms of how complex and how tied it is in context (Maton, 2013). These Mindset videos were observed, listened to, and transcribed. A voice recorder which transcribes the voice to words (a speech to text converter) was used for transcription.

3.6.2 Data Analysis

Creswell (2009) states that the analysis process involves creating sense from the data, preparing data for analysis, conducting various analyses, moving further and further into comprehension of the data, presenting data, and reaching an interpretation of the broader meaning of the data. In this study, data analysis involved observing two electronic documents and interpreting them to answer the three research questions posed in chapter One. Thus, document analysis, a form of qualitative research that uses a systematic procedure to analyse documentary evidence and answer specific research questions, was the approach to data analysis. According to Gross (2018), document analysis can be conducted as a stand-alone study or as a component of a larger qualitative or mixed methods study. Document analysis involved a series of iterative steps as indicated below.

The analysis of the electronic document occurred in three stages.

Stage 1: The pre-recorded Mindset videos were watched multiple times in preparation for the process of transcription. Transforming spoken words into written text in qualitative research is a vital step in familiarizing and immersing oneself in the data (Oluwafemi, et al., 2021). In the process of transcription, the researcher took notes of where and how different concepts were emphasised and highlighted the concepts in bold (See appendices 1 and 2).Thus, memoing allowed the researcher to collect additional data to provide a thick description of the phenomenon.

Stage 2: The researcher familiarised himself with the transcribed information. At this stage, the researcher created a set of pre-determined codes as informed by the theoretical/conceptual framework. . Quotations from the transcribed videos were sought to fit into these codes. To ensure credibility, the researcher requested another colleague not directly involved with the study to validate the matching of the codes with the quotations. The figure below shows the pre-determined codes and their associated meanings. The semantic codes and their specific meanings are described in tables 1 and 2 below. Semantic gravity, abbreviated as SG, describes how context-bound or abstract a meaning is, while semantic density, abbreviated as SD, describes how simple or complex meaning is.

To clarify how these tables were used, it is important to give an example: when a teacher explained a theoretical statement in the Mindset video, a code of SG− was assigned and when the teacher used condensed symbolic language a code of SD+++ was assigned.

Table 1 Shows the semantic gravity codes and their specific meanings.

Weaker	**Code**	**Indicator**
	SG−	Teacher explains a theoretical statement.
	SG+	Teacher refers to a hypothetical example.
	SG++	Teacher focuses on the real-world example / direct experience.
Stronger	SG+++	Teacher focuses on personal experiences / examples.

So, if the presenter (as transcribed) uses real-world example from learners or his/her direct experience, that statement will be coded as SG++.

Table 2 Shows the semantic density codes and their specific meanings

Stronger	**Code**	**Indicator**
	SD+++	Teacher uses condensed symbolic language to convey a concept.
	SD++	Teacher makes connections between the concept and other ideas so that it becomes part of a networked body of knowledge.
	SD+	Teacher uses subject terms, and explains what it means in an understandable way, giving more details about the characteristics and properties of the concept.
Weaker	SD−	Concepts or words from the subject are used to convey meaning in straightforward ways that a non- subject specialist could understand.

If the presenter uses condensed symbolic language to convey a concept, for example, using symbolic chemical equations (e.g., $2Mg + O_2 \longrightarrow 2MgO$), the semantic density code is SD+++. Using subject terms while explaining concepts in an understandable way by the presenter, will be coded as SD+.

Stage 3: During this final stage, the description of the transcriptions of the chemical reactions and equations concepts were assigned varying semantic codes which depended on the indicators that are shown above. In fact, a translational device was used.

A translation device was created that included examples from the lesson transcriptions. The translation device was adapted from Maton (2014) but was tailored to suit the requirements of this study. The translational devices were used to analyse the data on the stated concepts which have been used in the teaching of the topic of chemical reactions.

The translation device for semantic gravity (SG) was used to code the different statements from the transcribed Mindset videos on how context-bound or abstract the meaning of the concepts and statements were. This translational device was used in detail in tables 8 and 10 in coding different statements and concepts.

3.6.2.1 Translation device for semantic gravity

Table 3 Describes the translation device for semantic gravity

Code	**Indicator**	**Examples from Mindset video lesson transcriptions**
SG∓	Teacher explains a theoretical statement	reactants are the things that you've got at the start they will be the thing that will react together in order to make the things at the end this is what is formed or is produced in this chemical equation
SG++	Teacher refers to a hypothetical example	There are also transition elements that have multiple, what we call oxidation states, they can form multiple charges. For covalent compounds, now remember what covalent compounds going to be, (when a non-metal reacts with another non-metal)
SG+++	Teacher focuses on real world example/direct experience	Chemical reaction is when new substances are forming, it is not a physical change, it is a new substance that is forming and so what we focus on here is that we going to have a new substance forming

SG++++	Teacher focuses on personal experiences/examples	because that stuff can't come from nowhere and similarly it can't just go into nothing (Describing balancing equations)

3.6.2.2 Translation device for semantic density

Table 4 Describes the translation device for semantic density.

Code	**Indicator**	**Examples from the analyzed Mindset video lesson transcriptions**
SD++++	Teacher uses condensed symbolic language to convey a concept.	Balanced equation: $2Mg + O_2 \longrightarrow 2MgO$ $2H_2 + O_2 \longrightarrow 2H_2O$
SD+++	Teacher makes connections between the concept and other ideas so that it becomes part of a networked body of knowledge."	The valency is how many bonds the substance needs to make. Group 1, group 2, the valence electron and the valency are the same and group 3, whereas when you start going towards into the non-metal, the valency and the valence electrons are very different, if we go across now to ionic compounds the valency represents the charge on the ion
SD++	Teacher uses subject terms, and explains what it means in an understandable way, giving more details about the characteristics and properties of the concept."	Because in a chemical change new products are formed, when a chemical change occurs new substances are formed in a chemical reaction so old bonds break and new bonds form and a new substance with different properties will be formed. (Explanation for chemical reaction)

SD+	Concepts or words from the subject are used to convey meaning in straightforward ways that a non-subject specialist could understand."	We mean that matter cannot be created or destroyed so the number of atoms of each type that you started with you must end up with, ok, because that stuff can't come from nowhere and similarly it can't just go into nothing. (Explanation for balanced equation)

The translation device for semantic density (SD) was used to code the different statements from the transcribed Mindset videos on how simple or complex the meaning of the concepts and statements was. This translational device was used in detail in tables 8 and 10 in coding different statements and concepts.

3.7 Trustworthiness

In a qualitative study like this one, it is necessary to ensure that a report writer reports on findings that are trustworthy and reliable. According to Pilot and Beck (2014), trustworthiness or rigor of a study refers to the degree of confidence in data, interpretation, and methods used to ensure the quality of a study. This means trustworthiness determines whether the research truly measures that which it was intended to measure or how truthful the research results are. On the relationship between trustworthiness and reliability, O'Hara (2012) noted that it may be that trustworthiness is a species of reliability, in which case everyone/thing that is trustworthy is *ipso facto* reliable. This means that it is a fact to say anything that can be trusted is also reliable. O'Hara (2012) continued to say trust and reliance, and trustworthiness and reliability, share a good many logical properties. The findings should honestly reflect on what was gained from the data collection process. This means that the researcher's findings need to reflect truthfully on what he had gained from the data collection instruments. In this study, help from academics was sought by the researcher to validate the results, whereby they validated the translation device used in this research study. The researcher also used a variety of platforms available at the University of Witwatersrand to address the issue of trustworthy and reliability. The details of the platforms are described in detail below. The researcher once presented his research proposal to the research bonanza organised by the Wits school of Education where the researcher was given advice on the best way of presenting the proposal. There was also a lot of help and advice from writing retreats attended by the researcher in 2020 and 2021 where the researcher presented his proposal and later his findings respectively and both the proposal and the findings were validated by academics and colleagues. To develop trustworthiness in qualitative research, Lincoln and Guba (1985) in Cope (2014) presented four criteria: credibility, dependability, confirmability, and transferability.

Credibility is confidence in the 'truth' of the finding (Amankwaa (2016)). Polit and Beck (2014) concur that credibility refers to the truth of the data or the participant views and the interpretation and representation of them by the researcher. According to Cope, 2014 credibility is enhanced by the researcher describing his or her experiences as a researcher and verifying the research findings with the participants. A qualitative study is considered credible if the descriptions of human experience are immediately recognized by individuals that share the same experience (Sandelowski, 1986 in Cope, 2014). Other techniques used to establish credibility include prolonged engagement with participants, persistent observation if appropriate to the study, peer-debriefing, member-checking (where the researcher collects data and then returns the collected data or results to respondents so that they can cross-check the data with their own experiences), and reflective journaling (Connelly (2016)). For this report, peer-debriefing was done in writing retreats attended in 2020 and 2021 where the researcher presented his proposal and later findings respectively. Also, senior researchers like the supervisors and facilitators of the writing retreats also helped to mentor the researcher on how to produce a credible report.

According to Amankwaa (2016) dependability is showing that the findings are consistent and could be repeated. Polit & Beck (2014) concur that dependability refers to the stability of the data over time and over the conditions of the study. This can be achieved when another researcher concurs with the decision trails at each stage of the research process. Through the researcher’s process and descriptions, a study would be deemed dependable if the study findings were replicated with similar participants in similar conditions (Koch, 2006). Any other research done on this same topic should produce same results or themes as a way of validating this research. To achieve dependability of the findings, the reporter was always attending meeting every Tuesday organised by the knowledge-building LCT group since the start of this project where he presented his findings. The knowledge coded was agreed upon by the leaders of the project LCT. In addition to the above, the processes used in the study are adequately explained so that another researcher can repeat the same work to achieve dependability.

Confirmability is a degree of neutrality or the extent to which the findings of a study are shaped by the respondents and not researcher bias, motivation, or interest (Amankwaa (2016)). Polit & Beck (2014) concur that confirmability refers to the researcher's ability to demonstrate that the data represent the participants' responses and not the researcher's biases or viewpoints. The researcher can demonstrate confirmability by describing how conclusions and interpretations were established and exemplifying that the findings were derived directly from the data (Cope, 2014). In reporting qualitative research, this can be exhibited by providing rich quotes from the participants that depict each emerging theme (Cope, 2014). In this study, all the coding that was done, used the statements from the transcribed Mindset videos using the translational device which was approved by senior researchers during writing retreats and Tuesday meetings. Finally, in order to adhere to confirmability in this study, the researcher prevented bias through allowing one of the LCT scholars to analyse the data independently. In addition, the researcher reviewed his findings with the LCT research team.

Transferability is showing that the findings have applicability in other contexts (Amankwaa (2016)) that is findings can be applied to other settings or groups, in this case to other videos different from Mindset videos. According to Connelly (2016) researchers support the study's transferability with a rich, detailed description of the context, location, and people studied, and by being transparent about analysis and trustworthiness. The organised Tuesday meetings with the help of the facilitators and senior researchers helped the researcher to come out with a translational device for coding the Mindset video transcription in a way that makes the findings transferable to findings of other videos on the topic of chemical reactions. Since the study is qualitative and limited to a specific case, it is important that a detailed explanation be given so that the reader can determine if it is transferable to their context (Maher et al., 2018).

3.8 Ethical considerations

Ethical clearance and approval from the School of Education Ethics Committee of the University of the Witwatersrand was sought. The Mindset online videos to be used were from the You-tube, a public domain, therefore there was no need for consent. This meant the researcher did the analysis of the data by himself and chances of bias became higher. Driscoll (2011) warned about researcher bias by saying bias might be present in the way you ask questions, the way you take notes, or the conclusions you draw from the data you collect. He went on to say that there is little point in collecting data and learning about something if you already think you know the answer. According to Holloway and Wheeler (2010) qualitative researchers (considered to be the research instrument) cannot depend upon traditional approaches to address certain concerns such as bias and credibility but learn from a series of mistakes and this is considered an integral part of qualitative research. So, this researcher, through training from workshops and practice tried by all means not to be biased during data collection and analysis. Also, the researcher maintained the ethics of not tampering with the results. This is in line with Almıla's (2017) assertion that ethical standards promote the aims of research, such as knowledge, truth, and avoidance of error. For example, prohibitions against fabricating, falsifying, or misrepresenting research data promote truth and minimize error (Almıla, 2017), a recipe for this researcher's aim to make a truthful conclusion.

3.9. Limitations of the study

Considering that chemical reactions is a relatively one of the abstract topics in the chemistry curriculum, it is important to understand the depth of the teachers' content and pedagogical knowledge when teaching this topic. However, the qualifications of the presenter in this study were unknown, making it difficult to understand and oversimplify their ability to teach the topic. Since this was a case study, the findings cannot be generalized to the entire online videos; instead, it should be only confined to the videos of this study.

3.10 Chapter summary

This study is premised on the constructivist/interpretive paradigm. Qualitative research is the study's research approach which is a type of social science research that uses non-numerical data to interpret and analyse peoples' experiences and actions, (Crossman, 2018). The research design of this study is the case study. The data was qualitatively collected by observing and transcribing two Mindset videos which were analysed using discourse analysis.

CHAPTER 4: DATA/RESULTS PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter focuses on presenting the data to answer the main research question: How effective are Mindset videos on the teaching of chemical reactions to grade 10 learners?

This RQ was unpacked into three sub-research questions:

1. How are the concepts of chemical reaction and equations developed in online videos?
2. How does the teacher reduce the complexity and abstractness of the concept(s) of chemical reactions and equations when teaching online?

The researcher is going to present his findings in form of a table using mainly the two videos presented by the same Mindset educator at different times but teaching the same topic of chemical reactions. The description on development of concepts, how the complexity of the concepts is reduced, and challenges of online teaching will then follow.

4.2 Findings and discussion on Research Question 1

The section below presents the findings required to answer RQ 1: How are the concepts of chemical reaction and equations (including balanced equations), writing compound formulae reactants, products, and valency, developed in online videos?

The findings are presented in terms of semantic gravity and semantic density (Walton & Rusznyak, 2019). In the first RQ, the researcher sought to determine the ways/sequence used by the presenter to transform the ideas so that they can be appropriated by learners. The analysis of the transcripts revealed a pattern/sequence (shown on figure 13 and 14 (graphs) in which the concepts (chemical reaction, chemical equation, writing compound formulae reactants, products, and valency) were developed. In developing the concepts the presenter followed Rootman-le Grange and Retief’s suggestion that chemistry has a hierarchical knowledge structure, which means that an understanding of certain primary concepts is a prerequisite for one to be able to understand more advanced concepts (Rootman-le Grange and Retief, 2018) .

The presenter started developing the simpler concept like reactants and products before doing chemical reactions, for example.

For the SG and SD, the researcher modified the two translational devices tables 1 and 2 (above) into one table, in appendix 4 which is the same as in appendix 6 for videos 1 and 2 respectively, which uses SG1 and SG2 for SG statements and SD1 and SD2 for SD statements. Statements SG1 and SG2 are used for coding semantic gravity while statements SD1, SD2 and at times SD3 are statements from the two videos coded for semantic density for different concepts. The codes are at the bottom of each statement, for example, statement SG1 is coded SG-, statement SD1 coded as SD+++ and then repeated at the bottom of the table for clear comparison.

Table 5 Summary of appendix 4 showing possible computations used for drawing the SG-SD graph below for Mindset Video 1

Concept	Chemical Reaction	Balanced Chemical Equations	Compound Formula Writing	Reactant (s)	Product(s)	Valency
SG	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG-
SD	SD1 SD+++ SD2 SD+	SD1 SD+++ SD2 SD+ SD3 SD-	SD1 SD+++ SD2 SD+	SD1 SD+++ SD2 SD+	SD1 SD+++ SD2 SD-	SD1 SD++ SD2 SD+
Computations (Used to draw the graph)	SG-&SD+++ SG-&SD+ SG++&SD+++ SG++&SD+	SG-&SD+++ SG-&SD+ SG-&SD- SG++&SD+++ SG++&SD+ SG++&SD+	SG-&SD+++ SG-&SD+ SG++&SD+++ SG++&SD+	SG-&SD+++ SG-&SD+ SG++&SD+++ SG++&SD+	SG-&SD+++ SG-&SD- SG++&SD+++ SG++&SD-	SG-&SD++ SG-&SD+

		SG++&SD-				

Table 5 summarises the coding given to explanations of each concept taught, which is repeated at the bottom of table, in appendix, so that the coding can be easily compared. The coding for each concept, the semantic gravity (SG) and the semantic density (SD) of each concept, for example, for chemical reactions, is computed together to make possible combinations of the SG and SD of the concept, so that they can now be plotted on a graph (see Fig 9 below for video 1). The computation for chemical reaction is as follows: SG has codes SG1 **SG-** and SG2 **SG++** while SD has codes SD1 **SD+++** and SD2 **SD+.** So, SG1 **SG-** can compute/combine with either SD1 **SD+++** or SD2 **SD+** to give a possible combination of **SG- & SD+++** and **SG- & SD+,** then plot these two combinations/computations on the SG/SD graph below. Do the same for SG2 **SG++** computing with SD1 **SD+++** and SD2 **SD+** to get the following combinations: **SG++ & SD+++**, and **SG++ & SD+** (as shown in appendix 5). Appendix 5 shows possible computations for the concept chemical reactions as coded above. This is done for each and every concept and for each of the two videos. The computations/combinations are then plotted on the graph in Fig. 9.

