The effects of virtual reality and physical models on grade 11 learner understanding of geometric shapes in the chemistry classroom

by

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Submitted in accordance with the requirements for the degree of

MAGISTER EDUCATION

in

NATURAL SCIENCE EDUCATION

in the

COLLEGE OF EDUCATION

at the

UNIVERSITY OF SOUTH AFRICA

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University of South Africa (Pretoria)

30 September 2019

Abstract

With the abstract nature of Chemistry, teaching tools can be used to interpret symbols, molecular nature and geometric structures/spatial structures, which are essential skills students need for solving problems in Chemistry. Chemistry demonstrates concepts that cannot be visualized with the naked eye, which results in the increased need to use virtual reality and physical models in the Chemistry classroom. Chemistry education aims to advance learners' cognitive development by means of constructing their content knowledge, help them understand abstract concepts. However, learners encounter difficulties connecting Chemistry concepts to their imaginations, which affects their cognitive development, content knowledge and their metacognition, failing relation to the abstract world. Research has been done in the field of virtual reality and physical models, however more needs to be investigate within the South African context. In this study, the relationship investigated is between learner performance in grade 11 Chemistry and the effective use of teaching tools.

KEYWORDS

Grade 11 chemistry concepts, Virtual reality, Animation, Visualization, Physical sciences, Geometric structures, Learning difficulties, Teaching strategy, Cognitive theory of multimedia learning, Chemistry textbook, Teaching tools, Physical models, Virtual representations.

DECLARATION

Title: The effects of virtual reality and physical models on grade 11 learner understanding of geometric shapes in the chemistry classroom

I Thobile Precious Nkosi declare that this research report is my own unaided work, except as indicated in the acknowledgements, the text and the references. It is being submitted in partial fulfilment of the requirements for the degree of Master of Science education at the University of South Africa. It has not been submitted before for any degree or examination at any other institute.

______________________ Signed on 30 day of September 2019

Thobile Precious Nkosi

DEDICATION

I would like to express my sincere gratitude to my supervisor Prof Lindelani Mnguni for his unwavering support, time and encouragement at all times. Thank you for your patience with me and always believing I have in me. Thank you for motivating me and giving me hope during this journey.

Thank you to the Principals, learners and teachers from the schools that participated in this study.

My special gratitude goes to my family, my parents and my siblings. I thank my grandparents, especially my grandmother, this is for you. Being the first in my family to go to University, I thank you all for your constant support and love.

A special thank you to my mum and dad for their unwavering confidence and encouragement that helped me realise my potential.

CHAPTER 1

1. Introduction

In South Africa, the schooling system is organized according to grades R-12. Grade R-7 is called primary school and Grade 8-12 is called secondary school (also referred to as high school). Within the grades the learners are separated according to phases, that is, Grade R-3 is the foundation phase, Grade 4-6 is the intermediate phase, Grade 7-9 is the senior phase and Grade 10-12 is the FET phase. Focusing on the FET phase, learners get to choose the subjects they want based on the career choice they aspire to follow in future. One of the subjects that can be chosen is Physical Sciences which is divided into two parts, Physics and Chemistry. The present research study focuses on Chemistry.

Previous research has highlighted that between Grade 8 and 9 there is poor performance in the understanding of Chemistry concepts in South African schools. During the 2011, Trends in International Mathematics and Science Study (TIMSS) it was noted that the average science achievement for a Grade 9 South African learner is below the international centre point of 500 points (Mullis, Martin, Foy & Arora, 2012).

Typically, schools which are able to produce positively preforming learners are schools that have better facilities and teaching tools. According to Mullis *et al.* (2012) it also includes schools with enhanced instructional materials such as books and computers. Consequently, most private schools perform better that public schools' due to the availability of resources in their schools and the financial exposure for private school learners. In addition, research findings conclude that good school resources influence educational results and the availability of resources executes better educational outcomes (Taylor & Yu, 2009; Van der Berg, 2008).

Further, learner misconceptions, learning difficulties and the understanding of scientific models is some of the misunderstood concerns in Chemistry educational (Teo, Atta, Bukhari, Taisir, Yusuf & Idris, 2014). To this end, research has been done to explore virtual reality and physical models as teaching tools to assist in Chemistry, however, more needs to be investigated within the South African context. Additionally, there is a need to explore learner misconceptions which can lead to learning difficulties, particularly in rural areas around South Africa and the developing world (Demircioğlu, Ayas & Demircolg, 2005).

For example, concepts in Chemistry such as, valence electrons, Lewis structure, geometric shapes, interpreting structures and naming are some of the learning areas where learner experience the greatest difficulties (Department of Basic Education, 2006). The mentioned Chemistry concepts are essential for the foundation of an individual's Chemistry knowledge. Thus, it is significant that learners are equipped with well-advanced Chemistry understanding for the development of their Chemistry knowledge and academic improvement. When learners are given the opportunity to stimulate their cognitive growth, metacognition and content development in a stimulating learning environment, learning occurs (Vygotsky, 1978).

The research gap explored by the current research study therefore includes difficulties experienced by learners when attempting to connect Chemistry concepts to their imagination of the abstract world. According to Piaget (1978), children tend to practice their thinking and actions into systems called schemes, and these schemes become mental representations of events of their outside world. This implies that learners who fail to understand Chemistry concepts are bound to experience difficulties, when required to relate the abstract nature of Chemistry to the abstract world, which results in poor academic achievement in Chemistry.

2. Problem Statement

The research problem central to the present study is divided into three components, namely, poor learner performance, the role of teaching and learning methods as well as lack of resources to support learning in chemistry. These are discussed in detail in the following sections.

2.1 Poor learner performance

Chemistry is seen as an important branch in other fields of science, as it assists learners in knowing what is happening around them (Elinikety, Nahum, Tracey & Zwaenepoel 2004). However, a large number of learners in the South African education system perform poorly in Chemistry due to its abstract nature. This is because Chemistry concepts are microscopic, complex and occur at a molecular level (Al-Balushi, 2009). According to Mnguni (2014), Chemistry concepts are not always understood by learners as they occur at a level not seen by the human eye.

Much research has been carried out with the aim of exploring strategies for improving learner performance in Chemistry. However, it remains a concern that poor performance in Chemistry exists. Previous research in South Africa has reflected the trend in poor learner performance in Physical Sciences, including chemistry, in the NSC (National Senior Certificate) final examination. The results obtained from one of the biggest provinces in South Africa, KwaZulu-Natal reflects a decline in learner performance which is a huge concern over the last number of years. Looking into the year 2013, 50332 wrote the NSC examination and the pass rate for Physical Sciences was 66.4%. In the year 2014, 45143 candidates were seated for the examination and 55.8% passed. Out of the 50163 candidates who wrote the examination in 2015, only 25984 passed representing 51.8% (National Certificate Examination School performance report, 2015).