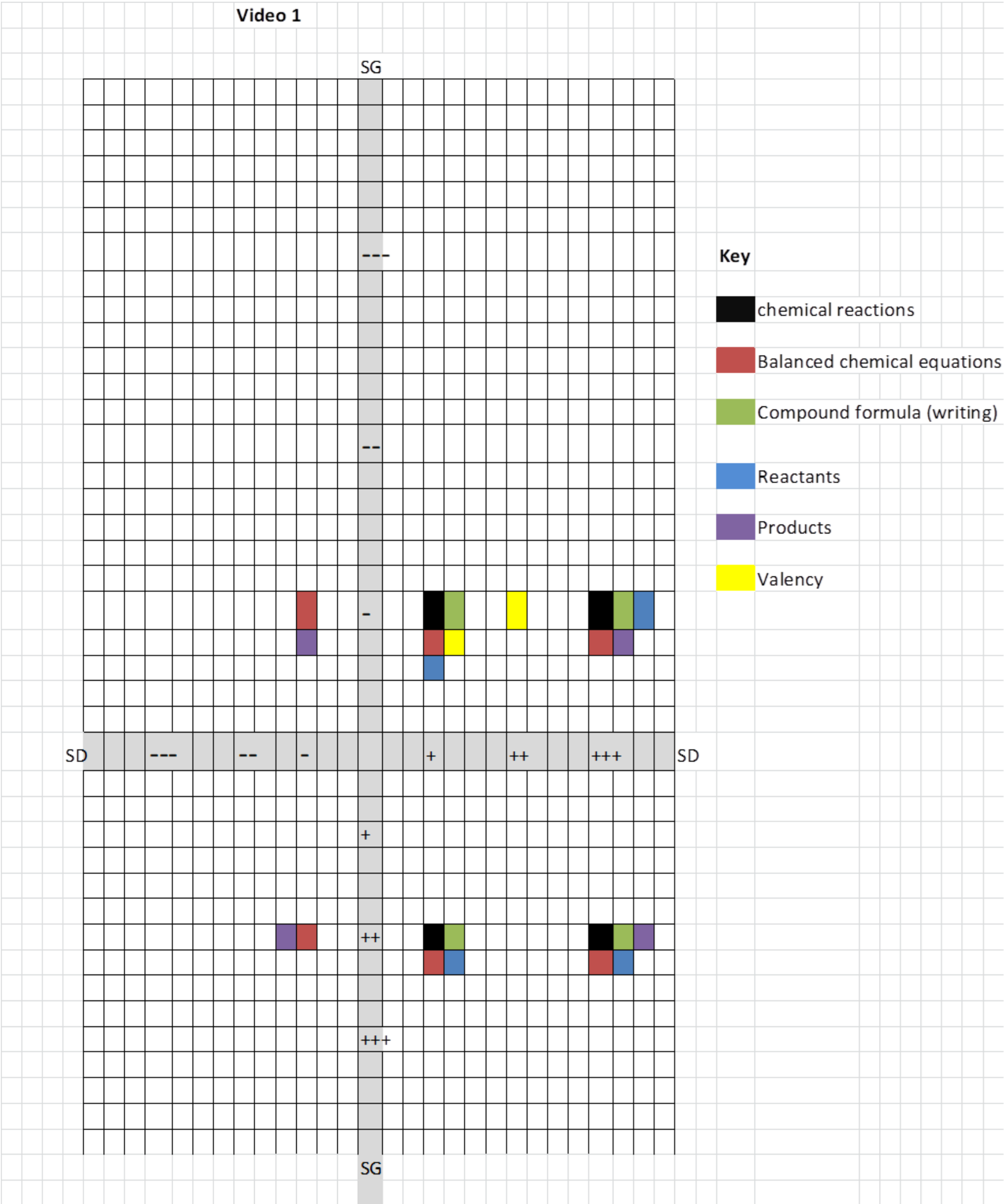


Figure 9 Graph Showing SG and SD for the chemical reaction concepts for Video 1

By checking figures 4, 5, 6, and 7 which are from Maton 2014, it is important to note that it is conventional that the Y-axis for the upper quadrants is negative while the lower Y-axis is positive, which is completely opposite to the mathematical Y- Cartesian.

Description of the graph for each concept is done after the graph for video 2, so that the explanation for both graphs for a concept is done at once and where necessary compared.

There was also computation of the codes that was also done for video 2 and possible computations presented in appendix 6 from which a graph (fig. 10) was plotted.

Table 6 Summary of appendix 6 showing possible computations used for drawing the SG-SD graph below for Mindset Video 2

Concept	Chemical Reaction	Balanced Chemical Equations	Compound Formula Writing	Reactant (s)	Product (s)	Valency
SG	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG-
SD	SD1 SD+++ SD2 SD+	SD1 SD+++ SD2 SD+ SD3 SD-	SD1 SD+++ SD2 SD+	SD1 SD+++ SD2 SD-	SD1 SD+++ SD2 SD++	SD1 SD++ SD2 SD+
Computations (Used to draw graph)	SG-&SD+++ SG-&SD+ SG++&SD+++ SG++&SD+	SG-&SD+++ SG-&SD+ SG-&SD- SG++&SD+++ SG++&SD+ SG++&SD+ SG++&SD-	SG-&SD+++ SG-&SD+ SG++&SD+++ SG++&SD+	SG-&SD+++ SG-&SD- SG++&SD+++ SG++&SD-	SG-&SD+++ SG-&SD++ SG++&SD+++ SG++&SD++	SG-&SD++ SG-&SD+

The SG/SD graph was plotted from the computations from appendix 6 table.

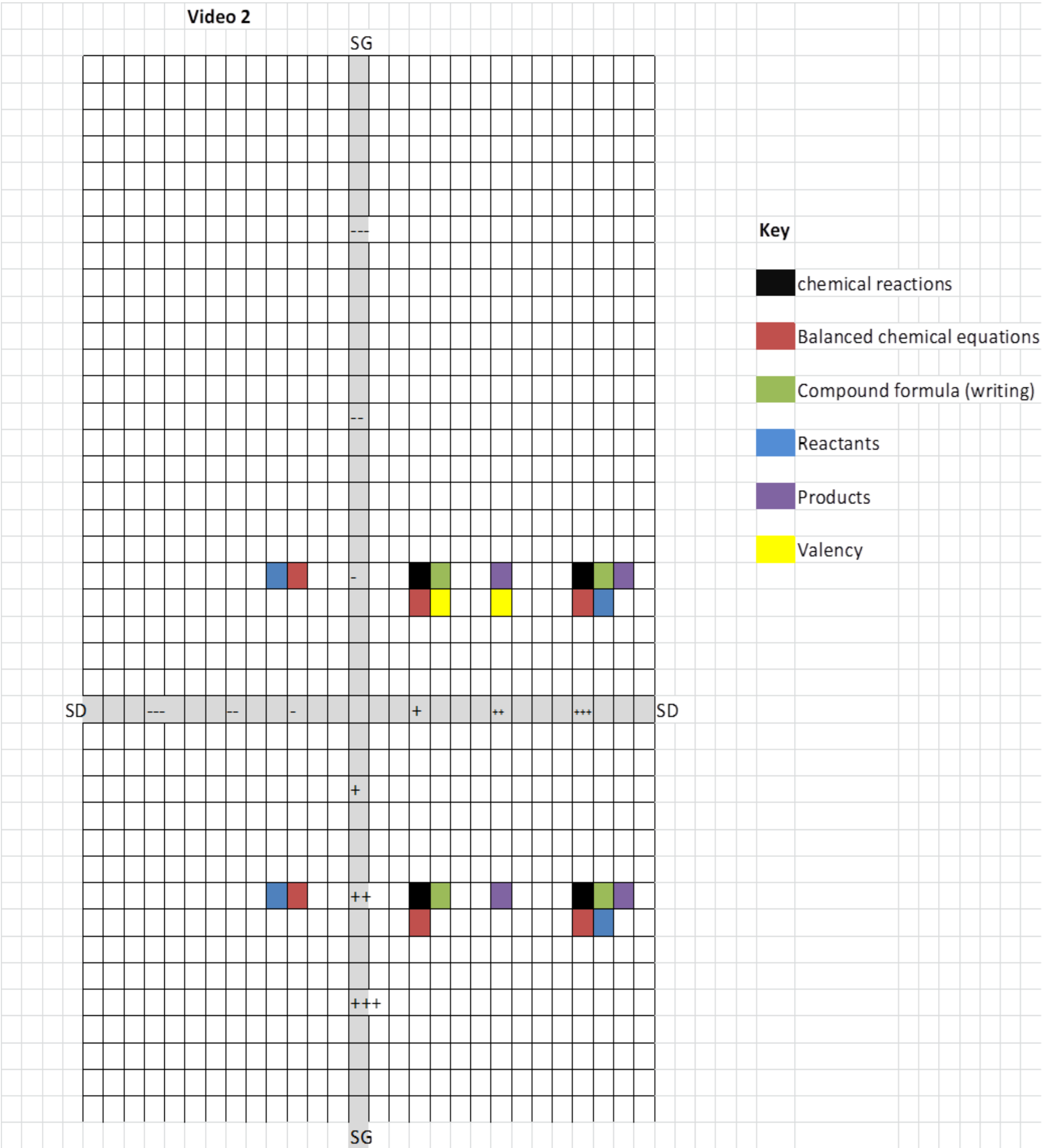


Figure 10 Figure 10 Graph Showing SG and SD for the chemical reaction concepts for Video 2

Chemical reaction as a concept is generally found on the upper and lower right-hand quadrants named the rhizomatic code and worldly code respectively for both videos 1 and 2. The rhizomatic code (SG−, SD+) is where meaning is relatively context independent, but complex, it shows the meaning that has strong semantic density and weak semantic gravity. In the worldly code (SG+, SD+), meaning is still complex but relatively context dependent and more concrete, the meanings have both semantic density and semantic gravity being strong. The learner who grasps the concept at this level really grasps the real scientific concepts covered under this topic and can deal with real challenging scientific situations. The concept has been well developed as at one time the presenter focussed on real world example which the learners understood, when the presenter said, "*this is when new substances are forming"* and then moved to the rightful technical terms to differentiate such learners from those who do not do science, non-subject specialists. In video 1, the presenter used the following technical terms to describe chemical reaction, "*we going to start with reactants and those change into products", while in video 2 the following technical terms were used, "so old bonds break and new bonds form and new substances with different properties will be formed".*

Balancing of chemical equations as a concept has been well presented and developed as it is found on all the four quadrants, the upper and lower right-hand quadrants, namely rhizomatic and world codes, the upper and lower left-hand quadrants, called the prosaic and the rarefied code respectively. The rhizomatic code (SG−, SD+) is where meaning is relatively context independent, but complex. In the worldly code (SG+, SD+), meaning is still complex but relatively context dependent and more concrete. Prosaic code (SG+, SD−) represents meaning that is less complex and simpler, but context dependent. The rarefied code (SG−, SD−) is where meaning is relatively simple but context independent and thus more abstract. As the presenter gave instructions, she moved through concrete and everyday language, for example, "*because that stuff can't come from nowhere and similarly it can't just go into nothing* to scientific and abstract language, for example,

the idea is about the conservation of mass, …… that the total atomic mass of the reactants must be the same as a total atomic mass of the products.

As the presenter moved from simple or known to complex or unknown, the learners were helped to understand the concept of balancing chemical reactions. In addition to the explanations given, examples were also given where balancing of different equations was done, including that of magnesium reacting with oxygen to produce magnesium oxide and that of hydrogen reacting with oxygen to form water as shown below:

Words:

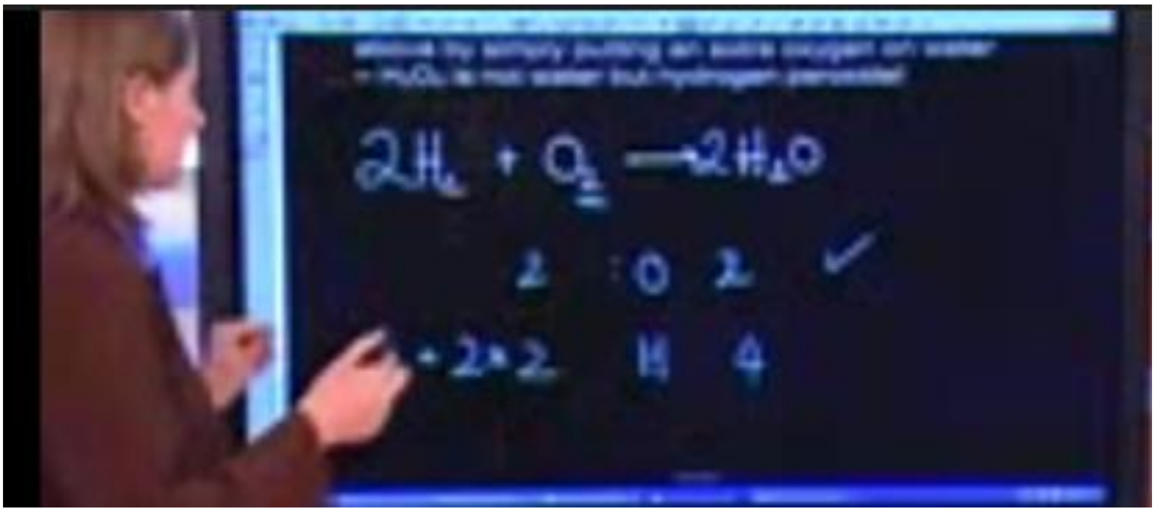
Magnesium + oxygen $\longrightarrow$ magnesium oxide

Symbols:

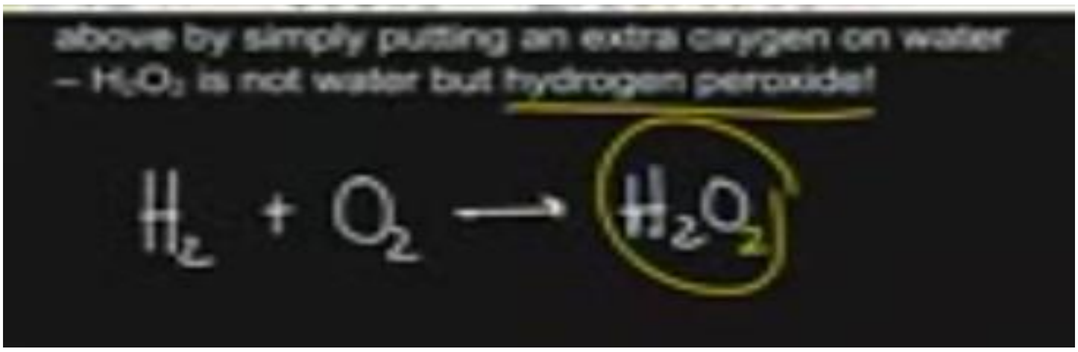
$Mg + O_2 \longrightarrow MgO$ (Not balanced)

$2Mg + O_2 \longrightarrow 2\,MgO$ (Balanced)

Balancing of a chemical reaction and subsequently equation where hydrogen reacts with oxygen to produce water:



The presenter made it clear that when balancing a chemical equation, we do not change subscripts but coefficients of chemical formula as changing of the subscript for water, H_2O to H_2O_2, in trying to balance the equation brings a new and different product called hydrogen peroxide (H_2O_2) and not water (H_2O) (see the diagram below).



Simulations on balancing of equations were also done, where learners could see two magnesium atoms (2 Mg) reacting with a molecule of oxygen element (O_2) to give 2 molecules of magnesium oxide (2MgO). Seeing the simulations helped learners to understand the balancing of equations where they could see the balanced number of atoms on both sides.

The concept of writing the correct chemical compound formula is found on the upper and lower right-hand quadrants which are called rhizomatic code and the worldly code respectively for both videos 1 and 2. Under worldly code, real world examples and symbols are highlighted. While on the rhizomatic code abstract concepts and specific symbols are given. This gives a balance in the development of the concept as the presenter gave real everyday examples like the use of the periodic table and then the technical or scientific terms like the different charged particles (ions) given (see below) that a science learner must grasp.

+1	**Ammonium ion**	**NH^+**
-1	**Hydroxide ion**	**OH^-**
	Nitrate ion	**NO_3^-**
-2	**Carbonate ion**	**CO_3^{2-}**
	Sulphate ion	**SO_4^{2-}**
-3	**Phosphate ion**	**PO_4^{3-}**

The presenter also showed how the compound formula can be deduced using the periodic table and the above list of ions as shown below:

Question 1

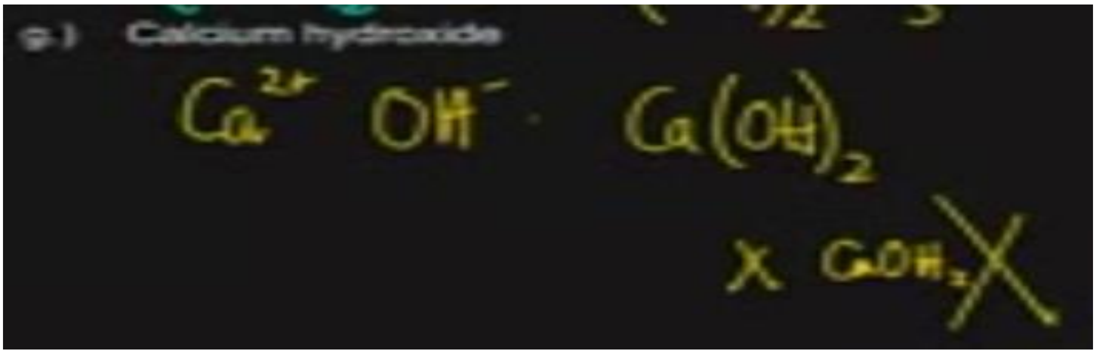
Write the formula for each of the following:

(a) Magnesium iodide

Mg^{2+} I^{-} $\longrightarrow$ MgI_2

(C) Copper sulphate

Cu^{2+} SO_4^{2-} $\longrightarrow$ $CuSO_4^{2-}$



Take note that the presenter pointed out that it is wrong to write calcium hydroxide as $CaOH_2$ as that 2 will be only for hydrogen and yet it is for both hydrogen, H and oxygen, O, but correctly as Ca $(OH)_2$.

Reactants, as a concept, is found on the upper and lower right-hand quadrants, respectively called rhizomatic and worldly quadrants in video 1 and covers all the four quadrants called rhizomatic, worldly, prosaic and rarefied codes in video 2. The rhizomatic code (SG−, SD+) is where meaning is relatively context independent, but complex. In the worldly code (SG+, SD+), meaning is still complex but relatively context dependent and more concrete. The prosaic code (SG+, SD−) represents meaning that is less complex and simpler, but context-dependent. The rarefied code (SG−, SD−) is where meaning is relatively simple but context-independent and thus more abstract. There is the covering of the concept using everyday examples and real scientific terms in both the videos, but in video 2, the idea of reactants was well developed. It went through all teaching- learning styles of teaching from known to unknown, from simple to complex, from everyday examples for example, *so reactants are the things at the start of the equation,* to technical or scientific terms which may be abstract like *reactants are those that change into products.*

The concept, product, covered all four quadrants called rhizomatic, worldly, prosaic and rarefied codes in video 1 and only the upper and lower right-hand quadrants named the rhizomatic and the worldly codes for video 2. As stated earlier on the rhizomatic code (SG−, SD+) is where meaning is relatively context-independent, but complex, in the worldly code (SG+, SD+), meaning is still difficult but relatively context-dependent and more concrete. The prosaic code (SG+, SD−) represents meaning that is less complex and simpler, but context-dependent, while the rarefied code (SG−, SD−) is where meaning is relatively simple but context-independent and thus more abstract. Video 1 helps learners to see what a product is clearly and therefore was well developed as shown below besides describing it as something formed:

Reactants ⟶	Products
(Start)	(End)
(LHS)	(RHS)

The concept of valency is found on the upper right-hand quadrant called rhizomatic code. Most of the description is abstract, and the terms used are technical or too scientific; *valency represents the number of bonds the substance can make for each substance*. This concurs with Maton (2014), that the rhizomatic code (SG−, SD+) is where meaning is relatively context-independent, but complex. It shows the meaning that has strong semantic density and weak semantic gravity.

4.3 Findings and discussion on Research Question 2

The section below presents the findings required to answer RQ 2: How does the teacher reduce the complexity and abstractness of the concept(s) of chemical reactions and equations, reactants, products, valency, writing compound formulae when teaching online?

To answer this second question, the researcher used the semantic waves for each concept for each of the two videos 1 and 2. The concepts are considered in their context not as isolated concepts, hence the time indicated on each concept ranges from the time it was introduced until its discussion ended. The semantic waves came from semantic gravity or semantic density derived from the video transcriptions using the translational device for both videos (as shown in Tables 7, 8, 9 and 10 which were derived from appendices 4 and 6). The reduction and abstractness of each term will be explained after the tables and graphs of semantic gravity and density, starting with chemical reactions. Take note that in general, strong semantic gravity (SG+++) and weak semantic density will show that complexity and abstractness reduction and maximum cumulative knowledge is acquired by the learners.

The stronger the Semantic gravity (SG+), the more meaning is dependent or is tied on its context and the meaning would therefore be concrete; therefore, concreteness is mainly affected by semantic gravity. The stronger Semantic gravity (SG+++), the more the concreteness of a concept and the less the abstractness of the concept, and therefore the more the learner would understand the concept.

The concept of Semantic density describes the degree into which the teacher changes knowledge from complex to more simple forms that learners can understand (Walton and Rusznyak, 2020). Maton and Doran (2017) comment that to make the semantic density weaker, a complex concept should be simplified and made more understandable by using common words and everyday examples. So, a weaker semantic wave, means the concept has been simplified (complexity is reduced), so mainly semantic density deals with complexity of a concept, with a weaker SD showing a reduced complexity of a concept for the learner. According to Rootman-le Grange and Retief (2018) it is therefore crucial that an effort is made to make explicit the connectedness of concepts and the hierarchical knowledge structure of chemistry to support students’ learning of the subject

Thus, during semantic waves profiling, meaning was lifted out of gravity by abstracting away from concrete meaning, and then brought back again to concrete and simpler meaning, thus the strengthening and weakening of both semantic gravity and semantic density (Mouton (2020)). This brings about the decontextualization and recontextualization of knowledge over time, thereby leading to knowledge building in two directions (Maton, 2014a).

Table 7 Showing the semantic gravity of the lesson as represented by chemical reactions concepts

Concept	Chemical reactions	Chemical balanced equations	Compound formula writing	Reactants	Products	Valency
Semantic Gravity (SG) (V 1)	**SG1** **SG-** **SG2** **SG++**	**SG1 SG-** **SG2** **SG++**	**SG1 SG-** **SG2** **SG++**	**SG1 SG-** **SG2** **SG++**	**SG1 SG-** **SG2** **SG++**	**SG1 SG-**

This table (7) shows the semantic gravity and semantic density of each concept as derived from tables in appendices 4 and 6 and these semantic codes were plotted to give the graph, fig. 11, and table 8 is exactly like table 7 (and was used to plot fig.12), showing the presenter made sure she teaches the same concept the same in video 1 as well as video 2. Take note that the time during which the concepts were taught or developed is also indicated and some concepts' time overlap. This shows that the concepts were not taken out of their context, but in context, the whole video lesson was considered.

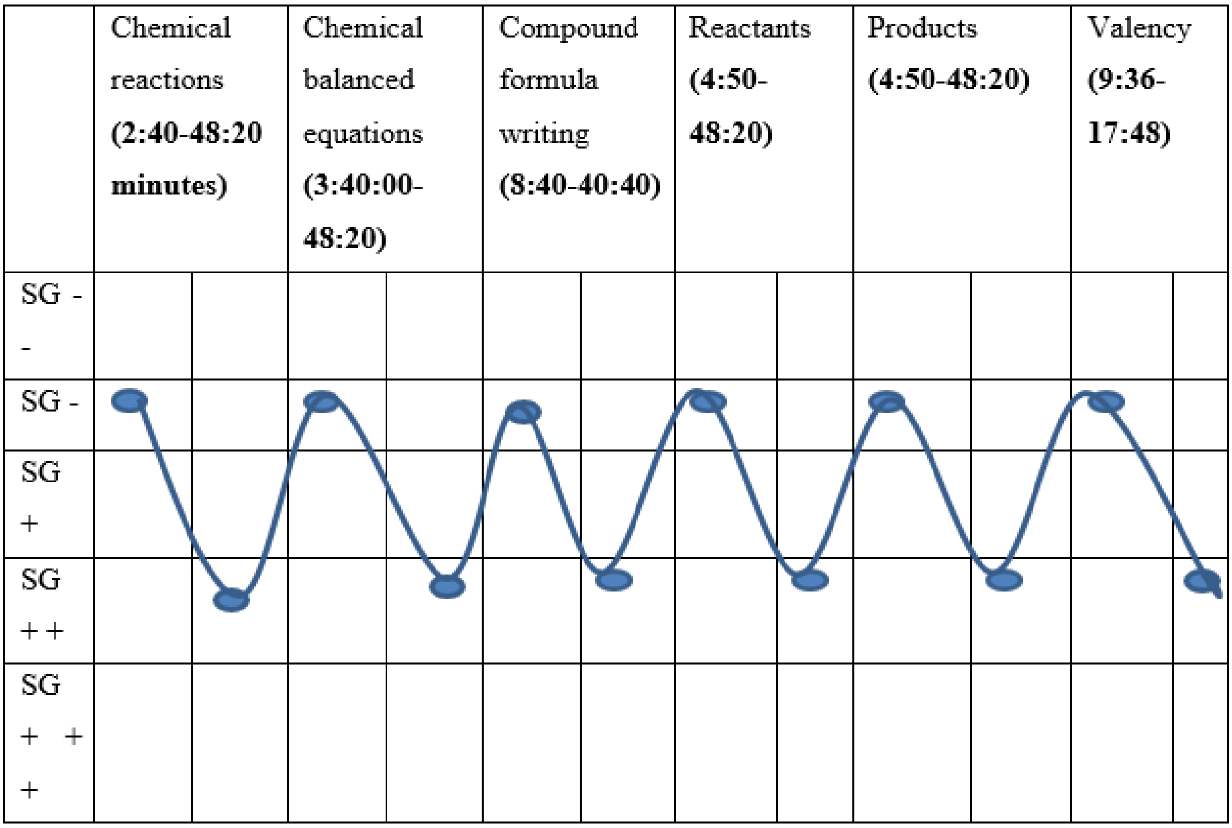


Figure 11 Showing semantic gravity graph for Video 1

This graph, fig. 11 has been plotted using the data in table 7 above and it shows the semantic waves of how SG was unpacked and repacked during the presentation of the video lesson, following concepts covered/done during the presentation.

Table 8 Showing the semantic gravity of the lesson as represented by chemical reactions concepts.

Concept	Chemical reactions	Chemical balanced equations	Compound formula writing	Reactants	Products	Valency
Semantic Gravity	**SG1 SG-**	**SG1 SG- SG2 SG++**	**SG1 SG- SG2 SG++**	**SG1 SG- SG2 SG++**	**SG1 SG- SG2 SG++**	**SG1 SG-**

(SG) (V 2)	**SG2 SG++**					

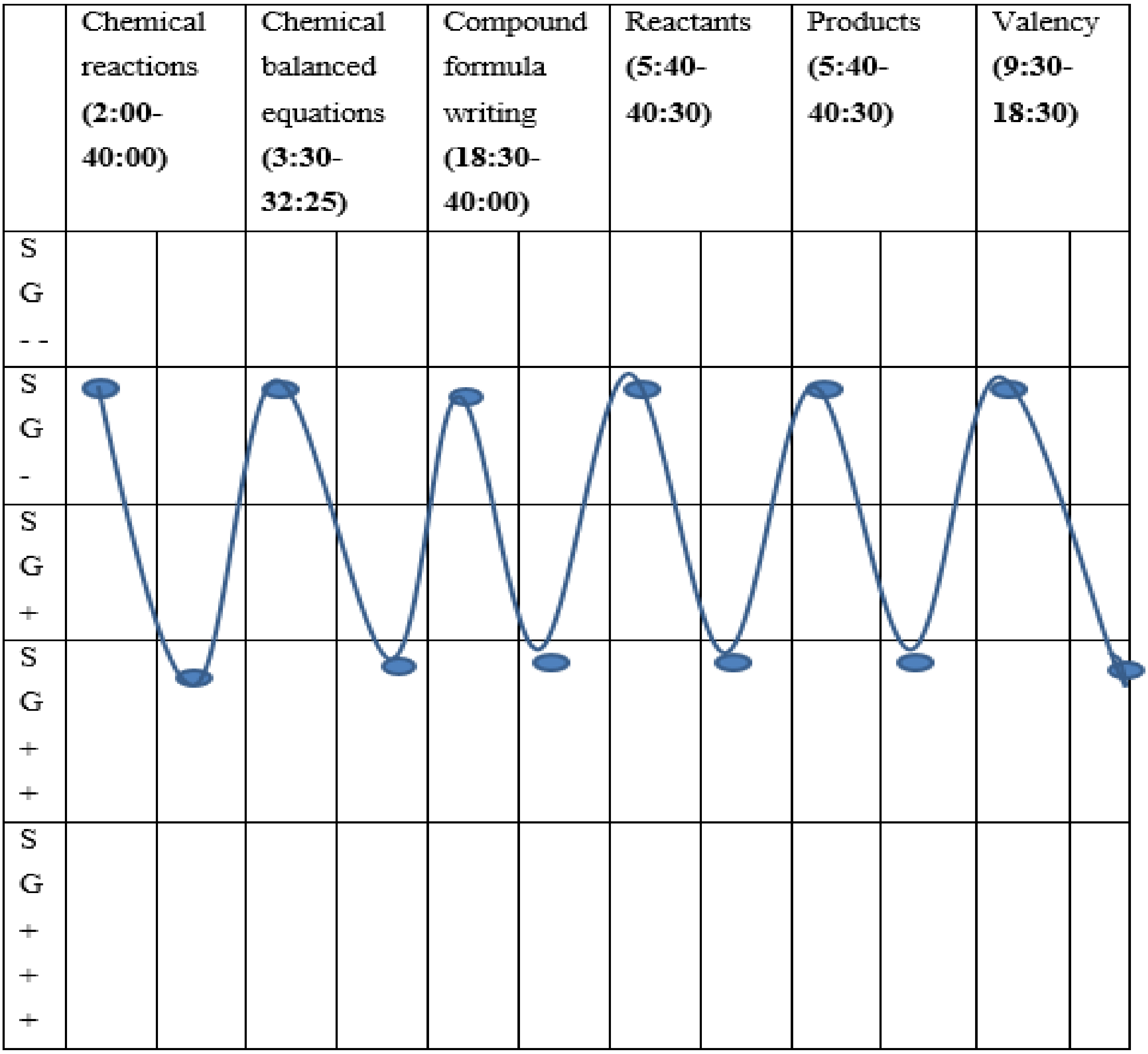


Figure 12 Showing semantic gravity graph for Video 2

This graph, fig. 12 has been plotted using the data in table 8 above and it shows the semantic waves of how SD was unpacked and repacked during the presentation of the video lesson, following concepts covered/done during the presentation.

Table 9 Showing the semantic density of the lesson as represented by chemical reactions concepts (Video 1)

Concept	Chemical reactions	Chemical balanced equations	Compound formula writing	Reactants	Products	Valency
Semantic Density (SD) (V1)	**SD1 SD+++ SD2 SD+**	**SD1 SD+++ SD2 SD+ SD3 SD-**	**SD1 SD+++ SD2 SD+**	**SD1 SD+++ SD2 SD+**	**SD1 SD+++ SD2 SD-**	**SD1 SD++ SD2 SD+**

This table (9) shows the semantic gravity and semantic density of each concept as derived from tables in appendices 4 and 6 and these semantic codes were plotted to give the graph, fig. 13, and table 10 is exactly like table 9 (and was used to plot fig.14), showing the presenter made sure she teaches the same concept the same in video 1 as well as video 2. Take note that the time during which the concepts were taught or developed is also indicated and some concepts' time overlap. This shows that the concepts were not taken out of their context, but in context, the whole video lesson was considered.

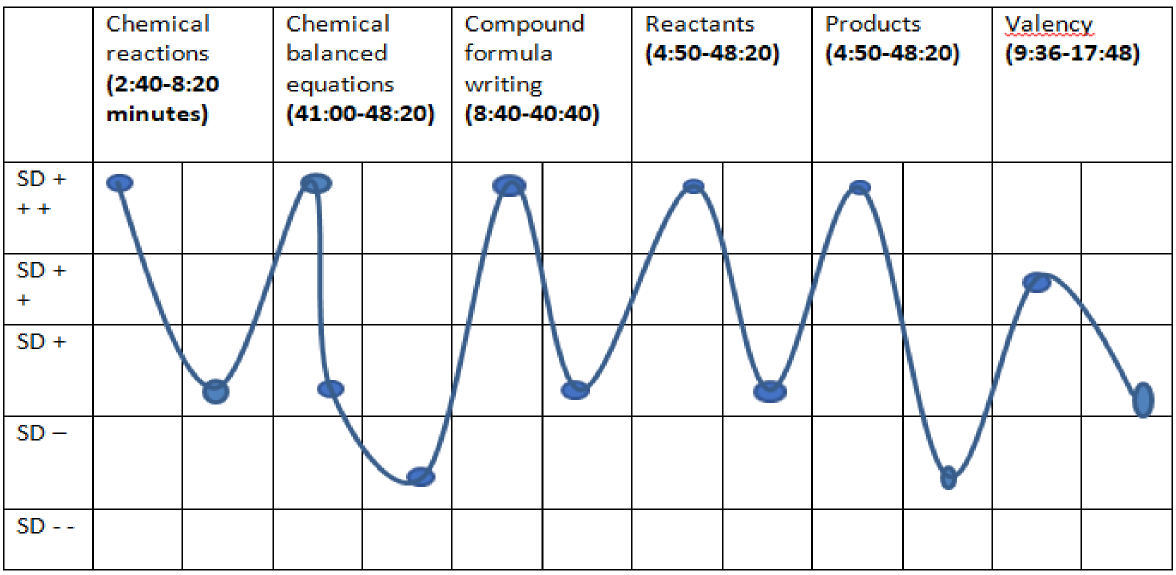


Figure 13 Showing the semantic density of the lesson as represented by chemical reactions concepts (Video 1)

This graph, fig. 13 has been plotted using the data in table 9 above and it shows the semantic waves of how SG was unpacked and repacked during the presentation of the video lesson, following concepts covered/done during the presentation.