Chemistry is perceived as a difficult subject and in the South African schooling system, learners generally perform poorly in Chemistry. For example, the Department of Basic Education diagnostic report for 2018 shows that the number of Physical Sciences learners who scored 40% and above is 36. 9% (in 2014), 36.1% (in 2015), 39.5% (in 2016), 42.2% (in 2017) and 48.7% (in 2018) (Department of Basic Education, 2018). In the Chemistry component of the exam, the average marks were below 50% in 8 out of ten questions. In 2018, worst performance was on questions that tested learner's knowledge of preparation and nomenclature of esters (48%), organic reactions (49%), reaction rate & stoichiometry (48%), chemical equilibrium (43%), acids and bases & stoichiometry (44%), galvanic cells (46%), electrolytic cells (45%), and fertilizers (39%) (Department of Basic Education, 2018).

In addition, while there are specific reasons for this poor performance, it is a subject of debate. Hence, the present researcher believes that the complex nature of Chemistry makes it hard for learners to understand and to relate to Chemistry concepts, which results to the high drop-out rate and the poor Grade 12 National results. Thus, the South African pass rate is constantly low particularly in subjects like Physical Sciences and Mathematics (Department of Basic Education, 2018).

The lack of positive performing learners in the final NCS examination causes more harm to the future of the learner, as it minimises a number of career opportunities within the science fields. For an example, the minimum requirements for acceptance for a diploma or a bachelor's degree study at a higher education institution, requires candidates to obtain 40-49% and 50-60%

achievement in Physical Science. With the poor performance in Physical Sciences according to the results obtained from the NCS a large volume of learners do not meet the minimum requirement to advance their education in universities as a result of poor performance in Physical Sciences in the Grade 12 NSC examination.

2.2 Teaching methods

According to Buddha, he believed that the mind is everything. What one thinks is what they become, poor teaching methods affect our minds and our thinking towards the subject. Whereas Aristotle says the exclusive sign of thorough knowledge is the power of teaching. Thus, effective teaching methods and teaching strategies play a role on the learners' academic achievements and learning outcomes. When a teacher uses effective teaching methods they cater for the needs of the learners for that particular subject.

Zoller (1990) advocates the important use of various teaching methods and Gardner (2004) supports the use of various teaching methods because of the multiple intelligences that exist in each classroom. Teaching methods can be viewed as a guide to the curriculum to assist learners to being analytical thinkers and problem solvers. For good and authentic teaching, the teacher should be able to use various teaching methods as this ensures improvement in learner performance. If the correct teaching methods can be used in Chemistry, learners will have the ability to acquire Chemistry knowledge, the laws and principles of the Chemistry phenomena more positively. The nature of Chemistry cannot be understood if the teaching method limits learners to thinking like scientists (Gilbert, 1997).

In order to improve learner performance in Chemistry education, there are a number of factors that contribute to the poor performance that needs to be acknowledged and improved. The first is the inequality of the opportunities presented to others when being taught in school. In South Africa, we have private schools which have a good financial structure. Whereas, government conducted schools are not as privileged. In private schools' teachers can improve learner performances by upgrading their teaching methods by utilizing resources, teaching tools and science labs. However, the same is not true for government schools, where primarily the only source of information is the teacher and if lucky the textbook too.

Previous studies have shown the effective use of different teaching methods, it was found that 65,4% of South African teachers believed that teaching methods can improve learner performance. Whereas 13,7% believed that teaching methods have no significant role, rather the content knowledge of the teacher that is important for learner academic achievement (Jouber, 2011). The same study also indicated that when particular teaching methods were used, learners performed differently.

Further, in every classroom learners will acquire knowledge in their own way, some learn by seeing and hearing or reflecting and acting. Which means teaching methods also vary, some strategies are instructional lecturing and others demonstrate or discussions. The key to how much learners learn in a class is determined by the methods used and how it corresponds to the manner in which the learner learns. There are a number of teaching methods that exist, that can be used in various classrooms and for various subjects. It is key to note, a teaching method will only be beneficial is the outcome it intends to bring, is the same as that the teacher aims to achieve.

The lecturing teaching method follows a semi-formal method of discussing topics and problems in the lesson. This method can be used as a mean to orientate learners or be used as a manner to introduce a subject or topic. During interactive lecturing, there is an interchange between teacher and the learners and this can promote active learning and better attention to focus (Snell, 1999). This method saves time, it allows flexibility for the instructor and it is easy for one to adapt to it. However, this teaching method has a limitation as it involves a one-way teaching approach, it poses limitations in the teaching of skills. For subjects like Chemistry, this method might have limitations, since Chemistry requires more attention to improve the imagination of the learner.

Further, the discussion teaching method is used to build imaginative solutions to learner problems. This teaching approach aims to stimulate the learners thinking and the interest of the learner to emphasis the main teaching points (Garside, 1996). This teaching method has the ability to positively increase the learners' commitment and results in more permanent ways. However, this form of teaching requires highly skilled instructors.

Whereas, the demonstrative method is a strategy used to teach manipulative operation in the classroom (Çibik, Diken & Darcin, 2008). In a Medical study conducted on the use of tools for the demonstrative teaching method, the implementation of using models to demonstrate improved the medical students' understanding and performance (Hampton & Sung, 2010). The results show that the group that used 2D models performed better than the group that used traditional teaching methods and non-interactive materials. The teaching method that utilizes tools is beneficial as it saves time and it can be applied when addressing a large group, however, it requires careful preparation and requires specific classroom skills.

If learners are not assisted in understanding the abstract nature of Chemistry they will fail to build their cognitive growth and might never fully understand the subject. This demonstrates the need to explore the use of virtual reality and physical models as a mean to improve learner performance alongside the different teaching methods known. Learners need tools to assist in simplifying and magnifying complex concepts.

2.3 Learning styles

Gardner (2000) believes in the uniqueness on how individuals acquire knowledge, which he refers to as multiple intelligences. Some learners find it easy to understand mathematical concepts while others need to be drawn a picture to what is going on, others find it easy to remember the way to places previously visited while others cannot image their own kitchen. By understanding our minds and its needs, we can either improve or destroy the ability of achieving academic success.

According to Willingham, Hughes & Dobolyi (2015) learning styles can be understood from two separate forms, the first is based on the ability of the learner and the second is the preferred learning style. Learning style theories can be understood by differentiating learning as being visual, auditory and kinaesthetic learners (Dunn, Dunn & Price, 1984) or between understanding learners as being visual and verbal learners (Riding & Rayner, 1998). Learning styles theories focus on the preferred learning style of the learner and looks at the cognitive processing of information between intuitive learners or being an analytical thinker (Allinson, & Hayes,1996) or as being an activist, reflecting or a pragmatic thinker (Honey & Mumford, 1992). For learning ''styles'' to have some sort of value on human cognition and learning, it is important that it holds more than just ability. Learning styles refer to how one is able to do things, the concern of ability is how well one is able to do it (Willingham *et al.,* 2015).