Table 10 Showing the semantic density of the lesson as represented by chemical reactions concepts (Video 2)

Concept	Chemical reactions	Chemical balanced equations	Compound formula writing	Reactants	Products	Valency
Semantic Density (SD) (V2)	**SD1 SD+++ SD2 SD+**	**SD1 SD+++ SD2 SD+ SD3 SD-**	**SD1 SD+++ SD2 SD+**	**SD1 SD+++ SD2 SD-**	**SD1 SD+++ SD2 SD++**	**SD1 SD++ SD2 SD+**

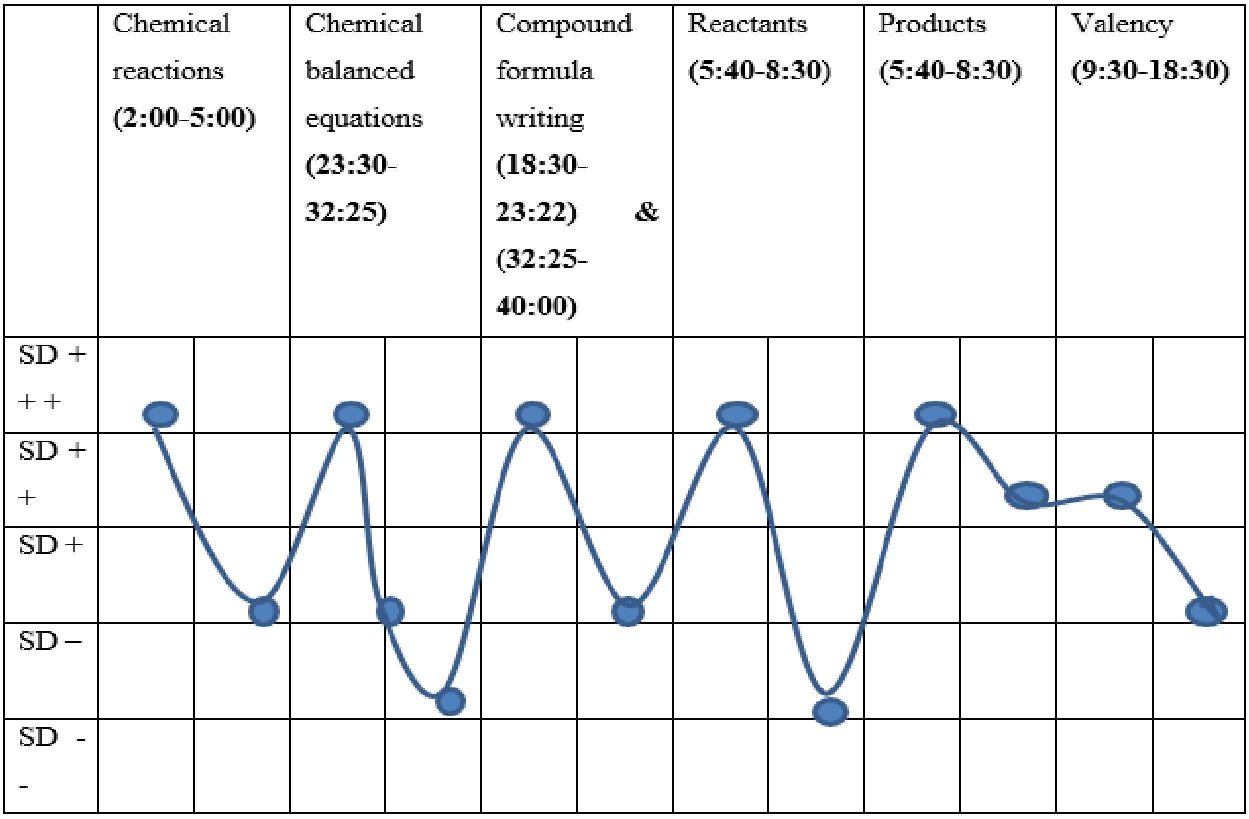


Figure 14 1Showing the semantic density of the lesson as represented by chemical reactions concepts (Video 2)

This graph, fig. 14 has been plotted using the data in table 10 above and it shows the semantic waves of how SD was unpacked and repacked during the presentation of the video lesson, following concepts covered/done during the presentation.

For the concept of chemical reaction, the presenter tried to reduce complexity and abstractness as shown in the semantic wave graphs shown in figure 11 and 12 for gravity and 13 and 14 for semantic density for videos 1 and 2 respectively. The semantic gravity started being weak (SG-), showing the concept was too abstractly explained: *we going to start with reactants and those change into products.* The presenter started to unpack it to a stronger semantic gravity (SG++) in both videos as the presenter started to focus on real world examples stating that *chemical reaction is when new substances are forming, it is not a physical change, it is a new substance that is forming and so what we focus on here is that we going to have a new substance forming* (Fig 11 and 12). For semantic density, it started at strong density (SD+++) and ended with a weaker semantic density (SD+). Knowledge building is characterised by relatively strong semantic gravity and relatively weak semantic density. This shows complexity and abstractness reduction on the term. The next concept to be discussed is the balancing of chemical equations.

For the semantic gravity, for balancing of chemical equations, the graph was the same for both videos (fig. 11 and 12). It started at SG-, a weak semantic gravity, showing that the explanation of the concepts started at weaker semantic gravity which is not easy for the learner to grasp. The presenter was at this point in time talking about the conservation of mass before and after reaction, but later unpacked the concept to a stronger semantic gravity (SG++) where the presenter used real world example, like:

We mean that matter cannot be created or destroyed so the number of atoms of each type that you started with you must end up with, ok, because that stuff can't come from nowhere and similarly it can't just go into nothing.

As for semantic density, the presenter started with a strong density of SD+++ and moved through the middle strength of SD+ and finally a weaker sematic density of SD- for both videos (see fig 13 and 14) . Semantic density has to do with knowledge complexity and the more complex knowledge is the stronger the semantic density (SD +) and the less complex knowledge is, the weaker the semantic density (SD -). The presenter's cycle moves from abstract and complex to concrete and simple path. Semantic gravity was therefore stronger, and the semantic density was weaker and this is a combination that gives knowledge accumulation. Presenter started by using condensed symbolic language to convey a concept (SD+++):

$$2Mg + O_2 \longrightarrow 2MgO$$

Presenter then used subject terms, and explained what it means in an understandable way, giving more details (SD+):

It is about the conservation of mass, and the idea that number of atoms on the left-hand side is equal to the number of atoms on the right-hand side because stuff doesn't just disappear.

Concepts or words from the subject are used to convey meaning in straight forward ways that a non-subject specialist could understand (SD-):

We mean that matter cannot be created or destroyed so the number of atoms of each type that you started with you must end up with, ok, because that stuff can't come from nowhere and similarly it can't just go into nothing.

The above clearly shows that the presenter unpacked the concept of balancing chemical equations and tried to simplify it and reduce its complexity and abstractness as clearly shown in figures 13 and 14 for both videos. Chemical formula writing was another concept considered in this study.

Figures 11 and 12 shows that chemical formula writing, it started at SG-, a weak semantic gravity, showing that the explanation of the concept started at weaker semantic gravity which is not easy for the learner to grasp. The presenter was at this point in time explaining a theoretical statement (SG-) which a learner could hardly grasp:

So, when we think of writing a chemical formula, go to the periodic table. It will tell you what the charge will be, you just need to organise them to get to a neutral compound. To write the formulae of ionic compounds, we need to balance the charges to make a neutral compound.

The presenter later unpacked the concept to a stronger semantic gravity (SG++) where the presenter used real world example, like:

We dealt with magnesium oxide earlier in today's show, but I thought it would be helpful to point it out to you again magnesium Mg 2 +, how do I know that? It's in Group 2 on the periodic table. Oxygen, would form two minus, why? Well because it's in group 16 on the periodic table and the issue then is simply to balance the charges.

The learner who is now familiar with the periodic table may be able to understand the above.

On semantic density, the presenter started with a stronger SD+++ density which was then repacked to a weaker semantic of SD+. This helps to reduce the complexity of the concept to a real-world example where the learner can manage to grasp the content.

Next is the concept of reactants. It is important to note that this concept was presented together with the concept, product. The semantic gravity graph showing the gravity on both videos is shown on figures 11 and 12 while the ones showing semantic density of the reactants and products are figures 13 and 14. On SG, both concepts went through SG- to SG++, showing that the introduction of the terms started being abstract, where the presenter started by saying the reactants are substances that react while products are substances that are produced. This is abstract to the learner as SG is weak, but when the presenter started to unpack the terms to concrete (SG++), the learners could understand. For example, reactants are: *so, reactants are* *the things at the start of the equation and they will be on the left-hand side* and for products: *products will be (are things) on the right-hand side (RHS)* (SG++).

On semantic density as shown on figures 13 and 14 for both terms and for both videos, for reactants, on the first video it went through SD+++ through to SD+, while in the second video it went through SD+++ to SD-. For product, SD went through SD+++ to SD- in video 1 and SD+++ to SD++ for video 2. For reactant, the presenter in video 2, did her best to reduce complexity of the concept than in video 1. Likewise, the presenter did her best to reduce the complexity of the term product in video 1 (SD+++ to SD-) better than in video 2 (SD+++ to SD++).

The last concept to be discussed is valency. In terms of SG, in both videos as shown in figures 11 and 12 only ended at SG-, meaning the term was left abstract: the valency *is how many bonds the substance needs to make.* In such a case the learner would hardly understand anything because the semantic gravity is weak.

In terms of SD, the concept valency went through SD++ to SD+ in both videos as shown in figures 13 and 14. Complexity has been reduced to SD+, but not as much as with other concepts, most of which complexity was reduced to SD-. The term remained a bit complex for the learners to understand.

CHAPTER 5: SUMMARY OF FINDINGS, DISCUSSIONS AND CONCLUSION

5.1 Introduction

The previous chapter presented and interpreted the findings of this study. The aim of this chapter is thus to summarize the overall results. To do so, the researcher will provide a brief overview of the most important findings and some conclusions drawn from the interpreted data.

In addition, this chapter will outline the study's recommendations, implications, and limitations. The overall purpose of this study was to explore and assess the cumulative knowledge-building practices of online learning materials through Mindset videos on chemical reactions in Grade 10. The goal of this study was to answer the following main research question: how effective are Mindset videos teaching of chemical reactions to grade 10 learners? The following sub-research questions were addressed:

1. How are the concepts of chemical reaction and equations developed in online videos?
2. How does the teacher reduce the complexity and abstractness of the concept(s) of chemical reaction when teaching online?

The findings are summarized below using the two research questions that guided this study.

5.2 Summary of Findings

The findings of this study revealed that there were continuous semantic waves for most concepts, especially balancing chemical equations, compound formula writing, reactants, and products. There were also significant shifts between stronger and weaker semantic gravity and density for these concepts in both videos. Regarding semantic gravity (SG), the presenter was able to move from abstract concepts to concrete and context-dependent examples, strengthening semantic gravity. The presenter moved from concrete examples to more abstract ideas, weakening semantic gravity for balancing chemical equations, compound formula writing, reactants and products for both videos. By strengthening and weakening the semantic density (SD) over time, the presenter could unpack dense concepts by putting them into simple and understandable forms for learners. She was also able to shift from simple and understandable meanings of the concepts of balanced chemical equations, compound formula writing, reactants and products to condensed symbolic language, which characterizes scientific concepts. This is in fulfilment of Chinaka's assertion that chemistry is an abstract subject that requires students to operate on three levels of thought which are the macro, the micro, and the symbolic levels (Chinaka, 2021). With such movement in the semantic gravity and semantic density it shows the concepts were well developed and that the presenter reduced the complexity of the concepts.

5.3 Findings Discussion

Before the discussion of the findings, it is very important once more to clarify which of the semantic codes are responsible for complexity of concepts and which one is responsible for the abstractness of the concepts. The stronger the semantic gravity (SG+), the more meaning is dependent or is tied on its context and the meaning would therefore be concrete; therefore, concreteness is mainly affected by semantic gravity. The stronger semantic gravity (SG+++), the more the concreteness of a concept and the less the abstractness of the concept, and therefore the more the learner would understand the concept.

The concept of semantic density describes the degree into which the teacher changes knowledge from complex to more simple forms that learners can understand (Walton and Rusznyak, 2020). Maton and Doran (2017) suggest that to make the semantic density weaker, a complex concept should be simplified and made more understandable. This can be achieved by using common words and everyday examples. A weaker semantic wave means the concept has been simplified (complexity is reduced). Semantic density mainly deals with complexity of a concept, with a weaker SD showing a reduced complexity of a concept for the learner. It is also important to note that reduction of both abstractness and complexity also leads to a better development of the concepts and therefore the two questions' (RQ1 and RQ2) discussions are done at once here.

According to Jaber and BouJaoude (2012), learners generally have challenges or difficulties in understanding abstract and complex chemical concepts. The presenter of the two videos did her best to reduce the complexity and abstractness and hence developed well all the stated concepts including chemical reactions and equations, writing compound formulae, reactants, products and valency. This is because the graph for both videos (see graphs in chapter 4) show that all the terms went through SG-, showing abstractness of the work through to SG++, a stronger semantic gravity which showed reduction of abstractness. The presenter started using real world examples and everyday examples, unpacking the abstract work to concrete work. An exception of this is on valency, which only mainly remained at a weaker SG, SG-. This was the case for both videos. So, valency was poorly developed. Equally the same, semantic density started being strong at SD+++ for all the concepts in both videos, showing a complexity of the concepts as they are introduced. The packing, unpacking and the repacking of the concepts lead to a weaker semantic density as shown in the graphs in chapter 4, figures 11 to 14. Weaker semantic density means reduced complexity of the concepts and hence well-developed concepts. A combination of a stronger gravity and weaker density shows reduction in abstractness and complexity, leading to knowledge building in learners. Figures 9 and 10 can also be used to explain the reduction in complexity and abstractness and hence the development of the concepts.

All the concepts fit on Maton’s (2013) worldly code where real-world examples which include learners’ previous knowledge were given, and later the rhizomatic code where abstract concepts, the real science concepts were then taught to the learners. This supports the idea of teaching from the known to the unknown, from the simple to the complex and from concrete to abstract, and thus reducing complexity and abstractness resulting in knowledge building on this topic of chemical reactions showing that the lessons were well developed. Walton and Rusnak (2020) contend that knowledge building is important in the process of learning because it allows teachers to integrate already existing ideas from the learners with new knowledge. This makes learning meaningful and valuable to learners as they can relate from previously learnt ideas. Generally, the semantic gravity went through all the codes, but passing strong semantic density and weak semantic density, showing the lesson was generally well developed.

Thus, during semantic waves profiling, meaning was lifted out of gravity by abstracting away from concrete meaning, and then brought back again to concrete and simpler meaning, thus the strengthening and weakening of both semantic gravity and semantic density (Mouton (2020)). This brings about the decontextualization and recontextualization of knowledge over time, thereby leading to knowledge building in two directions (Matron, 2014a). Upon such movement in the semantic gravity waves and semantic density waves as shown above, it shows the concepts were well developed and that the presenter reduced the complexity of the concepts.

5.4. Implication(s) and recommendations for future research

Teaching of the topic on chemical reactions is not an easy task as most of the concepts are too abstract and have very little in common with everyday examples. Attending these Mindset lessons live has an advantage over listening to the pre-recorded Mindset videos because then one can directly ask questions to the presenters and be answered directly for maximum knowledge building. Recommendations include the idea of getting Grade 10 learners who has not been taught about chemical reactions in Grade 10, to listen to the videos and then give them a test on this topic and assess their understanding than just to analyze the presentation only without checking for its effectiveness on learner performance. The Mindset videos can also be compared with other companies’ videos on the same topic of chemical reactions. The Mindset video lessons can also be compared with contact lessons done face to face on the same topic and compare the effectiveness of each of them. Further research should be done to explore how a variety of distance modes of teaching, such as live online lessons, build cumulative knowledge and respond to the aspect of developing learners into knowers of science. The researcher recommends that these Mindset videos can be used for teaching the topic of chemical reactions to learners or for intervention and for supporting or supplementing or complementing classroom teaching.

5.5. Conclusions

The studying of the semantic gravity and density graphs for each concept, including the teaching of chemical reactions and equations, shows that the concepts were generally well developed in the two videos, and the presenter tried her best to reduce the complexity and abstractness of these terms which could result in the knowledge building. The SACE, as part of the professional teacher's standard, entails that learners should develop and use the specialist subject matter. This has been inculcated in these videos as the presenter used everyday examples to explain the concepts until she moved to technical explanations of the concepts as expected by SACE.

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APPENDICES

Appendix 1 VIDEO 1 TRANSCRIPTION

Topic: Representing Chemical Change: Chemical Formulae and Equations

Lesson Description:

Use symbols to represent chemical reactions

Practice writing chemical formulae

Balance chemical equations

Identify state symbols

Grade 10, we going to be looking at representing physical change of chemical change, the writing of formulae, balancing equations, an incredibly important section of work and grade 11 and 12, this is something that's very important for your revision so that you can build out in terms of all the different chemical chemistry that you do, so it's the basis of a new language of chemistry **(1:00).**

Well, Grade 10S, as we have said we going to do chemical change today and focus on representing chemical change. I also want to say it's not learning a new language this is going to be fundamental as you move forward in your studies of chemistry because we are representing change and what we want to be able to write chemical formula and write chemical equations and so that the scientists across the world can all be speaking the same language as we write symbols and work with these equations **(2:38).** So come to the board with me as we looked through what we going to be doing in this lesson.

In this lesson we are going to use symbols to represent **chemical reactions (2:49)** and you remember last time we spoke about physical and chemical change and physical change is particles rearranged. So, think about water being heated from ice melting to a liquid, the particles which were sticking together in crystal in a solid that have not been able to move apart and able to flow over one another, that's physical change, the substance haven't changed itself. Whereas in **chemical change** we are looking at new substances being formed so just this term is **chemical reaction**, I'm going to write a new substance is formed. **(3:30)** In a **chemical reaction,** so we want to write symbols to represent the chemical reaction. We are going to do a lot of practicing of writing formulae, so writing the formula for potassium hydroxide, for all those types of things. Then another key concept is to **balance equations** and you might have heard of **balancing equation** and people say it is really hard, it’s not, you just need to understand the concept and then we also speak about states or phase symbols, so you might have a little of solid liquid or gas or aqueous solution. **(4:17)** So let's get straight into it, a **chemical reaction**, I want you to notice here that this is when new substances are forming, **(4:26)** it is not a physical change, it is a new substance that is forming and so what we focus on here is that we going to have a new substance forming, we going to start with **reactants** and those change into **products**, **(4:50)** so **reactants** are the things at the start of the equation and they will be on the left-hand side. Now I want you to notice my short handwriting (LHS- left-hand side) and the **products** will be on the right-hand side (RHS) **(5:09)**

Reactants $\longrightarrow$ Products

Start End

React Formed/Produced

As we read from left to right so the reactants are the things that you've got at the start they will be the thing that will react together **(5:20)** in order to make the things at the end this is what is formed or is produced, in this chemical equation, so what you got is you have got the **reactants** on the left, going to the products on the right, okay, **(5:43)** and it's very important that you are working with those with **reactants** form so you can get when you get a word equation that you can interpret what they're starting with me what the meaning you can get, so as they form the new substance, substances from left to right hand side **reactants and products.** The next is that there are different ways to write equation three different types of equations, firstly you could have a word equation, **(6:19)** then you could also go with a symbol equation, lastly, we need to focus on writing a balanced, key word, symbol equation, balanced symbol equation, and I'm going to start with the first two and then we spend the last segment talking about writing a balanced equation. what most people struggle with is going from the words into writing symbols the reason that they struggle with that is because they don't have a good understanding of the periodic table and chemical bonding which is actually the basis of how we write things **(7:21)** so it's very important that Grade 10, 11 and 12 that you go back and that you will recap some of the work we've done previously okay it's incredibly helpful if you can go and revise that work because the chemical bonding section will certainly build on what you've done doing what we're doing now so I'm going to spend quite a bit of time **writing symbol equations** and specifically here **writing formulae** so let's go across to that section, one more thing, before I move on from here is that you have seen us write reactants and products and you've seen we've got in the middle here an arrow, so is it from left to right as we show the directions the reaction is taking place, it is important to note that actually some reactions are reversible they go in both directions and so a reversible reactions can be forward and reverse, reversible, some reactions take place in both directions we are at this stage going to focus on the forward reaction but as you get to grade 11 and 12 you will do reversible reactions as well. **(8:40)** So, let's get it get plugged in in terms of **writing chemical formulae,** because I know this is the section that many people struggle with. Consider the group number when you're working with the group number and by group number I'm thinking the group number in the periodic table okay, if I go across to my periodic table in a moment here, there it is these are your groups so that's going to be group one can we have group two, these are the groups that we are talking about okay, these vertical columns. Consider the group number it will help you to find the **valency** of each substance in the compound. **(9:36)** For example, in writing potassium chloride. Go and look for potassium in the periodic table, and go and look for chlorine, chloride in the periodic table and then you can work out on how these things work in terms of **writing the formulae. (9:56)** So, consider the group number to find the **valency** of each substance in a compound and as I say they're going back and revise your notes on chemical bonding. For covalent compounds, now remember what covalent compounds going to be, when a non-metal reacts with another non-metal okay so those things on the far right-hand side or the right-hand side of the periodic table that goes to be nonmetals when they react together. What you going to have here is for covalent compounds, the **valency** is a helpful number because it represents the number of bonds the substance can make. For each substance draw out the bonds as little "arms" and then link it to them know I'll do one with you I've chosen **(10:54)** to work out ammonia now ammonia is made up of nitrogen and hydrogen. Nitrogen on the periodic table let's go and find it there it is in group 15 and I know it also made of hydrogen gas which is in group 1, it's a non-metal but because it has only got one valence electrons it's linked with the other ones with only one valence electrons. I'm jumping back and I've got here nitrogen is in group 15, it can make only three bonds why is that will because we know that all substances want to have a filled outer energy levels, okay so what you going to want to happen is to get the same outer energy level structure as the noble gases so this want to have a filled out energy level **(12:00)** how many more does it need it to get to 18, it going to need to get 3 more okay so 18 – 15 get equal to 3 bonds, and I'll just put in there 18 - 15 is going to get me equal to 3 bonds. Another way of working that out is to draw out the valence electrons, so I've got nitrogen I'm drawing a Lewis diagram 12345 why because I know the group 15 is going to have five valence electrons. so nitrogen has 5 valence electrons in the outer most energy level, it then has a valency of 3, why? Well, because look it's got three unpaired electrons it wants to Pair up in those three places and it's a simplified model but hopefully it's going to help you. So, when this thing bonds, sorry we haven't gone to hydrogen, let's do hydrogen, it has one valence electron, how many bonds can it make? It can make only one bond select to hydrogen with its one little electron and so hydrogen is going to be able to fit in I need some more space to write, right what we have got is that nitrogen with its 12345 and the hydrogen can come and fit in 123 there you are, the formula is going to be in with its 3 bonds and the hydrogen with its 1, 1, 1 those little arms linking up and so I know that my **formula** is going to be NH_3 okay. **(14:04)** So, the idea here with covalent compounds is use little arms to make the bond to represent a little bond and you can link up how many bonds okay this is quite a useful technique as you work on the number of valence electrons and the **valency,** and how many bonds it can make. Let's go for break and after break we work on ionic and writing formula.**(14:38)**

I heard from Jamie, and I've heard from Kelvin listen up here's your question. Jamie, you asked, where do we get 18 from? 18 is the group number that you can see at the end here that is indicated for the noble gases so that is the total number of filled up the number for the number of filled out to energy level, with the idea is that a noble gas structures are most stable when it's got the most filled out energy level **(16:08)** and very often we call that number 8 as well because the old periodic table didn't number these guys the transition elements okay so often some periodic table call that group 8, at least we now call it group 18 for the noble gases. Hope that answers your question and then Kelvin asked about clarifying the idea of valence electrons and the valency, very, very important that you get the idea and valence electrons are the ones that are in the outer-most energy level. **(16:57)** If the ultimate level is energy level 3, all the other are level 3. Whereas the **valency** is how many bonds the substance needs to make **(17:10).** Group 1, group 2, the valence electron and the **valency** are the same and group 3, whereas when you start going towards, into the non-metal, the **valency** and the valence electrons are very different, so go back and revise both. **(17:37).** If we go across now to ionic compounds the **valency** represents the charge on the ion ok **(17:48)**now I want to explain that quite significantly if I am if we've got a magnesium atom, and magnesium let's go and find it, it is in group, in group 2 over there okay that means it has two valence electrons so I'm going to just draw them in as a little crosses there we have them okay if that substance becomes an ion what does it mean? It becomes a charged particle those have been given away and so magnesium is left behind without those valence electrons and it's going to be left with an overall charge of

2+, why, because it's now short of two electrons, it has given them away right, and electrons are negative so overall it's left now more positive. Metals will always have a positive charge and they have given away their valence electrons in outermost electron nonmetals and metals are going to be positive. Nonmetal will gain electrons so let's change our colour here, nonmetals will gain, so what type of charge do you think they're going to have if they're going to gain electrons, are going to take us extra electrons are they taking extra negatives on board as well then? They will form what type of ions? Well, surely, negative and the right that out negative ions. This is done always in order to have a complete filled out energy level. The idea is that a metal its quickest route to getting a filled out energy level is to go to the level below, okay to give away electrons to go to a full complete outer energy level of the level underneath okay so they would rather give away one then gain an extra 7 or they would rather give **(20:00)** away 2 than gain an extra 6, the shortest route to complete out energy level where as nonmetals will happily gain, only need to get one or two or gain three electrons to get to that filled out energy level. So, I've got a summary here of the different groups. I'm going to change this one had done let's change it to sorry let's change it to sodium, **(20:32)** I want to focus on metals, group 1 will form a 1+, group 2 form a 2+ ion, group 3 or its actually group 13 is going to form 3+ ions are going to give away. Then we go across to group 16, these are non-metals, they have got one or two to get to a filled energy level, so group 16 to get up to group 18 it needs to take up only 2 electrons, so notice the charge is a negative charge, by how much, by 2, so it is -2, group 17, -1, and 18 is zero charge.it does not need to gain anything as it has a perfect filled outer energy level. **(21:25)** So, when we think of **writing a chemical formula,** go to the periodic table.**(21:31)** It will tell you what the charge will be, you just need to bring them together and organise them to get to a neutral compound. To **write the formulae of ionic compounds**, we need to balance the charges to make a neutral compound, okay, so I've gone through a list of them because I know the people struggle with it if you had Magnesium Oxide and you're asked to write the formula for Magnesium Oxide, go back to working with magnesium so Mg, what's it going to be it's in group 2, so Mg is 2 +. Oxygen it's going to be in group 16, what is going to become oxygen 2 - and so the formula then notice it's a 2+ and a 2 -, they match up perfectly and so we only need one of each side for the written them x 1 x 1 the formula is a simple MgO, magnesium oxide. **(22:39)**Now let's do something harder one, potassium. If I got potassium Oxide will potassium go and find it, where is it on the periodic table is going to clear all scribbles that I've got okay so we can see clearly potassium is down here it is in group one so what type of ion will it form will form a positive ion, by positive one is going to give away that one valence electrons **(23.20).** oxygen over here is in group 16 so it's going to become a negative ion and non-metal it's going to gain two electrons to get to that filled out the energy level so if we go back to our periodic table, we have here potassium has a one plus, the oxide has a two minus and the focus that I need you to notice that I want the final formula to be neutral okay so I have got one positive and two negatives so I've got two negatives there what about this one, I'm going to have to times the potassium by 2 then we can have an overall 2 + and 2 - is going to equal to zero and when I write my final formula notice I don't have any of the charges shown there because I'm showing that they are now balanced I've written a chemical formula that is neutral.**(24.28).** Let’s do a few more, calcium is in Group 2 let's check it, calcium there it is in Group 2 and chlorine is here in group 17 so if I go across here calcium. I know it's a two plus the chloride is going to be a 1- because it’s from group 17 how many chlorines do I need I have to have two of them because notice I've got a two plus charge overall two plus charge, I must have and -2 so how am I going to get that. That’s why I have to times the chlorine, **(25.16)** that whole thing by 2 and so haven't been taken off formula just crossed that and right again calcium chloride would be calcium I only need one of them chlorine, Cl_2 the idea that we have to have two chlorines for every calcium. now this can be very challenging work back from the periodic table. From the periodic table look at the group write on the charge and then work for them let's go across to some more hints on this writing chemical formula now you will never notice that for all of those we've just had group number work with group number, and you are sorted. **(26.08)** There are also transition elements that we could that have multiple, what we call oxidation states they can form multiple charges so we will have to tell you which one which charge the substance is going to have and so Roman numeral do that for you the Roman numeral behind the name of an element in a compound will indicate the charge on that element so I'm giving you an example here of iron 3 oxide **(26.39)** it tells me immediately the Roman numeral those three little lines, those are Roman numeral that tell you that the charge on the ion if he is going to be 3 okay **(27.03),** if it going to be positive or is it going to be negative, think about it, it going to be positive, why, because this is metal so it's going to give away electrons, so I have fe3 plus the oxide from there I know oxygen group 16 I know it's going to be a 2 - now I'm going to jump down because I feel like we need some more space to write this okay and so I'm going to write that again, Fe3+ **(27.37)** and oxygen 2 -, and my question to you is how you going to get this thing to be neutral, ok, we want it to be neutral **(27,50).** how you going to get it in neutral you've got + 3 and -2 the best bet is to look for luckily in maths you are going to look for the lowest common denominator, whatever (28 mins) lowest Common multiple. what is the lowest common multiple between, well 3 and 2. The lowest common one I can see is 6 and so I'm going to write there + 6 and -6 because what I'm trying to get to is to say how I want this to be giving me a plus 6 and then I can get a minus 6. What do I need to multiply 3 by to get to +6, what do I need to multiply by two, what I need to multiply that to by to get to -6 I need to multiply that by three the objective is to get these things to be electrically neutral came to have no overall charge so very helpful just by the way **(29)** a quick hands to you can also do a little bit of a cross multiplication does work watch out there that you and it's have an understanding of why it works the idea is that you wanting to get to this lowest common multiple k, so that solving that problem I specifically wanted to point out to you this idea of the Roman numerals because you cannot forget things like if you have Fe2, iron 2 oxide k and iron one oxide things like that so just watch out the Roman numerals tell you the charge and you can immediately work with the charger let's go across to the board and noticed that there are some important what we call polyatomic ion now poly polynomial poly means many atomic atom, ion would be a charge particle, I have written that down here there are some very helpful we work with a lot and I thought let me just write them down you've got them you can reference them some more they will be very useful for you to know these are ions which are called which are charged particles made up of many many poly atoms. So polyatomic ion **(30.25)** These we treat as a unit (30.29) so if I speak about a sulphate I know it's SO_4^{2-} ,it's a unit that I'm going to treat completely by itself, I want to suggest to go and learn is there are only seven of them that we use on a regular basis I have included them and this is a whole big chunk of tables that you can go and reference and work with and I know Megan has put them up on the page quite helpful that that you could go and reference but I wanted to check these 7 that you just go and quickly learn them and if you can memorize them whenever you they come you come across them it's going to be much quicker for you instead of going to have to go and find them so I've got them here for you I've grouped them into 1 this is plus one that's – 1, - 2, - 3. So, I have grouped them in the charge order **(31.24)** just say to help you remember the charge on them so ammonium is one that we often come across helpful to note ammonia is nh3 that's something you might also remember so ammonium is going to have something extra and it's got an extra hydrogen which gives it an extra plus one charge hydroxide, hydro referring to hydrogen, oxide referring to oxygen **(31.58),** OH - , nitrate very useful one to note, NO^{3-} , carbonate CO_3^{2-} . sulphate $SO_4\ ^{2-}$, Phosphate, PO_4^{3-} . These be very helpful for you to go in and work with part of them could we do and come across them significant .Tracy, I think they are telling me like at break now because it's just I think a few questions cut I'm sure you are testing help I don't feel like a do this you can do this so going to take a short break and when we come back, we'll work on a practicing quite a few questions have been exactly and don't forget you can down

So grade 10s, we can go through some questions and I've got a whole bunch of questions here for you on **writing the Formula** so write formulae for the following, magnesium iodide okay well magnesium is going to be in Group 2 so it's going to be a 2 + iodide jumping back here it is iodine sorry that I'm not there it is in its in group 17 so it's going to be I, what charge positive or negative, negative charge **(34.40)** by how much by one, ok, now we have to look at it we want to balance for the Charges okay so we want to have two iodine for every one magnesium, so notice here, my final formula is going to be MgI_2, ok **(35.03),** the of the focus point is that you want the charges to balance so I have to have sorry have to have two of those for every one of those ok notice in my final and in my final formula no charges are showing because I've already got a neutral compound I don't need to show the charges so the next time zinc two fluoride so they think too they tell me it's zn 2 + the Roman numeral indicate what the charge is going to be fluoride f-minus why because it's in group 17 there it is in group 17 I'm running out of colours so we'll go with that and in the same way we have got Zn with two plus **(36.09)** I need to two fluorine and fluoride sorry if there then copper Sulphate, now copper is an interesting one, copper, it's very often to two plus sorry let's just do that, (36.20)copper two plus, sulphate, this is the one I suggest you go and learn because you are going to meet them more often so I know it's on your page you going to go and check me it's SO4 2 - 4 when I should just go back and check there we had it sulphate SO4 2 - so as I write the final formula notice if it's 2+ and 2 - the charges cancel or balance out so my final formula is SO4 (CuSO4). Potassium chloride, potassium is in group 1, so K plus **(37.18),** potassium group 1, chloride, Cl, group 17, so chloride will be Cl minus, we have got a nice quick one to one ratio there so KCl. Let’s get a few harder ones, sodium nitrate, sodium let's work with Sodium finding it there it's in group one and it's going to have an Na plus charge. Nitrate, this is one of the polyatomic ions that I suggest going and learn as a chemical, nitrate will be NO3 minus. Now notice the charges are there, they cancel, plus 1 and minus 1, so my final formula would just be NaNO3. Now I come to ammonium carbonate, ammonium NH4 +, carbonate, I want to go back and show you on the polyatomic ion, ammonium with NH4 plus, carbonate CO32 -, **(3854),** so we can go write them down, notice I am going to write them down in terms of indicating my working, CO32 - **(39.02),** just to work with the ions first, they want to get the ions written down you can go in terms of writing them as one file formula, **balancing** them. The question is how we going to get to this to **balance** because here I've got a 1 plus and there, I have got a 2 -, we need to have two of the positives, would you agree with that? would it be ok for me just to write NH42 and work with the rest of it. Hopefully, you are saying no, (39.38) no Tracy that going to be terrible that looks like 1 Nitrogen and 42 hydrogen, that’s terrible, of course not, no we can't write it like that because it would indicate the two next to the hydrogen which is not what I want I want 2 of the whole thing, right, so what you need to notice is that we can use brackets to work with this and treat it as a unit, okay so wherever you have got multiples of polyatomic ions treat them as a unit, put them in brackets and work at them, so my final answer is going to be NH4 in brackets **(40.18)** then 2 of those, because that's going to give me the two positives and the carbonate, CO3 **(4025).** The last one, calcium hydroxide, I've got calcium is in Group 2 + hydroxide, 0H -, you see how it is quick and easy if you go and learn these and when I write my final formula I need to have two of the hydroxide so Ca(OH)2, again I don't want to write it so this is not as CaOH2 because that indicate the 2 on the hydrogen and not on the oxygen, so that is not true follow with me brackets and closing it helps to indicate that we have taken enough care of the unit. Now I want us to move on and work on writing chemical formulae, not only chemical formulae, but **balancing equations**. I am going to work on this quickly because I want us to get to some practice **(41.23).** The idea is what we spoke about last week about the conservation of mass, and the idea that number of atoms on the left-hand side is equal to the number of atoms on the right-hand side because stuff doesn't just disappear. So, you can go and work through those notes. I have given them quite thoroughly to you. But I want to highlight to you that the total atomic mass of the reactants must be the same as a total atomic mass of the products this also means that the total number of atoms in the reactants must be the same as the total number of atoms and the product at the end. Stuff doesn't just disappear **(42.03).** So, let's go with this example, hydrogen and oxygen react explosively to form water. Write a **balanced chemical equation** for this reaction. So, notice that I have just lay this out step-by-step. We said let's do it in words first. Hydrogen and oxygen together make water. In symbols, I have written H, notice here this is diatomic, which means H2, 2 atoms together hydrogen exist as a diatomic, there are others that are also diatomic which include nitrogen, oxygen and hydrogen, fluorine, chlorine, bromine, iodine, all the halogens **(42.54),** so notice when you write a symbol equation, you have to have to show the correct symbol formula and water H2O notice that the equation is not balanced and I think and I've got a page here, let's go across to water and this is actually showing separating water the reverse of what the question I have on the board **(43.23),** so if I start with 1 Water, there it is 2 hydrogens and oxygen and I go to one there and let's make one here, is the thing that will have a look my balancing scales for hydrogen says 2 as to 2 and that's equal, the oxygen I have got one going to 2, that can't happen one thing can't suddenly become two, so what must I do? **(43.47).** Well obviously, have to have two oxygens at the start so let's increase that number to 2 and we have oxygen that's **balanced** on the left and on the right, but hydrogen. Oh no, the hydrogen is thrown out. It has got four and two so what can I do? I can change this hydrogen there and make that two and now notice that we have big smile face is **balanced** left hand side and right-hand side. The idea is simply that you going to be counting the number of hydrogen and oxygen on the left-hand side of the reactant and on the right-hand side of the products ok and you've got to make sure that they are equal because stuff can't be created or destroyed. So, matter cannot be created or destroyed (44.35), those atoms at the start must be there at the end. So, let's go back to the equation that we had and make sure we can balance it. I said here for a **balanced chemical reaction**, the number of atoms number of atoms of each element in the reaction is the same as the number of atoms of each element in the product, so it must be there at the start, it must be there at the end. In order to balance an equation, we put coefficients **(45.08)** in the front of the reactants and products until the number of atoms of each is the same on both sides of the equation. Note, you may not change any subscripts, NB, NB as that would change the identity of the substance you that you are working with. **(45:30)** So, let's go and work on this equation. I'm going to jump down to the bottom because I'd like more space. I will write it again, we had hydrogen + oxygen formed water. Notice that I've got two oxygen here, but only one oxygen there. Would it be ok for me to say by just throwing another two in there, NOO, of course not. Why, is that water? **(46.08)** H_2O_2, NOO it's not, that stuff is actually hydrogen peroxide, highly toxic, very very dangerous, okay not the same thing as a water so no you can't just go and something plug in a little subscript and there but maybe it will work if I do that now you can't, once you have the equation and simple forms you've got the right formula for every substance **(46.31)** you then have to leave it and just work with multiple of everything okay so I'm going to take that away ok go back to what we've got we need to have multiples of these things so I noticed I've got two oxygens there so I'm writing a little table on the side oxygen I know I've got two but I only have one the side so I'm going to put two in front of H2O okay so that's now oxygen is sorted happy, hydrogen, I've got two this side for hydrogen and now I've got two multiplied by the two so I've got four on the products what am I going to have to do I have to come across here and said it's not supply that part 2 which is going to give me four **(47.19),** so I'm multiplying the front there and I've changed the coefficients at the front which is telling me how many I have. We are balancing overall chemical reaction. Let's go across to do one or two more. I have this equation at the start. I actually didn't do this one with you, but let's go through this one together: magnesium and oxygen form Magnesium Oxide, so Mg + O2 form of MgO, that's the formula for Magnesium Oxide, Let's start with the oxygen. I've got oxygen two there but only one on this side so a big two in the front, now I've got to magnesium I must go back and put two in the front of the magnesium ok. That it all there is to