Previous research has highlighted the importance of using different learning styles and creating learning environments based on different learning styles. Learning styles can be seen as one of the most important aspects when determining individual differences in learning (Özyurt & Ozyurt, 2015). A recent study conducted in United Kingdom, Turkey, the Netherlands, Greece and China showed that over 90% of teachers agreed that learners understand better when they receive information personalised for their preferred learning styles (Howard-Jones, 2014).

In an ordinary classroom setting, some learner might be exited to learn and other learners might look bored. This is not that learners do not want to learn, but it could mean that the method of teaching is not supported by their learning style. Learners who get bored or inattentive during the lesson, achieve poorly on tests and examinations (Felder and Silver- man 1988; Godleski 1984). The same can be true for South Africans poor academic results in Chemistry, it might just be that the learner need the lesson to be a more interesting in order for them to consume information.

According to Gardner (2004), there is no correct or wrong learning style, only misguided learning styles. We all learn differently and different subjects require different learning demands. If the correct learning style can be used to cater for the needs to the learner, learners can perform better. There is a use for every existing learning styles, however when used for the wrong subject or topic, learners will encounter learning difficulties (Gardner, 2000). Multiple intelligences should not be taken for granted in the classroom especially with subject like Chemistry, because the correct learning styles can minimize the complex nature of Chemistry.

2.3 Resources

Graf and Liu (2010) stipulates that teaching tools and educational tools are valid instruments to accompany teaching methods and learning styles. Teaching tools are resources that help teachers close the gaps in classrooms by engaging learners more effectively and to make learning more fun.

In a study conducted by Pani, Chariker & Naaz (2012, 2014) in medicine on the anatomical views which compared the sectional presentations, concluded that when using 3D demonstrations, the participants performed better than when using the 2D representations. The ability for one to see what has always been imagined through 2D or 3D provides a better clarity for the complexity and the images in the textbook. Moreover, in another study conducted by Takkunen, Turpeinen, Viisanen, Wigren, Aarnio & Pitkaniemi (2011) which used simulation in a medicine study, demonstrated positive results and outcomes.

If the use of resources can improve the understanding of medicine students it can improve learner performance in Chemistry, as Chemistry is an important field for medicine studies. This implies that adequate resources can be used in Chemistry education to assists with the complex nature of Chemistry (Chingos and West, 2010). Owen (2008) indicates that resources can break misconceptions by allowing the learner to explore, analyze and engage in the concepts. Teaching resources can improve learner performance; thus, further research is required to explore the use of physical models and virtual reality to improve learner performance in chemistry.

3. Rationale of the present study

In light on poor performance in Chemistry, and associated factors, including teaching and learning methods and lack of resources, the present study seeks to explore the role that could be played by the use of virtual and physical models in teaching selected topics in Chemistry. Related research on the use of teaching tools in the Chemistry classroom has been conducted in various countries around the world, Finland (McIntyre, 2015), Nigeria and Germany (Shawl, 2016) to name a few. However, in South African, the largest number of studies conducted for Chemistry education is done for Grade 12 learners and for University students. When looking at the target group for Chemistry research in South Africa, most is mainly for the improvement of the National Grade 12 results at the end of their academic year.

Chemistry concepts are introduced in Grade 10 to learners in South Africa and formally tested in the NCS Grade 12 examination. The focus on Chemistry should not only be from Grade 12, but closer attention to the grades that build the Grade 12 content for the final examination.

Though a large amount of resources goes to improving Grade 12 results it is too late, the focus should be from Grade 10 and 11 because these two grades are the building blocks for the final Grade 12 Physical Sciences examination. The Grade 12 Physical Sciences content is mostly concepts from Grade 10 and 11 and only introducing a few topics in Grade 12. Even though money is allocated for Grade 12 learners, they perform poorly based on the poor Chemistry foundation in Grade 10 and 11. It is therefore important, from an educational perspective to implement teaching tools for the classroom to support the textbook for academic improvement. There is very little research present on the interest on the knowledge of Chemistry in Grade 10 and 11.

Therefore, the rationale of this study is to explore virtual and physical model as potential teaching resources for Chemistry learners to improve learner performance. These teaching tools can be used to support the Chemistry textbook used in the classroom to assist learners in improving their academic achievement. The current study aims to explore, the effects of using teaching tools such as physical models and virtual reality on Grade 11 learners' understanding of geometric shapes in the Chemistry classroom. Secondly, it is important to understand the learning difficulties experienced by the learners and learning barriers that negatively influence their teaching and learning towards their performance in Chemistry.

The data that was gathered from this study could serve as meaningful information to assist in improving Grade 11 Chemistry learners' academic results for the final Grade 12 NCS results.

4. Research Aims and Research Question

The purpose of the research study is to investigate the change in learner performance for Grade 11 Chemistry learners when the textbook is supported by teaching tools namely; physical models and virtual reality. The study also aims to understand the learning difficulties experienced by the Chemistry learners when teaching and learning occurs.

Emanating from the aim of the study, the following main research question was asked:
What are the effects of virtual reality and physical models on Grade 11 learner understanding of geometric shapes in the chemistry classroom?

To respond to the main research question, the researcher explored the following research sub-questions:

a) What are the effects of using physical models as a teaching tool on learner performance in geometric shapes?

b) What are the effects of using virtual reality as a teaching tool on learner performance in geometric shapes?

5. Introduction to research methods

The current research study looked at how effective teaching tools such as physical models and virtual reality could improve Grade 11 learner performance and understand the learning difficulties associated with learning Chemistry. The aim of this research study is to explore the difference in performance when teaching tools such as physical models and virtual reality are used in the Chemistry classroom in support of the textbook.

The researcher adopted a mixed method approach, which has the ability to be implemented in high capacities when approaching a study, by addressing complex practical problems with the liberty to adjust to the researchers' values. A mixed method approach is a blend of qualitative methods and quantitative methods. In this research study, the qualitative method approach has equal value as the quantitative research method. Both methodologies where conducted concurrently in the research study and both phases where conducted on the same day.

Further the research used a number of components, including, pre-test, post-test, an intervention of teaching tools, Likert Scale questionnaires and interviews as part of the methods in the study. These methods where adopted in order to improve validity, reliability, credibility and trustworthiness.

5.1 Research approach

A mixed method research approach is supported by Morse (2016) as being advantageous with the ability of being used to explore lived experiences and interactions between people and their environment. This form or research allows the researcher the liberty to explore, as it is not statistical, but it incorporates multiple realities (Morse, 2016) The qualitative phase for any research study can be described as the psychology of the study (Levitt, Bamberg, Creswell, Frost, Josselson and Suarez-Orozco 2018). The qualitative phase aims to improve skills when interpreting the gathered data (Bogdan & Biklen, 1992). Further, the data collection instrument used was a Likert Scale questionnaire with open-ended questions and an interview session was held. Further Creswell (1994) supports this concurrency, as he argues that in quantitative research well-managed techniques lead to correct reliability and validity.