balancing I've given you a few hard questions to work on and you can safely look at those **(48:20)** and the last point I'd like to make is to talk about the state of compound. Very often in equations, they give you these little symbols, g standing for gas, liquid, solid and aqueous would be for aqueous solutions. **(48:41)** Very often those little symbols are indicated to you to help you and as you work with these chemical formulae. So Grade 10s I really hope that's helped you and you just chemical formula and be able to write chemical formula and balance equations thank you much for joining me I'll see you next week Megan over thank you so much no matter if 11 or 12 so let me just quickly before you guys all the application for you guys jump me with saying why do they all want to know where they can download the application on the Amazon the link page around the bottom of the noted on the web page on its answer to be on the website it's effectively the Asian or you can just **Google phet simulation balancing chemical equations,** it's there for you okay cool that's a great one to work with 1/10 it's really fun and it comes up with a happy :-) that you got the sound on it makes sense for you to okay perfect thank you so much I really learnt so much in this lesson is ridiculous I know you guys because you giving me so many Formula and I don't even know what's going on but it's cool I didn't know I can always go back to being here with me and if you want like the next few minutes starting in a few seconds will be here so thank you so much that's all from me.

Appendix 2 VIDEO 2 TRANSCRIPTION

Chemical change and representing chemical change

Representing chemical change is foundational and if you can get this right today you will be set up perfectly for Grade 10 and grade 11 and grade 12 physical science because we wanted to represent chemical change and we discussed in our show about physical change and chemical change and the differences between them. But it's very important to understand represent chemical reactions and write formulae so and it's going to stand you in good stand all the way through your chemistry career representing chemical change. In this lesson we are going to focus on (1) using symbols to represent chemical reactions, we'll (2) practice writing chemical formulae and that's something that I know if students do struggle with so we need to make sure we get that right and then I think master K you asked a question a while back and in a previous show about what is a simpler way to balance equations? I want to tackle that with you today as well and we will be looking at (3) balancing those chemical equations and because of course the reality is that equations don't happen without being balanced, they have to be balanced because sometimes we write in them without being balanced because we write them in a simple format but they actually all have to be **balanced** and they can't occur without being

balanced because matter cannot be created or destroyed so I want to start with a challenge question **(3:10)** because I have given this to you as a word equation so I've given it as a description and what you need to do is go and write their individual formulae and then balance it. So, your challenge question: write a balanced symbol equation from the following word equation from the following word equation, from the description going right at aluminium reacts with solid copper 2 oxide to produce copper metal and aluminium oxide. I'll leave that with you. So, turning out to the summary as we think about it, I want to remind you what we spoke about, a physical change and when we spoke about a chemical change. **Chemical change** is quite significant because in a **chemical change** new products are formed, when a **chemical change** occurs new substances are formed in a **chemical reaction** so old bonds break and new bonds form and a new substances with different properties will be formed **(4:18)** new substances even though we're thinking **chemical reactions** where is physical change remember we said in physical change particles could be moving further apart they could be going through a phase change but they are still the same substance. Now we need to **write formulae** because we are dealing with a chemical change, substances, breaking old bonds forming new bonds, new substances forming **(4:45)** so it's very helpful to be able to represent that and to describe the chemical change so that could be described in a way, it could be written in symbols and then it needs to be written as a balanced symbol equation. The reason I say this is because across the world scientist needs to communicate with the value of Internet we can communicate with people and all different countries and so if maybe you were studying something about Magnesium Oxide you want to maybe be discussing with another person another scientific across the world you also need to go on to represent that and in a written format so it's very important that we can identify and write symbol equations and then balanced equation. So, a few key points, well, to start off with reacting **reactants** are on the left-hand side of the equation and the **products** are what is formed so they'll be on the right-hand side of the equation **(5:51)** and an arrow is used to represent the direction of the reaction that's important to note, the **reactants** are going to be changed to **products**. It is important to note actually that some reactions are reversible so that the arrow could go the opposite way or both ways and we'll do that later on as we get to reversible reactions. it is important to identify here is that an arrow pointing in One direction is showing **reactants** turning into **products** so I mentioned Magnesium Oxide, let us think of this equation as we discussed and writing formulae and balancing equations (6:35)

Magnesium burns in oxygen to produce a white substance Magnesium Oxide. In words, notice, we've got there the words magnesium + oxygen is forming Magnesium Oxide and noticed the arrow from the left-hand side here we've got **reactants** and this is our **product.** In simple form we now want to write each individual substance so magnesium, Mg + oxygen, O_2 forms Magnesium Oxide, MgO. **(7:17)** It's incredibly important to identify the original, the true formula for each substance so what you should note here is magnesium is magnesium metal, as an element just by itself. Oxygen O2, hold on a moment look at the two on the bottom here, notice that it is a diatomic substance, so each substance must be written in the correct formula. Remember some elements exist as diatomic molecules and oxygen as one of them O2. I've written out a list here, hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine, and iodine, all the halogens are all diatomic, **(8:05).** When we say something is diatomic it means two atoms combined together di- means two, two atoms so but it is only diatomic if it is by itself, the reason I say that is because it's so reactive it can't just be one individual atom it will pair up with its next neighbour. So, oxygen O2 and so when we write this formula, magnesium plus oxygen, the oxygen must be written in its diatomic form, and that form Magnesium Oxide. Now I've made a note here that this is not yet balanced because we going to come to balancing. But I want you to identify we've gone from words to a symbol equation, writing the correct symbol for each of those substances, so this is where many times students come and stuck and that is **writing the original formulae**, **writing the correct formula** for any substance so I want to talk through covalent bonding and how to identify covalent substance how to **write formulae** for those and then I want to talk about ionic. There are two methods but obviously it does depend what you dealing with, so if we have we are dealing with covalent compound we would consider the group number now when I say the group number the group number helps us find the **valency** of each substance in the compound so I'm going to my periodic table **(9:42),** group one would have a valency of 1, group 2 would have a valency of two, group 3, I'm going to jump across to group 13 which have a valency of 3 **(9:54).** Group 4 will have a valency of 4, group 5 will have a valency of 5. Well now it's getting closer to the end group 18 so how many bonds does it need to make, only another three okay so group 15 should have a valency of three, group 16, valency of 2, group 17 a valency of one, group 18 a valency of 0. And if you can work with the valency from the periodic table that's going to significantly help you know we spoke a lot about valency when doing chemical bonding so you might want to go and recap that **(1027).** Then let’s go back to our notes, the **valency** represents the number of bonds the substance can make for each substance_draw the bonds as little arm and linkage, so I've given an example here of ammonia (giving myself space). Ammonia is made up of nitrogen and hydrogen so I'm going to start by drawing the nitrogen down here nitrogen it has got, lets draw Lewis's diagram 1 2 3 4 5 valence electrons I get that because going across we find nitrogen there it is it's in group 15 so it's going to have five valence electrons coming back here notice those 5 valence electrons. How many bonds can it make look we have got space for a bond in there a bond over here and a bond over there okay so it has got space to make three more bonds it wants to make 3 bonds. **(11:39).** Now I will take these arrows away because what I would like to show is hydrogen linking up with this and hydrogen can make is in group one there it is, it's a non-metal so watch out for that it's a non-metal but hydrogen will be able to fit in and makeup a bond here, hydrogen can make a bond there and with this one as well so in a sense you've got three single covalent bonds, covalent meaning sharing bonds. Group 15 can make three bonds group one can make one bond, the formula as you can see, I've drawn from the Lewis diagram I could represent nitrogen with it three bonds. I'm going to show this lone pair at the top but that will help you and hydrogen, hydrogen, hydrogen fit in there very easily I can identify the **formula** is NH3. The lone pair, the type of lone pairs is ready paired up with two atoms, 2 electrons in the atom, from within the same atom so it's already paired, it's not unpaired, so the formula here in NH3. How do I get that? **(13:06).** I looked at the **valency**, how many bonds each substance can make, and I linked up the little arms, hydrogen to make one, nitrogen need to make three and for the formula NH3 **(13:19).**

When we go across, we discussed covalent bonding, covalent happens specifically when you're dealing with a non-metal and another non-metal that's how you can identify covalent bonding. If you're dealing with ionic bonding so ionic substances, substances that are formed from ions, substances that have given electrons away or taken electrons up, they have formed charged particles or ions and so we want to look at the charge to help us write the correct formulae, formula for each substance, so ionic compounds, the valency **(13:59),** remember the key word **valency**, how many bonds it can make, specifically for ionic substances will represent the charge on the ion, so either going to be a positive charge and negative charge, partly which identify things that have few electrons, metal only, group one have got one valence electron, group 2, two electrons. Group 3, three valence electrons. they've got so many more to gain they would rather easier just to lose in terms of energy to give away electrons much much easier so metals will always have a positive charge and I'm going to write little plus sign next to the metals will always have a positive charge as they give away their valence electrons. In comparison non-metals will gain electrons so if they're taking up extra negative particle negative electrons that's taking up extra electrons, they then overall would become negative so when they gain electrons, they would form negative ions so next to non-metals here, I am writing a big negative (**15:16).**

This is always done in order to obtain a filled outer energy level and that is always the perfect number, that's the purpose of bonding for substances, to become more stable so they have a filled outer energy level. In doing that we can say okay well then if I'm dealing with something in group one it will form one plus charge because it gave away it's one electron, if I'm dealing with something in group 2 it will form a two-plus charge on that substance because it must have given away two electrons and so you can work your way through the periodic table. So, I have given a quick summary table here with one maybe I shouldn't have used hydrogen, let's change that to something like a lithium, would form a one plus charge, remember hydrogen is a non-metal so very often it would involve the not the complete transfer of electrons that usually will undergo very often undergo covalent bonding depending on what its bonding with. So, we have got lithium, it is in group one, a 1 plus charge, magnesium in group 2, a 2 plus charge, aluminium is in group three, it's going to have formed a 3 plus charge and the way he would work this out, let me give myself some space at the bottom here you could literally write that aluminium has got its three valence electrons, when it bonds, what's going to happen? **(16:54).** Very often is that it would give those electrons away and so it is going to be left as Aluminium overall with a 3 plus charge and that's what we mean but I don't think we have to draw this out every time because I want to look at the periodic table and say I know what's going to happen it's going to form aluminium 3 + . So, going back to our little table here I'm leaving out group four and five or 14 and maybe we should call this group 13, then I'm leaving out 14 and 15 because then the non-metal so they would form covalent bonding very often group 16 or gain electrons because it's only got two more to gain so it's going to gain electrons group 17 would gain 1 electron to get to the filled-out energy level and group 18, zero. The key issue here is that we want to know the original charges so that we can balance the charges and I have got a couple of examples here to show you what you mean in terms of balancing the charges. **(18:11)** We dealt with magnesium oxide earlier in today’s show, but I thought it would be helpful to point it out to you again magnesium Mg 2 +, how do I know that? It's in Group 2 on the periodic table. Oxygen, would form two minus, why? Well because it's in group 16 on the periodic table and the issue then is simply to balance the charges so, focus, balance the charges, so, notice I've got a two plus and a two minus. It is already balanced, MgO is my answer. Let's do another one, beryllium chloride. Beryllium, I've already written there, has a 2 +, chloride, 1 -, so let's **write the formula**. It would be, I’ve got two positives, I'm going to have to have two of the chloride to give enough negatives to even out those charges we want to make the charges balanced, we want to make this thing overall neutral, ok, $BeCl_2$, recognise ionic bonding we want the overall charges to be balanced. Lithium oxide, so I've got the original substances their Lithium, Li+, oxygen, O^{2-} , we writing the formula so we balancing the charges, lithium, I've got only one positive so I need to have two of them with the one oxygen, Li_2O. Calcium chloride, calcium Ca^{2+}, because it's in Group 2, fluoride F^- because it's in group 17 and once again I'm going to have to have two negatives, so CaF_2. Now to start here for a moment and focus on this F_2 story, that is not in any way saying that fluorine, it has to have a two there because it's diatomic, no no no no, something only is diatomic when it's by itself. This is the F2 there, it could be aluminium fluoride which would be AlF3. It's not got anything to do with being diatomic or not rather it's got to do with balancing that charge, ok. What happens if you don't know from the periodic table what's the charge should be? Well, then we going to tell you what the charge should be because something like iron have a number of what we call oxidation state, a number of charges that can form, so I would have to inform you, tell you in the question what the charge is in the specific case. So iron 3 oxide, notice that Roman numeral behind the name of the element in a compound indicates the charge on that element **(21:24)** and so immediately when I write OH- ion, H is positive and it tells me it's 3, Fe 3 +, O2- because that's for oxygen I can work that out now I need to write this as a balanced formula so Fe, I must have two of them to get to plus 6 (+6) and oxygen I would have to have three of them to get to -6 so that my charges balance again ok, what many people do here is actually do cross multiply, I don't want you to focus on that, I want to focus on what will get me overall charges balanced. Here I have to have two of the iron and 3 of the oxygen ions to get the charges to balance (Fe_2O_3). Lastly, when we speak about ions, I think it's helpful for you to go and learn and memorize a few polyatomic ions. Poly means many atomic atoms, an ion of a charged particle so there are ions, polyatomic ions are charged particles made up of many atoms very helpful very useful to know and I would recommend that you learn these 7 at least so that when you come across an equation you not struggling and thinking what is a carbonate again? It's 7, simple formulae, go and learn them do a quick quiz with a friend and make sure that you've got them in your mind. They're going to stand you in a very good stand, so ammonium is NH^{4+}, hydroxide 0H -, nitrate NO^{3-} , carbonate CO_3^{2-}, ^{sulphate} SO_4^{2-}, phosphate PO_4^{3-}. $^($**23:22).**

And we want you (Mindsetters) to ask your questions because this is fundamental stuff and that's why I'm taking more time going through because I really wanted to catch this and I know master K you asked a question a while back about balancing equation. And so today we are going to tackle that in this segment. Now, when we speak about a **balanced equation** what's the meaning? We mean that matter cannot be created or destroyed so the number of atoms of each type that you started with you must end up with, ok, because that stuff can't come from nowhere and similarly it can't just go into nothing. So, what we saying when we **balance equation** is that it's just a counting game, actually, the number of atoms of each element in a reactant, must be the same as the number of atoms of each element in the products. In order to balance an equation, we have to put big numbers in the front now we call these big numbers coefficients. May be in maths if we are doing this, 2x + 5 the big number 2 is the coefficient so we can take coefficient and place them in front of the reactants and the products until the number of atoms of each element is the same on both sides of the equation. Recall that I spent a long time with you talking through the writing individual formulae and once you've got that formula, it's the correct formula of all that substance taking that you've done and correct the correct formula you can't change that formula, it is the correct true formula. What we are saying is that do not, do not ever change any subscript as this would change the identity of a chemical substance, **(26:22)** for example, we couldn't **balance the reaction** below actually, by simply putting an extra oxygen on water and I want to write this equation out for you, okay, so if I've got hydrogen + oxygen forming water, H2O, (H2 + O2 – H2O) you might say I have put a good tally, hydrogen atoms oxygen atoms, on the left pretty much doing a little left hand side is right hand side left hand side I've got two so two on that side, two on that side, perfect. Oxygen, I've got two and only one, problem, it's not balanced, it looks like I've got two oxygen atoms and it's going to only one oxygen atom so where has the other one gone? Well, the reality is that's not possible, so instead it must form two water molecules and what we are saying here is that it is not true to go and put another two in there (H2 + O2 – H2O2) that is completely wrong (**27:39).**

Why is that wrong, because that stuff not water anymore, and that's what I'm saying in this statement over here, do not change any subscripts, that small below take so any subscripts below, those small numbers, as they change the identity of the chemical substance. We couldn't balance the equation by simply putting an extra oxygen on water and forming H2O2, that's not water anymore, that's hydrogen peroxide, very different stuff. **(28:12).** So how do I do it then? Well, I'm going to let's take this little this and rewrite this and we've got H2 + O2 forms H2O, what can I do? Well, I can't put big numbers in the front, so notice I've got two oxygen atoms I must put a two in the front, of that, so I've now forming two water molecules and that then means if I tally up, I've got two oxygen (reactant) and two oxygen (product). Hydrogen, well

I've got two x 2, 2 x 2 which is giving me four in the product and that's we have started with four in the reactants so I must have a big two there so that again two times two which is four ($2H_2 + O_2 – 2H_2O$), and so really balancing is already just actually a bit of multiplying and counting, counting how many of each substance you've got. Always focus, remember please not ever to go and change subscript because if you change the subscript, you are changing the substance you are really dealing with. **(29:38).**

I'm going to jump across quickly and to show you that quick game you can go and play this practice, and this is making ammonia so I'm going to do, I think I need to go back here, there we are, I am going to have one nitrogen, notice nitrogen is diatomic. I'm going to have one hydrogen; hydrogen is also diatomic **(30:10)** and what does it form? It's going to form ammonia, NH_3. **(30:18).** Looking at it, is it balanced? It's definitely not balanced. Can you see I have got two nitrogen, two blue dots on the left and only one on the right so what am I going to do? Drawing it is very helpful, I must have two of them in the products. Now I've got the correct number of blue dots, the nitrogen, I haven't got the correct number of hydrogens, no I haven't. I've got 3, 6 on that side, only two on this side, so is that balanced yet? No, there it is, I've got three hydrogen molecules that's going to be 6 hydrogen atoms on the left and 6 hydrogen atoms on the right and gives me a six on both sides, yes, I have got this thing balanced **(Simulation) 31:07).** Now, when you work with balancing feel free to draw them out but watch out, diatomic molecules can be a big catch so watch out for diatomic molecules.

I've got the link on the notes you can go and play with those. Let's finish the one we started right at the beginning which was magnesium plus oxygen forms Magnesium Oxide and looking at that can you identify, I've got the correct number of oxygen on the left, two, but I need two on the right, so big number in the front and then a big number in the front of the magnesium as well ($2Mg + O_2 – 2MgO$) so yes that should be balanced because I've got two and two and two oxygens two oxygens it's perfect. Balancing equations should not be a struggle for you it really shouldn't, it should be something that you say yes, I can do that very easily but you've got to start with the correct formula, you've got a start with the correct substances because otherwise you can count all you like, you cannot get the correct equation. **(32:23).** So, watch out, write the correct formula for difference substances.

So, we going to go into some questions now and I'm going to focus on t1his first question, writing the correct formula for each of the following: Magnesium iodide. Magnesium is in Group 2 on the periodic table so it's going to form a 2+ charge, Iodide, here it is in group 17, so it is going to form a 1 minus charge. So going across here, I would write here, Mg2+, Iodide, I one minus ($Mg^{2+}I^{-}$). Then I write the final formula, well I've got to balance the charges, so I need to have to have two of the iodides to balance off with the two from the Mg, so MgI_2.

Next one, copper, notice they are telling me the charge on the copper, why, well because copper is here (pointing at the transition elements on the periodic table) as one of the transition elements and so we don't know what its oxidation state is going to be but they tell us, notice that it's a metal, so it would always form a positive ion. So, Cu2 +, fluoride, I^-, I can recognise it's a halogen so it's 1 -, the same as iodide ($Cu^{2+}I^{-}$). So, the formula is going to be CuF_2. I have to have two of the negatives to balance out those two positives.

Next one, calcium sulphate. Calcium is in Group 2 on the periodic table, so Ca2 +, Sulphate, where is that on the periodic table? Note, it's a polyatomic ion, so you need to go and learn it, okay, so I would remember it's $SO_4{}^{2-}$, and so notice that whole thing I can just write down and I can memorize sulphate $SO_4{}^{2-}$, and very quickly I am now balancing the charges, so it's done for me already, $CaSO_4$, sorted **(34:54).**

Potassium chloride, potassium K +, chloride, Cl minus (Cl^-), ($K^{o}cal^{-}$). It's a one plus and a 1 - , they are balanced already, so KCl.

Lithium nitrate, lithium is in group 1 of the periodic table, (I am running out of colours here), there we are lithium nitrate, so lithium one plus. Nitrate, NO3 -. that's one of those polyatomic ions that I suggested you learn. Lithium nitrate, $LiNO_3$.

Ammonium carbonate, ammonium is NH4 one plus, and carbonate, CO_3^{2-} ($NH_4CO_3^{2-}$). Now we have got a little bit of a problem because I want to have two of those ammonium and one of the carbonate but how do I do two of those whole thing because if I put a two next to the four it's going to look like 42 and I don't want that. If I say 2 multiplied by 4, it will give 8, but then surely they don't say anything about the nitrogen no it's not so the way you overcome this is put in brackets, very easy to do, we write NH4, but I want two of them (NH4)2 and then the Carbonate, because it's only an individual it can only need one it can be very easily there, $(NH_4)_2CO_3$. **(36:37)**

Last one, sodium hydroxide. Sodium hydroxide Na plus, hydroxide, 0H -, and so final answer here, Na0H. I hope that really helped. You need to practice writing correct formulae. As soon as you get correct formulae then you can look at balancing. You can't look at balancing before you've got the correct formulae, and then correct equation.

Let's turn to the next question and I've got some questions here on balancing. So, this one is easy because they have already given me the correct formulae. Balance the following equation: ammonium carbonate form ammonia plus carbon dioxide plus water

(NH4)2CO3 – NH3 + CO2 + H2O). This is a decomposition reaction, notice, it's breaking down into simpler substances. And so, all I'm going to really do here is write up a bit of a tally whatever I got. I've got nitrogen, I've got hydrogen, I've got carbon, I've got oxygen, and I want to just count left hand side, right hand side. Now nitrogen, do you notice the two over here is multiplying that whole bracket, so it's 2 X 1, which is giving me two, but on this side, I only got one of them. So, what am I going to need to do is go and put a big number two in the front of that nitrogen and that's going to help the notice I said that's two times two which is going to give me two **(MISTAKE BY PRESENTER: 2X2=2, INSTEAD OF 2X1=2)**, nitrogen is balanced. tick it off **(38:33** We might get to check them because we could come back and make some changes but nitrogen for the moment is balanced.

Let's go to the next one, Hydrogen, I've got 4 x 2 is going to give me eight and here I've got two times three is giving me six, but two there, notice I've got another two down here, I've got a total of 8, all the way there, because 3X2 is 6, plus extra 2, it gives me 8, so yes, hydrogen looks like it's fine for now. Carbon, carbon has just got one there, notice, carbon just has got one, that's easy. We going to change to oxygen, oxygen have got 3 on this side and two there plus one, giving me three, so yes, the carbon was balanced, and oxygen was balanced. They are all sorted. **(39:59).** Notice balancing it really just about counting but you have to have the correct formulae for each substance first. Mindsetters I hope this really helped you, we are taking a short break **(40:12).**

And I know Mindsetters is really important to challenge us otherwise how are you going to be learning new stuff? So, I've got one more question here, but I think I have the question on the page about that you were asking. Here is the question from Banyana: Is nitrite and nitrate different? Yes nitrite and nitrate are different, so nitrate is the formula I gave you and that was NO_3^{-}, Nitrite, one with an "I", with an "I" there is NO_2^{-} **.(42:00).** They are different, I said I have given you the top seven polyatomic ions, the ones we use most often. But there is whole list of polyatomic ions you can go check out in your textbook and we have got everything sign at.co.za you know that's where you can go and learn a lot more but I definitely want you to know at least those top seven of them. Nitrate has a bigger number of oxygens, so that could be helpful.

Let's deal with this as we specifically dealing with the second question here. Lead 2 nitrate solution reacts with potassium iodide solution to form a precipitate, a solid of Lead iodide while potassium nitrate remains in solution and they're asking us to write a balanced equation for this. Don't freak out. Take it one step at a time. Start by writing the individual formula and once you got the formula then it's just a matter of counting. So, let's go with writing the formulae, lead 2 nitrates would be Pb2+, nitrate, NO3 -, reacts with potassium iodide, potassium K+, iodide, I-, to form a precipitate, a solid of Lead iodide so that's forming Pb2+, iodide, I-, while potassium nitrate remains in solution, potassium, K+, nitrate, NO3-.

($Pb^{2+}NO_3^- + K^+I^- - Pb^{2+}I^- + K^+NO_3^-$).

Now, all I've done is just write the ions out there not yet balanced is not yet written as the correct formula but it's going to help me so I want to start next by actually writing the formulae, so notice that is a two plus that is a 1 -, I have to get the charges to balance so we've got Pb(NO3)2 with a two at the bottom, that shows I've got two nitrate ions for everyone one lead ion. **(44:28).** Now it's forming or its reacting with potassium iodide. Notice the charge is 1 + 1 -, that is, K I already balanced, with the balanced charge forms lead 2 Iodide, so Pb2+, I must have 2 Iodide, so PbI_2. For potassium nitrate, KNO3.

$Pb\,(NO_3)_2 + KI\ -\ PbI_2 + KNO_3$

We now have this yellow the correct symbol equation, but it's not yet finished because I haven't balanced it. **(45:15).** Balancing it is just counting so I now want to work through Pb, how many, 1, 1. Nitrogen, I've got two (reactant side) and only one (product side), so what do I do? I put a big number two in the front there so two times 1 is going to give me 2. Oxygen, I've got 3 X 2 is 6, no more oxygen, there we are, 2 x 3 is also 6, the oxygen is sorted. I've done Lead, I've done Nitrogen, and I have done oxygen.

$Pb\,(NO_3)_2 + KI\ -\ PbI_2 + 2KNO_3$

Potassium, we have potassium, K, there is one and there is 2, so what do I have to do here? A big 2 in the front there, coz that's now 2 X 1.

$Pb\,(NO_3)_2 + 2KI\ -\ PbI_2 + 2KNO_3$

And the last one I have to do is Iodine, which is two on the left, two times one and two on the right which means that they are all balanced. Very, very important Mindsetters is to make sure you have the correct original equation. Notice, I have to write correct ions first and then I have to balance each of the charges, then I write individual substances and then I write the whole full equation with checking the balancing. So, once you've got the original formula don't go and mess with the subscript, the subscript is important, you got to leave them as they are. **(47:04)**

Now I want to tackle the challenge question that I set for you again I gave it to you as a description and I'm asking you to write the formula. So Aluminium, aluminium, Al, reacts with solid copper 2 oxide, so, copper, notice they tell me it's 2, so it’s a 2+, oxide is 2 minus, O2-, to produce copper metal that form Cu, and aluminium oxide, aluminium is a 3 +, how do I know that? The periodic table, and Oxide O2 -,

$Al + Cu_2+O_2^- - Cu + Al_3+O_2^-$

Now it's not done yet, so actually what I'm going to do is I'm going to just take these away **(47:59)** so you don't think that it is actually correct equation yet, it's not (giving us some space), now I want to write the correct original formulae, so Al plus, that's going to be quiet simple CuO because it’s a two plus and a 2 minus, forms copper, aluminium oxide, notice here, we've got to get balanced charges, overall neutral, so it's going to be Al_20_3 because I can get to + 6 and -6.

$Al + CuO - Cu + Al_2O_3$

Now it's a matter of counting. So, we are going, Al have got 2,so I need a big 2 in front, I have got Cu 1, 1, I have oxygen 3 there, and I need to have a three here, so 3 there, Watch out, is this thing sorted yet, no its not because now I have changed the Cu, because the Cu is now 3 times 1, so here I have to put a 3 on that one as well, so check it,

2 Al + 3CuO - 3 Cu + Al2O3

And that is the whole challenge question sorted. It’s actually not that bad **(49:45)** but you have to write the original equation, original substances, correctly first.

Is it necessary to first write the ions before balancing. No, it’s not. You know it’s not necessary, it’s something that I do as a practice, because it would be very helpful. It’s a balance to check if you have written them correctly. Yes, I would recommend writing the ions, but it’s not necessary, your focus is getting the original formula right and then you can balance. **(50:41).**

For the concepts to be discussed, the researcher has just picked on the main explanations given in the videos and tabulated them (Table 7) for easier reference.

Appendix 3 Videos 1 and 2 Transcription of explanations of the concepts on chemical reaction

Concept	Video 1	Video 2
Chemical Reactions	a **chemical reaction,** I want you to notice here that this is when new substances are forming, it is not a physical change, it is a new substance that is forming and so what we focus on here is that we going to have a new substance forming, we going to start with reactants and those change into products. Examples were given in the video.	Chemical change is quite significant because in a chemical change new products are formed, when a chemical change occurs new substances are formed in a **chemical reaction** so old bonds break and new bonds form and a new substance with different properties will be formed. Examples were given in the video.
Balanced chemical equation	The idea **(of balanced equation)** is what we spoke about last week about the conservation of mass, and the idea that number of atoms on the left-hand side is equal to the number of atoms on the right-hand side because stuff doesn't just disappear. But I want to highlight to you that the total atomic mass of the reactants must be the same as a total atomic mass of the products, this also means that the total number of atoms in the reactants must be the same as the total number of atoms and the product at	Now, when we speak about a **balanced equation** what's the meaning? We mean that matter cannot be created or destroyed so the number of atoms of each type that you started with you must end up with, ok, because that stuff can't come from nowhere and similarly it can't just go into nothing. So, what we are saying when we balance equation is that it's just a counting game, actually, the number of atoms of each element in a reactant, must be the same as the number of atoms of each element in the products. In order **to balance an equation**, we have to put big numbers

	the end. Stuff doesn't just disappear. Examples were given in the video	in the front now we call these big numbers of coefficients. May be in maths if we are doing this, $2x + 5$ the big number 2 is the coefficient so we can take coefficient and place them in front of the reactants and the products until the number of atoms of each element is the same on both sides of the equation. Examples were given in the video
Compound formulae	So, when we think of **writing a chemical formula**, go to the periodic table. It will tell you what the charge will be, you just need to organise them to get to a neutral compound. **To write the formulae** of ionic compounds, we need to balance the charges to make a neutral compound, okay, so I've gone through a list of them because I know the people struggle with it if you had Magnesium Oxide and you're asked to write the formula for Magnesium Oxide, go back to working with magnesium so Mg, what's it going to be it's in group 2, so Mg is 2 +. Oxygen it's going to be in group 16, what is going to become oxygen 2 - and so the formula then notices it's a 2+ and a 2 -, they match up perfectly and so we only need one of each side for the written them x 1 x 1 the formula	The key issue **(to writing a chemical formula)** here is that we want to know the original charges so that we can balance the charges and I have got a couple of examples here to show you what you mean in terms of balancing the charges. We dealt with magnesium oxide earlier in today's show, but I thought it would be helpful to point it out to you again magnesium Mg 2 +, how do I know that? It's in Group 2 on the periodic table. Oxygen, would form two minus, why? Well because it's in group 16 on the periodic table and the issue then is simply to balance the charges so, focus, balance the charges, so, notice I've got a two plus and a two minus. It is already balanced, MgO is my answer.

	is a simple MgO, magnesium oxide.	
Reactants	have a new substance forming, we going to start with **reactants** and those change into products, so **reactants** are the things at the start of the equation, and they will be on the left-hand side. the reactants are the things that you've got at the start they will be the thing that will react together in order to make the things at the end this is what is formed or is produced in this chemical equation, so what you got is you have got the reactants on the left, More examples were given in the video.	reacting **reactants** are on the left-hand side of the equation, the **reactants** are going to be changed to products. More examples were given in the video
Products	the **products** will be on the right-hand side (RHS) Reactants → Products (Start) (End) (LHS) (RHS)	the **products** are what is formed, so they'll be on the right-hand side of the equation, reactants are going to be changed to products
Valency	the **valency** is how many bonds the substance needs to make. In group 1, group 2, the valence electron and the **valency** are the same and group 3, whereas when you start going towards into the non-metal, the **valency** and the valence electrons are very different, if we go across now to ionic compounds the	the **valency** represents the number of bonds the substance can make for each substance. dealing with covalent compound we would consider the group number now when I say the group number the group number helps us find the **valency** of each substance in the compound so I'm going to my periodic table group one would have a valency of 1, group 2

	valency represents the charge on the ion	would have a valency of two, group 3, I'm going to jump across to group 13 which have a valency of**.** Group 4 will have a valency of 4, group 5 will have a valency of 5. Well now it's getting closer to the end group 18 so how many bonds does it need to make, only another three okay so group 15 should have a valency of three, group 16, valency of 2, group 17 a valency of one, group 18 a valency of 0. so ionic substances, substances that are formed from ions, substances that have given electrons away or taken electrons up, they have formed charged particles or ions and so we want to look at the charge to help us write the correct formulae, formula for each substance, so ionic compounds, the valency, how many bonds it can make, specifically for ionic substances will represent the charge on the ion, so either going to be a positive charge and negative charge,

Table 7 only includes the transcription of videos 1 and 2. It is from this transcription that statements and concepts were taken and coded to make tables 8 and 10.