The quantitative phase of the research study seeks to investigate a phenomenon (Rasinger, 2013). In relation to the current study, the researcher aimed to see if the use of teaching tools can improve learner performance in a Chemistry classroom. The researcher used a methodology to explain the findings and numerical values where used to draw immediate conclusions for the collected data. Further, the instruments used for the quantitative phase of the study, is a pre-and post-content test with a total of 15 marks to prove the hypothesis. The content test used was created by the researcher using past papers from the Department of Education in South Africa. The test questions asked, included topics on valence electrons, geometric structures, orientations, molecules and the naming of molecules. The researcher followed the marking guidelines implemented and provided by the Department of Education in assessing and grading the tests.

5.2 Population and sampling

The study was conducted in Witbank Mpumalanga where non-random purposeful sampling was used to select participants. The criteria set by the researcher included a sample size of 200 participants in Grade 11 with Physical Sciences (particularly Chemistry) as a subject. The participants needed to be in a registered school in South Africa, in a school following the CAPS Curriculum.

What the criteria did not take into consideration was; the number of boys and girls in each group, the age of the participating learners, learners repeating the grade, background and upbringing. South Africa learners come from different homes, some are from working-class homes and others are raised by their grandparents, which was not a limitation for the current research study. Factors such as learners' marks, the school they attend, management of the school (fee-paying schools and\or no-fee paying schools) where not take into account.

5.3 Data collection instrument

The data collection instrument ensures validity since the test was developed by the researcher using previously moderated Grade 11 examination papers from the Department of Basic Education in South Africa. The reliability of the used instrument adheres to the guidelines that are provided with past examination papers, the content knowledge test and the cognitive level of understanding as per CAPS document. Finally, the validity of the data collection instrument will be reflected through the Department of Education prescribed content.

The quantitative data was collected through the written content tests. The participants were given a content test and the entire tests was out of a total of forty marks. For the pre-tests and the post-test, the participants answered the questions based on their Chemistry knowledge and understanding. Each question was given a point that the participants could obtain for getting it correct. Once the participants completed the content test, the researcher collected all the written content tests and tallied all the marks and gave each participant points out of the total of forty. Further the researcher, converted the points obtained into percentages to give an indication of the participants understanding and knowledge of Chemistry as per test, per question and the topic area.

The qualitative part of the research study was the Likert Scale questionnaire with open-ended questions. The Likert Scale was written after the content test (for both the pre-tests and the post-test), it was attached right at the back of the test. The Likert Scale allowed the participants to answer questions based on selecting 'Agree', 'Neutral' or 'Disagree'. The researcher gave each option that the participants could select a numerical value, 'Agree' was given the value of 1, 'Neutral' was given a value of 2 and 'Disagree' was given a value of 3.

Once all the questionnaires were collected the researcher converted the selected options into values and by doing so the researcher was able to numerically see the value of their response.

This assisted the researcher to determine the percentages of those that Agreed, those that were Neutral and those that Disagreed.

In addition, since the current research study aimed to see a change in the learners' performance, the same analysis was done for the Likert scale for the post-tests. By acquiring the before and dafter results of the intervention, the researcher to prove the hypothesis.

5.4 Data collection procedure

The procedure that was followed by the researcher for the research study, the researcher firstly organized the 200 participants into two equal groups, group 'A' and the other group 'B'. Group A was referred to as the physical models and group B was referred to as the virtual reality.

On day one, both groups had to complete a Chemistry content test with a Likert scale questionnaire with open-ended questions. Take note that the research study was a sequential mixed method approach. This phase of the research study was the baseline assessment to see how effective the school textbook was for the participants Chemistry knowledge. Once all the learners had completed the given content test and the questionnaire, it was collected by the researcher. The researcher gathered the data and recorded all the findings.

A week after the first content test and the questionnaire was completed, phase two took place. The researcher intervened with adequate teaching tools specifically physical models and virtual reality. This process of data collection was done during school hours in a Chemistry classrooms, where the researcher taught the participants using the designated teaching tools, group A was taught using physical models and group B was taught using virtual reality.

In addition, the researcher taught group A with bio-Chemistry model tools. The biochemistry molecular set is a set used for biochemistry students and at times used in the medical field, which was purchased online. The researcher had 15 of these sets and learners where able to participating and share in groups. The learners were required to build molecular structures using the bio-Chemistry sets. The lesson covered a number of important basics for Chemistry including geometric structures, valence electrons, intermolecular forces, molecular shapes, orientations and naming of molecules as prescribed by CAPS Document.

Further, on the same day group B was be taught using virtual reality tools, such as videos, simulations and Phet assimilations. The lesson covered a number of important basics for Chemistry including geometric structures, valence electrons, intermolecular forces, molecular shapes, orientations and naming of molecules as prescribed by CAPS Document. The researcher played a video on each topic and used Phet assimilation were required to assist the learner in understanding better.

A week after the intervention, both groups wrote the same content test and questionnaire that was written at the beginning of the research study. This phase of the study aimed to see if the participants had improved their marks with the support of the teaching tools. Once the participants had completed the content test, the researcher collected the data from both groups and record the findings again. In addition, the data collected on day one, was can be seen as the 'baseline data' for the study. The data gathered after the intervention was then compared to the data that was collected before the intervention.

5.5 Data analysis and interpretation

For the quantitative aspect of the research study, a t.test was used to analyze the data. The content test counted out of forty marks. For the content test, each question was assessed individually and compared with that of the other participants and in each group. The researcher used the gathered data from the content test and compared how the learners performed per question, per group. Once the comparison was done, the results obtained enabled the researcher to analyze and conclude whether *a) teaching tools improved learner performance as support to the textbook b) the learning difficulties associated with the teaching and learning of Chemistry.*

The results gathered by the researcher enabled the researcher to conclude which group showed a greater percentage in improvement. The researcher compared the gathered results from the pre-content test between the two groups and analyzed their responses to the Likert Scale questionnaire to understand their learning difficulties. Further, the same was done for the post-content test for the two groups, where the gathered results were compared between the two groups and their responses to the Likert Scale questionnaire. This aimed to reflect if their learning difficulties and the challenges experienced before were still existing.

The data analysis for the qualitative phase of the research study, for both the pre-tests and the post-test, the researcher converted the Likert Scale questionnaire results to numerical values in order to see how many 'Agree', 'Neutral', 'Disagree' were obtained per question. Therefore, the data obtained from the Likert Scale was analyzed, using the Mann-Whitney test. The results from the content test were analyzed using an excel spread sheet, t.test and the Cronbach Alpha for reliability.

For the last phase of the research study, the researcher randomly selected 20 participants from the two groups to be interviewed. This phase of the study sought to validate the findings and to get a deeper understanding of the data collected and the reasoning provided by the participants. The interview also aimed to give light on the learning difficulties experienced in the learning of Chemistry before and after the intervention. For the interview, the researcher recorded what the participants said in the interviews and drew on commonalities from the learners (using a tree diagram and v-diagram) and drew conclusions.