Appendix 4 Modified semantic gravity (SG) and semantic density (SD) translational device (for Video 1)

Term (Concept)	Chemical Reaction	Balanced Chemical Equations	Compound Formula writing	Reactants	Products	Valency

Indicator & Description/ Examples that come from the analyzed video 1 lesson transcriptions	**SG1** Teacher explains a theoretical statement: we going to start with reactants and those change into products **(V1) CODE:SG-** **SG2 Teacher** focus on real world example/direct experience: this is when new substances are forming, it is not a physical change, it is a new	**SG1** Teacher explains a theoretical statement: It is about the conservation of mass, and the idea that number of atoms on the left-hand side is equal to the number of atoms on the right-hand side because stuff doesn’t just disappear. But I want to highlight to you that the total atomic mass of the	**SG1** Teacher explains a theoretical statement: So, when we think of writing a chemical formula, go to the periodic table. It will tell you what the charge will be, you just need to organise them to get to a neutral compound. To write the formulae of ionic compounds, we need to balance the charges to make a neutral	**SG1** Teacher explains a theoretical statement: reactants are the things that you've got at the start they will be the thing that will react together in order to make the things at the end this is what is formed or is produced in this chemical equation **(Video 1) COD: SG-** **SG2 Teacher** focus on real world	**SG1** Teacher explains a theoretical statement: the products will be on the right-hand side (RHS) Reactants → (Start) Products(End) **(Video 1) COD:SG-** **SG2 Teacher** focus on real world example/direct experience: products will be on the right-hand side (RHS) **(Video 1)**	**SG1** Teacher explains a theoretical statement: the valency is how many bonds the substance needs to make. Group 1, group 2, the valence electron and the valency are the same and group 3, whereas when you start going towards into the non-metal, the valency and the valence electrons are very different, If we go

	substance that is forming and so what we focus on here is that we going to have a new substance forming **(V1)** **COD:SG++** **SD1** **Teacher** uses condensed symbolic language to convey a concept: Reactants $\rightarrow$ Products 2Mg + $O_2 \rightarrow$ 2MgO **(V1)** **COD: SD+++**	reactants must be the same as a total atomic mass of the products, this also means that the total number of atoms in the reactants must be the same as the total number of atoms and the product. **(V1)** **CODE: SG-** **SG2** Teacher focus on real world example/direct experience:	compound. **(Video 1)** **COD:SG-** **SG2** Teacher focus on real world example/direct experience**:** We dealt with magnesium oxide earlier in today's show, but I thought it would be helpful to point it out to you again magnesium Mg 2 +, how do I know that? It's in Group 2 on the periodic	example/direct experience: so, reactants are the things at the start of the equation and they will be on the left-hand side. the reactants are the things that you've got at the start they will be the thing that will react together in order to make the things at the end this is what is formed or is	**COD: SG++** **SD1** **Teacher** uses condensed symbolic language to convey a concept: Reactants $\rightarrow$ Products 2Mg + $O_2 \rightarrow$ 2MgO (**Videos 1)** **COD:SD+++** **SD2** Concepts or words from the subject are used to convey meaning in straightforward ways that a non-subject specialist could	across now to ionic compounds the valency represents the charge on the ion **(Videos 1 & 2)** **COD: SG-** **SD1** Teacher makes connections between the concept and other ideas so that it becomes part of a networked body of knowledge: the valency is how many

	SD2 Teacher uses subject terms, and explains what it means in an understand able way, giving more details about the characteristics and properties of the concept: Because in a chemical change new products are formed, when a chemical change occurs new substances are formed	We mean that matter cannot be created or destroyed so the number of atoms of each type that you started with you must end up with, ok, because that stuff can't come from nowhere and similarly it can't just go into nothing **(V1) COD:SG++** **SD1 Teacher** uses condensed	table. Oxygen, would form two minus, why? Well because it's in group 16 on the periodic table and the issue then is simply to balance the charges so, focus, balance the charges, so, notice I've got a two plus and a two minus. It is already balanced, MgO is my answer **(Videos 1) COD:SG++**	produced in this chemical equation, so what you got is you have got the reactants on the left **(Video 1) COD: SG++** **SD1** Teacher uses condensed symbolic language to convey a concept: Reactants → Products $2Mg + O_2 \rightarrow 2MgO$ **(Videos 1) COD:SD+++** **SD2** Teacher uses	understand : the products will be on the right-hand side (RHS) Reactants (Start) → Products(End) **(Video 1) COD: SD-**	bonds the substance needs to make. Group 1, group 2, the valence electron and the valency are the same and group 3, whereas when you start going towards into the non-metal, the valency and the valence electrons are very different, if we go across now to ionic compounds the valency represents the charge on the ion

	in a chemical reaction so old bonds break and new bonds form and a new substance with different properties will be formed. **CODE: SD+**	symbolic language to convey a concept: $2Mg + O_2 \rightarrow 2MgO$ $2H_2 + O_2 \rightarrow 2H_2O$ **(V1)** **COD:SD+++** **SD2** Teacher uses subject terms, and explains what it means in an understandable way, giving more details about the characteristics and properties of the concept:	**SD1** Teacher uses condensed symbolic language to convey a concept: Mg^{2+} $O^{2-} \rightarrow$ MgO **(Videos 1)** **COD:SD+++** **SD2** Teacher uses subject terms, and explains what it means in an understandable way, giving more details about the characteristics and properties	subject terms, and explains what it means in an understandable way, giving more details about the characteristics and properties of the concept: So, reactants are the things at the start of the equation, and they will be on the left-hand side. the reactants are the things that you've got		**(Videos 1 & 2)** **COD: SD++** **SD2** **Teacher** uses subject terms, and explains what it means in an understandable way, giving more details about the characteristics and properties of the concept: the valency is how many bonds the substance needs to make. Group 1,

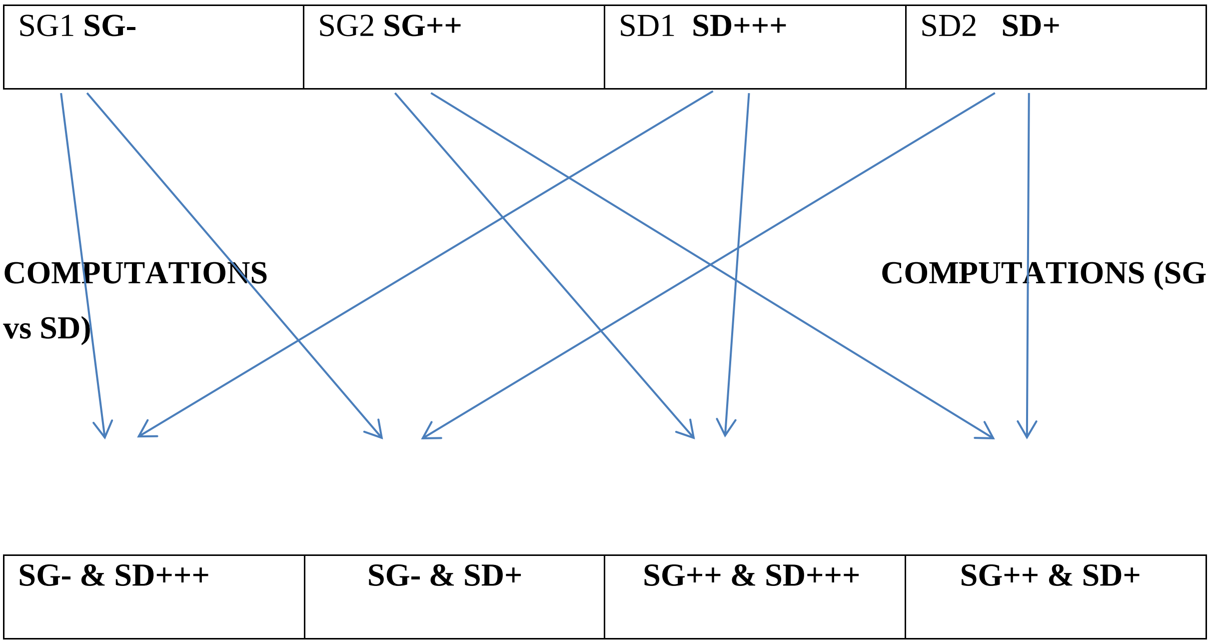
		It is about the conservation of mass, and the idea that number of atoms on the left-hand side is equal to the number of atoms on the right-hand side because stuff doesn't just disappear. But I want to highlight to you that the total atomic mass of the reactants must be the same as a total atomic	of the concept: to write the formula for Magnesium oxide, go back to working with magnesium so Mg, what's it going to be it's in group 2, so Mg is 2 +. Oxygen it's going to be in group 16, what is going to become oxygen 2 - and so the formula then notices it is a 2+ and a 2 -, they match up perfectly and so we only need	at the start they will be the thing that will react together in order to make the things at the end this is what is formed or is produced in this chemical equation, so what you got is you have got the reactants on the left. **(Video 1) COD: SD+**		group 2, the valence electron and the valency are the same and group 3, whereas when you start going towards into the non-metal, the valency and the valence electrons are very different, if we go across now to ionic compounds the valency represents the charge on the ion **(Videos 1 & 2) COD: SD+**

		mass of the products, this also means that the total number of atoms in the reactants must be the same as the total number of atoms and the product. **(V1) COD: SD+** **SD3** Concepts or words from the subject are used to convey meaning in straight forward ways that a non-subject	one of each side for the written them x 1 x 1 the formula is a simple MgO, magnesium oxide **(Videos 1) COD: SD+**			

		specialist could understand : We mean that matter cannot be created or destroyed so the number of atoms of each type that you started with you must end up with, ok, because that stuff can’t come from nowhere and similarly it can't just go into nothing **(V 1) COD: SD-**				

Semantic Gravity (SG)	**SG1** **SG-** **SG2** **SG++**	**SG1 SG-** **SG2** **SG++**	**SG1** **SG-** **SG2** **SG++**	**SG1 SG-** **SG2** **SG++**	**SG1 SG-** **SG2** **SG++**	**SG1 SG-**
Semantic Density (SD)	**SD1** **SD+++** **SD2** **SD+**	**SD1** **SD+++** **SD2 SD+** **SD3 SD-**	**SD1** **SD+++** **SD2** **SD+**	**SD1** **SD+++** **SD2** **SD+**	**SD1** **SD+++** **SD2 SD-**	**SD1** **SD++** **SD2** **SD+**

Appendix 5 Showing possible computations/combinations for the concept chemical reaction(s)



Appendix 6 Modified semantic gravity (SG) and semantic density (SD) translational device (Video 2)

Term	Chemical Reaction	Balanced Chemical Equations	Compound Formula writing	Reactants	Products	Valency
Indicator & Description/ Examples that come from the analyzed video 2 lesson transcriptions	SG1 Teacher explains a theoretical statement: we going to start with reactants and those change into products (V 2) CODE: SG- SG2 Teacher focus on real world example/direct experience: this is when new	SG1 Teacher explains a theoretical statement: It is about the conservation of mass, and the idea that number of atoms on the left-hand side is equal to the number of atoms on the right-hand side because stuff doesn't just disappear.	SG1 Teacher explains a theoretical statement: The key issue here is that we want to know the original charges so that we can balance the charges (Video 2). COD: SG- SG2 Teacher focus on real world example/direct experience:	SG1 Teacher explains a theoretical statement: reacting reactants are on the left-hand side of the equation, the reactants are going to be changed to products. (Video 2). COD: SG- SG2 Teacher focuses on real world example/di	SG1 Teacher explains a theoretical statement: the products are what is formed so they'll be on the right-hand side of the equation, reactants are going to be changed to products (Video 2) COD: SG- SG2 Teacher focuses on real world	SG1 Teacher explains a theoretical statement: the valency is how many bonds the substance needs to make. Group 1, group 2, the valence electron and the valency are the same and group 3, whereas when you start going towards into the non-metal,

	substances are forming, it is not a physical change, it is a new substance that is forming and so what we focus on here is that we going to have a new substance forming (V 2) COD:SG++ SD1 Teacher uses condensed symbolic language to convey a concept: Reactants → Products	But I want to highlight to you that the total atomic mass of the reactants must be the same as a total atomic mass of the products, this also means that the total number of atoms in the reactants must be the same as the total number of atoms and the product. (V 2) COD: SG-SG2 Teacher focus on	We dealt with magnesium oxide earlier in today's show, but I thought it would be helpful to point it out to you again magnesium Mg 2 +, how do I know that? It's in Group 2 on the periodic table. Oxygen, would form two minus, why? Well because it's in group 16 on the periodic table and the issue	rect experience: reactants are on the left-hand side of the equation (Video 2) COD: SG++ SD1 Teacher uses condensed symbolic language to convey a concept: Reactants → Products $2Mg + O_2 \rightarrow 2MgO$ (Video 2) COD:SD+++ SD2 Concepts or words from the subject are used to	example/direct experience: products are what is formed so they'll be on the right-hand side of the equation (Video 2) COD: SG++ SD1 Teacher uses condensed symbolic language to convey a concept: Reactants → Products $2Mg + O_2 \rightarrow 2MgO$ (Video 2) COD:SD+++ SD2	the valency and the valence electrons are very different, if we go across now to ionic compounds the valency represents the charge on the ion (Video 2) COD: SG-SD1 Teacher makes connections between the concept and other ideas so that it becomes part of a networked body of knowledge:

	$2Mg + O_2 \rightarrow 2MgO$ (V 2) COD:SD+++ SD2 Teacher uses subject terms, and explains what it means in an understandable way, giving more details about the characteristics and properties of the concept: Because in a chemical change new products are formed,	real world example/direct experience: We mean that matter cannot be created or destroyed so the number of atoms of each type that you started with you must end up with, ok, because that stuff can't come from nowhere and similarly it can't just go into nothing (V 2) COD: SG++	then is simply to balance the charges so, focus, balance the charges, so, notice I've got a two plus and a two minus. It is already balanced, MgO is my answer (Video 2) COD: SG++ SD1 Teacher uses condensed symbolic language to convey a concept: Mg^{2+} $O^{2-} \rightarrow$ MgO (Video 2) COD:SD+++	convey meaning in straightforward ways that a non-subject specialist could understand: reacting reactants are on the left-hand side of the equation, the reactants are going to be changed to products. (Video 2) COD: SD-	Teacher makes connections between the concept and other ideas so that it becomes part of a networked body of knowledge: the products are what is formed so they'll be on the right-hand side of the equation, reactants are going to be changed to products (Video 2) COD: SD++	the valency is how many bonds the substance needs to make. Group 1, group 2, the valence electron and the valency are the same and group 3, whereas when you start going towards into the non-metal, the valency and the valence electrons are very different, if we go across now to ionic compounds the valency

	when a chemical change occurs new substances are formed in a chemical reaction so old bonds break and new bonds form and a new substance with different properties will be formed. (Video 2) COD: SD+	SD1 Teacher uses condensed symbolic language to convey a concept: $2Mg + O_2 \rightarrow 2MgO$ $2H_2 + O_2 \rightarrow 2H_2O$ (V 2) COD:SD+++ SD2 Teacher uses subject terms, and explains what it means in an understandable way, giving more details about the characteris	SD2 Teacher uses subject terms, and explains what it means in an understandable way, giving more details about the characteristics and properties of the concept: to write the formula for Magnesium Oxide, go back to working with magnesium so Mg, what's it going to be it's in			represents the charge on the ion (Video 2) COD: SD++ SD2 Teacher uses subject terms, and explains what it means in an understandable way, giving more details about the characteristics and properties of the concept: the valency is how many bonds the substance needs to make.

		tics and properties of the concept: It is about the conservati on of mass, and the idea that number of atoms on the left-hand side is equal to the number of atoms on the right-hand side because stuff doesn’t just disappear. But I want to highlight to you that the total atomic //mass of the	group 2, so Mg is 2 +. Oxygen it's going to be in group 16, what is going to become oxygen 2 - and so the formula then notices it's a 2+ and a 2 -, they match up perfectly and so we only need one of each side for the written them x 1 x 1 the formula is a simple MgO, magnesiu m oxide (Video 2) COD: SD+			Group 1, group 2, the valence electron and the valency are the same and group 3, whereas when you start going towards into the non-metal, the valency and the valence electrons are very different, if we go across now to ionic compound s the valency represents the charge on the ion (Videos 2) COD: SD+

		reactants must be the same as a total atomic mass of the products, this also means that the total number of atoms in the reactants must be the same as the total number of atoms and the product. (V 2) COD: SD+ SD3 Concepts or words from the subject are used to convey meaning in straight				

		forward ways that a non-subject specialist could understand: We mean that matter cannot be created or destroyed so the number of atoms of each type that you started with you must end up with, ok, because that stuff can’t come from nowhere and similarly it can't just go into nothing				

		(V 2) COD: SD-				
Semantic Gravi(SG)	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG- SG2 SG++	SG1 SG-
Semantic Density (SD)	SD1 SD+++ SD2 SD+	SD1 SD+++ SD2 SD+ SD3 SD-	SD1 SD+++ SD2 SD+	SD1 SD+++ SD2 SD-	SD1 SD+++ SD2 SD++	SD1 SD++ SD2 SD+

Appendix 7 ETHICAL CLEARANCE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG | WSoE Wits School of Education

SCHOOL OF EDUCATION ETHICS COMMITTEE

CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	PROTOCOL NUMBER: 2022ECE007M
PROJECT TITLE	An assessment of online learning materials on cumulative knowledge building in chemical reactions at Grade 10 through the lens of Legitimation Code Theory (LCT): (A case study of Mindset videos).
INVESTIGATOR	TENSON JAMBAYA
SCHOOL/DEPARTMENT OF INVESTIGATOR	WSoE
DATE CONSIDERED	07 FEBRUARY 2022
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	NO RISK
EXPIRY DATE	Date of submission of the Research Report
ISSUE DATE OF CERTIFICATE	CHAIRPERSON Dr. Batseba Mofolo-Mbokane

cc: Dr Emmanuel Mushayikwa

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Chairperson of the School/Department ethics committee.

I fully understand the conditions under which I am are authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

Signature ____________________ Date ____/____/____

27 St Andrews Road, Parktown, Johannesburg, 2193 | Pvt Bag 3, WITS, 2050 | T +27 11 717 3007 | www.wits.ac.za/education

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