Lastly, once the data from both phases and groups was analyzed and recorded, the research focused on the following; how did the participants perform in their groups per question, how both groups performed in comparison with one another per question and collectively, how each group performed post teaching tool intervention and if there was an improvement with the use of teaching tools. The researcher analyzed the gathered data by interpreting the mean, mode, and median of the results recorded, which assisted in understanding the hypothesis.

Take note the researcher firstly taught group 'A' using physical models and group 'B' using virtual reality. To ensure the research study is fair the researcher also taught group 'A' using virtual reality and group 'B' using physical models. This is a measure to ensure all learners are treated equally and given the same opportunities. This phase occurred after the post-content test, to ensure that the results were not scrutinized.

6. Planning of the study and chapter outline

For the current study, the research report is divided into five chapters. Chapter one gives a full description of the ideas of the research study highlighting the contextual evidence to the poor performance in Chemistry and the learning difficulties associated with the subject in South Africa. Further a full description of the problems that supports the current research study and the questions that channeled this research is also reflected. In this chapter, the reader is also provided with the rationale of the research study being conducted for Grade 11 Chemistry learners.

Chapter two provides the theoretical framework supporting this research study and the issues around the topic. This is a guide to making sense of the research topic and analyzing from literature to draw on the poor performance in Chemistry education, particularly in South African. Further, this chapter shares the constructivism of Chemistry knowledge and the learning difficulties experienced by learners.

Chapter three provides a detailed description of the approaches used by the researcher in conducting the research study. Further, explanations regarding the selection of methods and methodologies used are also reflected. The subject of firmness and research ethics are discussed in this chapter. This chapter also provides information on the participants and their schools to enhance the readers understanding of the report.

Chapter four gives a detailed picture and evaluation of the results obtained. The results gathered in this chapter are presented in themes representing the two sub-research questions being answered. The chapter starts with an explanation of how the data was analyzed and the results of the data are captured in graphs, figures and tables.

Chapter five is the final chapter that underlines the summary of findings, discusses the limitations of the study as reflected by the researcher during the course of the study. Recommendations and propositions have been echoed upon them for future stakeholders for future research. In addition, the recommendations and suggestions for the various researcher for future research have also been provided.

7. Conclusion

The aim of this chapter was to create an argument to motivate the current research study, supported by literature to support the claims. Chemistry is microscopic, complex and occurs at a molecular level. Learners perform poorly due to Chemistry misconceptions and the associated learning difficulties around the subject. Teaching methods, learning styles and resources can be strategies used to improve learner performance in Chemistry education. Thus, further research is required to explore the use of physical models and virtual reality as teaching tools to improve learner performance. The conceptual framework incorporated is aimed at understanding the participants' Chemistry knowledge and learning difficulties associated with the subject. The importance of Chemistry will be discussed in the next chapter.

CHAPTER 2

2. Introduction

In the South African education system, Physical Sciences is a school subject learnt in Grades 10 to 12. The subject can be divided into two interrelated discipline, namely, Physics and Chemistry. The Chemistry component of the subject deals with the study of matter and energy and how these interact with each other at a molecular level. Consequently, Chemistry knowledge can be presented at a macro, sub-micro and symbolic levels. This knowledge is significant for everyday socio-scientific issues such as global warming, and is important in helping learners develop critical thinking skills.

Although Chemistry is central to a number of everyday concepts, Chemistry concepts are difficult to understand because of their abstract nature. For an example, people who work with medicine require a clear understanding on molecular structures and the bonds of molecules in order to predict what happens next, yet these cannot be visualized with a naked eye. While this is cognitively demanding for expert scientists, one can only imagine how cognitively overwhelming Chemistry is for learners who are novice scientists.

In the last hundred years, the world of scientific knowledge has evolved enormously leading to knowledge explosion (Reiss, 2006). The pace in which Chemistry knowledge is evolving requires more research to improve the teaching and learning of Chemistry concepts. With the changing times and evolving knowledge, the way Chemistry is taught in schools should also be improved. If there is no plan of action implemented to improve academic achievement, many careers will be affected, and the pace of the evolving scientific knowledge will decrease. Moreover, Chemistry is the building block for leading industries like biochemistry, pharmaceuticals, genetic modifications, metallurgists, chemical engineering and cloning to name a few.

In light of the above, therefore, the current chapter begins by discussing the different learning theories, the impact each has on learner academic and knowledge development. The various teaching theories will also be discussed along with the change they can bring in the classroom.

Further, this chapter focuses on the different teaching and learning resources available to improve academic performance in Chemistry. Thus, reflecting on various teaching and learning approaches, provides a reflective perspective on the potential effects of using alternative teaching methods and tools. Such methods that incorporate tools like physical models and virtual reality to enhance teaching and learning in chemistry.

2.1 Learning theories

Learning can be seen as being complex with no wrong or right accepted definition of the concept. Learning theories are a way in which we can use to understand how learners absorb, process and retain knowledge when learning is taking place. Factors that can play a role in learning, includes cognition, emotion, environmental influences as well as an individual's prior experiences (Knud, 2004).

However, a large number of corresponding theories of learning are constantly being advanced, some theories referring back to traditional understandings, where other theories are trying to explore new possibilities and ways of thinking (Illeris, 2018). With that said, learning is traditionally understood as the gaining of knowledge and skills, whereas today the concept of learning includes fields of emotions, social and societal dimensions (Illeris, 2018). This suggests that learning should be seen as a tool that can assist with the nature of future challenges, different fields and phases of life.

Learning reflects an individual's ability to internalize knowledge, by modifying prior knowledge, including behaviours, and skills (Gross, 2015). In fact, Gross (2015) suggests that learning is a hypothetical construct because it cannot be 'directly observed', but can be inferred from observable behaviour. This observation may include various assessment methods such as group assessment, peer assessment or through formal assessment. The various methods of assessment assist the teacher to get a reflection if teaching and learning had taken place.

In addition, the way in which the learner will reason and the score obtained will indicate to the teacher if the bench mark was reached (pass mark in South Africa is 33% for high school learners, except for language and mathematics), which concludes if learning had occurred. If learning was the same for every learner then all learners would get the same mark and failing would be taboo. However, that is not possible, which indicates that leaners do not learn and acquire knowledge the same way. Hence, we are faced today with a high dropout rate not only in school but in universities too, with a higher rate in subject like mathematics and science.

Chemistry teachers, and teaches in general, can use different teaching and learning theories in their instructional designs. According to Skinner (1990) a teacher's opinion on teaching and learning, on intelligence and how knowledge is constructed influences their way of teaching. Every teacher is different and most teachers, teach in a manner they think is good for their learners. Whichever method used for the teaching of science, the learning phase should be an approach that requires learners to think and analyse information, solve problems by making meaningful sense and connections to the real world (Blythe, 1998). The teacher's role is to take learners through the process of learning for content understanding to the ability of interpret information taught. If learning is achieved, the individual will grow cognitively and develop metacognition, which is the ability to think about thinking and in a given society this is the formula for how learners are categorized (Skinner, 1990). In light of the reported learning difficulties associated with the learning of chemistry, teachers could explore various teaching methods as guided by related theories in order to improve the learners' academic performance in Chemistry.

All learning theories have the ability to move learners from the place of not understanding to a place of confident reasoning. Whichever learning theory used, teaching tools can also be implemented as additional resources for knowledge development for complex concepts and those at microscopic level. Further, learning theories offer instructional approaches, whereas teaching tools will offer reality in the classroom. Thus, the process of teaching and learning requires more than just instructional talking from the teacher and a textbook. Teaching and learning requires learners to use tools to build understanding and provides for further explanation with the ability to bridge present gaps.

The quality of teaching and learner performance can be measured with the learning styles around an educational learning theory. The implementation of a teaching method and a learning style gives a clear picture of what was being achieved (Carew & Magsamen, 2010). Further, (Carew & Magsamen, 2010). argues that in a classroom the teacher's role is to be a mediator for content understanding, with the use of educational tools for learner cognitive growth, metacognition and academic improvement.

For a teacher to achieve learning in the classroom, various methods and strategies of learning and teaching can be implemented. In the philosophy of education, there are various teaching theories and learning theories that have been documented. According to Bell, (1993), teaching and learning theories differ in a number of ways, from their general assumptions to the principles that guide them. Educational theories attempt to explain, in different ways, how learning occurs, how knowledge is acquired and the basics of teaching (Bell, 1993). For example, the behaviourism theory reflects how new behavioural changes are attained between stimuli and response (Gross, 2015). Cognitivism theory explains how learning occurs through the internal processing of information (Mayer & Mayer, 2005). Constructivism theory focuses on the construction of our own knowledge based on one's experience. Whereas, the social media learning theory suggest the importance of learning collaboratively through social media (Mayer & Mayer, 2005).

2.2 Behaviourism learning theory

The behaviourist theory considers knowledge as existing independently and externally from a person, and a learner is perceived as a blank slate in need of experience (Skinner, 1990). Skinner's conceptualization of behaviourism began in the twentieth century and this approach to learning was prominent around the psychology of education. According to Marks (2018), the perception on behaviour from the view of a therapists, is behaviour being learnt or acquired. Behaviour can be learnt and unlearnt, which suggests that behaviour can be altered to suit the individual or environment.

The behaviourism views learning as based on a stimulus in which the individual makes a response too. For us to understand an individual's behaviour we must first understand the relationship between the stimulus and understand the response. The theory of behaviourism, views learners as passive and changes through positive or negative reinforcement, underlying learning as a change in behaviour (Skinner, 1974).

Further, Skinner reflects that by implementing mental changes as tools to assist in learner understanding, it will only add to the complexity of the problem. Therefore, if any tool is to be used it should be a tool that can provide further explanation (Skinner, 1990). Which means learning programs are based on the idea of stimulus-response relationships with the importance of reinforcing factors and instructional programs that implements learning theory.

Skinner is seen as the father of the behaviourist theory, however there are key players who have voiced their views for the theory. Pavlov's views were on the behaviourism theory of classical conditioning. Pavlov's theory was tested using dogs which repeatedly gave to a desired reaction. This experiment proved that a person's psychological views reflect their behaviour, a human's behaviour can be changed according to what is favoured (Pavlov, 1955).

Whereas, the behaviourist theory of conditioning was the views of Watson, who is a pure behaviourist. According to Watson learning is a process of engagement between the stimulus and response (Johnson, 2001). His views looked at behaviour that can be observed and measured (Watson, 1913). The last theorist is Thondike's, who's view of connectivism, which viewed learning as the process of forming associations or bonds. Thondike also classified the laws and principles of learning as law of readiness, law of exercise and the law of effect (Thondike, 1898).

When a learner walks in the classroom, they come to learn things they have never learnt before, to learn new concepts and give explanations for our world. Some concepts will be hard and others easy, but what they learn in the class they will carry with them forever. Thorndike stressed how important it is to build habits and procedures in learning especially in language learning processes (Barash, 2005). For an example, if you teach learners that the sky is blue they will believe the sky is blue, but if you teach them that the sky is blue due to scientific reasoning and the reflection of light, you have not only stimulated their minds, but adding true knowledge to their blank slates. Sarah (2006) suggests that the process that occurs between the stimulus and the response of the learner while learning cannot be measured.

Further, once a learner's "blank slate" has been filled with information their behaviours will change, either positively or negatively to the gained knowledge. According to the theory of behaviourism, it suggests that learning occurs when immediate behaviours or changes in behaviour are acquired through stimuli and responses, therefore resulting in a complete changed behaviour (Woolf, 1995).

Behaviourists argue that learner performance reflects the individual's external factors and behavioural conditioning as a universal learning process. If the behaviour is rewarded this reinforces change in the future for the learner, the ideas of positive and negative reinforcement are effective tools for learner performance and behavioural changes (Skinner, 1974). There is a great belief in positive remuneration for good behaviour and no remuneration for bad behaviour, which results in no repeated negative behaviour and an improvement in learner performance (Skinner, 1974).

However, Rotfeld (2007) argues that the term behaviourism was created by psychologists to theoretically explanation, predict, and test individuals. From the foundation of behaviourism, the concepts of behaviour deliver direction, in understanding the social acknowledgement for the control and depth of all appropriate variables when ignoring human thought and cognition (Sidney, 2015). This suggest that the ideas and opinions of behaviourists were not concerned with the minds of people, their main focus was behavioural responses from people. The behaviourists view their ideas and opinions in a scientific measure with the same acknowledgement as the hard sciences of Chemistry or physics (Sidney, 2015).

Albert Bandura is mostly classified as a behaviourist, Bandura himself opposes to behaviourism. It is impossible to make a statement independently to the behaviourist approach, while dealing with the cognitive approach or attempting to make a statement while handling constructivist approach. Therefore, the cognitive approach does not deny behaviourism, it claims that the cognitive process is seen in behaviourist learning. We cannot say that cognitive psychologists completely exclude the findings of behaviourists. Cognitive processes and activities such as the processing of information, mental representations, guesses and expectations are accepted to be a basis in the interpretation of learning. Cognitive theorists add to behaviourists' findings, to claim the cognitive process (Akdeniz, Bacanli, Baysen, Camak, Celikoz, Dogruer, & Yalin, 2016)

Further, Skinner (1979) argued that the mind and mental processes are "metaphors and fictions," and that "behavior" is a function of the "biology" of the organism. This helps us see that Skinner revealed no concern in understanding how the human mind operates, he was a true believer of the ideas of the behaviourist theory just as John Watson. Together Skinner and Watson have their main focus on behavior as being disturbed through external forces. Skinners views saw the human mind as being controlled by the individual's experiences. Which suggest that the according to Skinner the "mind" (not the brain) has nothing to do with how people behaved.

2.2.1 Main characteristics of the behaviourists learning theory

As discussed above, it is understood that behavior can be learnt and unlearnt. For one to understand the characteristics and factors of the behaviourist theory, one needs to understand the theory from the ideas of learning and conditioning, the transfer of learning, and the techniques and benefits to transferred learning (Mark, 2018).

Conditioning and learning through the behaviourism theory can be explained and understood in three types, the Classical conditioning, Operant conditioning and Social learning theory. Classical conditioning is when the individual's obtained behaviour becomes a reflex to the stimulus. Whereas, the operant conditioning is when the stimulus is achieved through punishment or rewards. The social learning theory is obtained through modelling (Green, Feinerer and Burman, 2015).

The discovery of classical conditioning from the behaviourist learning theory was from the work of Ivan Pavlov, where his ideas observed the behaviour of dogs. His observations lingered on the behaviour of dogs when they were feed, when the food was delivered to the dogs, when the person delivering the food was wearing a white lab coat or simply rung the bell, the dogs produced saliva, even when there was no sight of food or smell of food (Myers and David, 2008). Classical conditioning suggests this form of learning being the same as humans. The operant conditioning rewards the behaviour of learning and knowledge acquisition with reward or a punishment (Myers and David, 2008). This is because the reward increases the behavior, whereas punishment would decrease the associated behaviour. Social learning theory observes behavior and is followed with modelling (Smith, 2011).

The transfer of learning is based on the ideas on what we acquire at school, we somehow carry and apply to different scenarios ad settings (Kleibard, 2004). One of the first people to test this theory in educational psychology was Edward Lee Thorndike, a pioneer in research. He discovered the importance of transfer in learning, it is a rarely occurring phenomenon (Kleibard, 2004). One example to the importance of transfer, is does not occur often but involves surface structure and deep structure. The surface structure is the way a problem is framed (Willingham, 2009). What this suggests is the fact that once something has been learnt and the behaviour has changed, what was learnt can be transferred to a different situation using the same techniques that were learnt. Therefore, this is seen as the ability for people to see the deep structure of the problem and transfer the knowledge they have learned, to come up with a solution to a new problem (Willingham, 2009).

The techniques and benefits of transferred learning is affected by a number of various conditions, which influence the transfer of learning in the classroom (Cormier and Hagman 2014). These conditions include features of the task, features of the learner, features of the organization and social context of the activity (McKeough, 2013). If we look into features of the task, it includes practicing through simulations, the incorporation of problem-based learning, and the added use of knowledge and skills for implementing new plans (Cormier and Hagman, 2014).

In addition, since the academic world seeks to advance and improve the performance of learners in all aspects, through the schooling system and in higher education. Thus, the techniques of transferred learning aim to produce, achieving authentic learners, who have the ability to reflect on their past experiences, with the ability to participate in group discussions, practice skills, and participate in written discussions (Cormier and Hagman, 2014). Which suggests that all the mentioned features add value to a learner's ability to learning.

Further, the transfer of learning includes the use of structural techniques that can aid learning transfer in the classroom. These structural strategies include hugging and bridging (Harris, Lowery-Moore and Farrow, 2008), hugging uses the technique and tools such as simulations which is viewed as an activity to encourage reflexive learning. For an example, when a learner takes the lead to teach a lesson or when a learner role plays with another student, this is seen as a form of learning. I think for teachers to have learners take the lead in the classroom, whether explaining in a group or to the class, it is an indication of the amount of confidence with what they are explaining and their understanding. If learners are not sure of what they are expected to do or say, a teacher can pick it up and the problem can be fixed. These techniques show the ability to use and the development of critical thinking which engages the learners and assists them to appreciate what and why they are learning, which is one of the goals of transfer of learning (Harris *et al.,* 2008).

However, bridging is when given instructions aim to encourage abstract thinking, by pinpointing connections between ideas and the ability to analyse those connections. A practical example of bridging is when a teacher allows learners to analyse their past test results and analyse the manner in which the results were obtained. This technique requires learners to critically think of aspects such as the amount of study time and study strategies that they used. When learners can analyse their past study strategies, it can assist them in improving their study routines or help them develop new study techniques and strategies to improve their academic performance. These are some of the ideas important to succeed in hugging and bridging practices (Harris *et al.,* 2008).

This suggest that the techniques of the behaviourism learning theory reflect a number of benefits that can be employed in the classroom. Some of these include the ability to quickly learn a new task, the use of many real-life functions such as language and speech processing. The use of transfer of learning is helpful in teaching learners to apply higher cognitive thinking by applying their background knowledge to new situations.

2.2.2 Related teaching strategies of the behaviourists learning theory

The behaviourism theory views human behaviour as learnt rather than innate (Skinner 1974). Therefore, there are various teaching styles implemented by the behaviourist learning theory, the most common is instructional teaching also known as the lecturing approach. Which is seen as crucial for guiding learners, according to the behaviourism theory (Skinner, 1990).

An example for the instructional teaching approach used by behaviourists teachers is the famous chalk-and-talk teaching approach. It is seen as an important teaching method for the behaviourist theory, as it reflects a belief that verbal and aural teaching and learning methods are useful (Woolfolk, 1995). The chalk and talk teaching strategy allows the teacher to guide the learners through the lesson and pace the lesson, which gives the teacher total control in the classroom. The teacher has the ability to write, then explain and then give the learners a chance to copy notes rather than having all the notes on the board and having the learners copying them down. This allows the teacher to talk and share ideas within the lesson.

However, the downfall to this approach is the teacher-centeredness, since learners rarely share their ideas, rather they are guided by the ideas and the thoughts of the teacher. According to Knowles, Holten and Swanson (2005), by implementing this teaching approach the learners only get the opportunity to answer what is asked by the teacher and rarely get to construct and create their own thoughts. In this teaching approach, the teacher is the central point with no knowledge construction from the learners, and their minds not stimulated but only replicas of what is on the board and what is said, thus minimum knowledge development and critical thinking. This is because, the instructional and lecturing teaching methods according to the behaviourism theory, the teacher is not seen as a mediator. The teacher is seen as a person who shares ideas but does not assist learners in improving what they already know, which results in misconceptions and poor performance. In these teaching approaches, the teacher highlights what is important, however, does not guide or rectify learners to what is true and what is not.

Further, the human mind is constantly being re-evaluated and in the constant fore-front of scientific studies. According to Resnick (2017), the big question when using teaching approaches used by the behaviourist learning theory is to constantly ask oneself if the strategy used will affect the performance of the learner. This suggest that the goal should be an informing educational practice while extending the knowledge of how people learn, because behaviourist theory strives for changed behaviour in individual. It is important to understand, that a number of theories that have come forward reflecting the behaviourist learning theory to have more or less the same ideas as, Socrates and Plato who advocated, Itrad, Seguin, Mentessori and Binet who reiterated it. However, the constant question is, can on train the mind (Meichenbaum, 2017).

2.2.3 Related learning styles of the behaviourists learning theory

According to the behaviourist theory there are learning styles that can be implemented to expand self-growth and improve learning. Certain learning styles are available to assist learners with their knowledge acquisition and development (Skinner, 1990).

The idea of different learning styles being possible comes for the views of Gardner (2000), who believes in the multiple intelligences that are related to learning styles. The idea of multiple intelligences seeks to achieve the best possible learning styles that can maximise the potential of the individual academically.

The behaviourist theory has categorised the different learning styles into schemes that are common. In particular, these can be recognised as the verbal and aural learning styles (Gardner, 2000). The learning styles are those that are seen as promoting drill or rote work, repetitive practice in the class, receiving bonus point when doing well, where learners are given participation points, verbal reinforcement and the establishing or rules.

Unfortunately, the approach of behaviourism does not produce learners with authentic ability or a creative nature (Bruner, 1966). The behaviourist theory as guide for learning styles, produces learners who do what they are told and do not own up to responsibilities for their own learning or academic improvement. Instead it produces learners who replicate what they do daily with automated responses when having to performing tasks.

According to Sidney (2015), for us to understand learning, we need to look at learning in terms of perception, and educational retention, which suggest that many students learn through direct interaction and engagement. Learning though interaction and the engagement is a reflection of one's ability to learn within their environment and what they learn for their society. Where learning styles are brought forward as the core role of the teacher which is to instil a change behaviour.

However, from a behavioural point of view, it is supposed that the applicable chore role of a teacher is to provide stimulation and reinforcement (Sidney, 2015). The teacher can be seen as a learning style, as the teacher will enforce behaviour, based on the society and the environment and learners will respond accordingly to that. For an example, in the era of today with a large number of rape cases, girls are taught to behave in a certain manner and are taught to avoid certain behaviours, dress codes and lifestyles for their own safety. Based on how the teacher delivers the knowledge, the learners will learn as the information is given, training their minds to practise the gather knowledge.

One of the reasons for teaching and learning is the ‘grooming’ of people in a classroom or country. Therefore, the behaviourism theory is proved to be more effective when used to lead people in society towards morals and values which is achieved through repetitive behaviour (Bruner, 1960). The behaviourist theory can be implemented in a school system or environment to assist learners to learn about themselves and for the society to position them in the future. A good education system is vital, for ensuring well-grounded citizens (Modisaotsile, 2012), citizens that know not to litter, to respect the speed limit, understanding the importance of paying tax and to know their rights for a just society to name a few.

2.2.4 The behaviourists learning theory applied in Chemistry

The term "behaviourism" was devised by John Watson (1878 -1959). Watson believed that the behaviourist view was purely impartial and an experimental division of natural science with the aim to calculate and control behavior. This is the psychological philosophy of behaviourism, which believes that people's actions are driven by a need for individual gain, rewards or avoid punishments. As some theories support this by saying that the sole purpose of teaching is to facilitate learning (Entwistle & Ramsden, 2015).

In the current research study, it has been mentioned that Chemistry’s abstract nature and complexity is vast for learner understanding, thus resulting to poor achievement. Which suggests that learner understanding should be the main focus in Chemistry teaching and learning as to improve the current situation of poor performance in Chemistry. However, the behaviourist learning theory is more focused with apparent results from teaching and learning. The theory adopts the idea that if learners were presented with the right stimulus, they will be able to give you the response you want. The behaviourist theory fails to take note of student thoughts or feelings (Bush, 2006), rather it emphasises on stimuli effects that are able to provoke reactions and responses.

According to Bush (2006), the behaviourists believed that only recognisable, measurable and external behavior is worthy of scientific inquiry. Which is a reflection of the lack of implementation of the behaviourist theory in the Chemistry field. This is because the understanding and knowledge of Chemistry for learners cannot be measured and recognised by behaviour only. Chemistry is a subject that requires learners to critically reason, make cognitive assumptions and mental decisions. Whereas, Rotfeld (2007) suggested that psychologists created behaviourism as the foundation of theoretical explanations, predictions, and testing. This suggests a limitation in the fields of Chemistry education, as Chemistry looks at one reasoning abilities and knowledge skills.

Therefore, behaviourists theory is not interested in what might occur in people's minds, how they learn or reason, rather are solely interested in the behavioural responses of the individuals and how their attitudes change once the behaviour has been achieved. As a result, these responses were measured in relation to test stimuli. In other words, behaviourists saw this as a way for them to be viewed scientifically in the same way as the hard sciences of Chemistry or physics are viewed.

However, the behaviour theory focuses on the 'outer' learner and what the learner can execute (Mazur, 2005). For example, learners are assessed based on what they understood in the classroom, tests and exams reflect how much attention was given during the lesson. Learner performance is based on how much learners can replicate and how much of what the teacher said can they remember. Whereas, Chemistry education, focuses on what the learner can execute independently, the use of critical thinking and metacognition. If learners are taught about molecules and molecular properties, independently they are to construct what they understand, critically think and apply the concepts to complex ideas and used the gained knowledge to application in other Chemistry concepts. Consequently, the effectiveness of behaviourists learning styles may not be effective in Chemistry education.

Chemistry educators and/or researchers should have a constant eye to see the constant changes in learner teaching, learning and academic performance. This is because a good Chemistry preparatory course not only focuses on improvement of learner Chemistry content knowledge but also their affective outcomes (Villafane, Garcia & Lewis, 2014). However, not much research is present to the explanation or apparent changes in academic improvement in Chemistry brought by the behaviourist learning theory. The is not much research done in Chemistry using the behaviourist theory to improve learner academic results in Chemistry.

In light of the above discourse therefore, the current researcher suggests that behaviourist teaching and learning methods and styles may not be effective for Chemistry education. It is on this basis that the present study intends exploring alternative teaching methods to determine their effect on learners' content understanding in Chemistry. However, before that can be done, other theories must be considered. In the following section, the cognitive theories are explored.

2.3 Cognitive learning theory

The cognitive theory believes in knowledge acquisition and focuses on two aspects that guide this knowledge acquisition, as a teaching methods through the assimilation of concepts and the accommodation of concepts (Piaget, 2001). Assimilation takes place when a learner has learned new content and they try to understand it by relating it to something already know. If the learner is able to achieve this, there will be no misconception rather success in cognitive growth. Whereas, accommodation takes place when the existing content does not fit, learners build critical thinking by analysing what is true and what is false (Piaget, 2001). The cognitivism paradigm argues that the 'black box' which refers to the mind to be opened and understood just like one would do with a computer (Bruner, 1915).

Psychologists argue that instead of gaining knowledge from what we are able to see, we often learn by making connections and relations with what's new and old (Sharan, 2007). Every individual possesses their own unique perspective and idea of the world. This uniqueness is what gives humans the ability to create learning experiences and interpret given information in a manner like no other individual (Sharan, 2007). The ideas on how individuals view the world or interpret information, is an individual's cognitivism.

Cognitivism suggests that in order to understand learning, we have to recognize the brain as an important structure that processes information and interprets this information as we learn. The more we learn and acquire knowledge we improve our concentration, better out critical thinking and the ability to perform tasks better and more effectively. Cognitive learning helps us understand, why our brains are seen as the most incredible network of information, processing and interpretation in our bodies as we learn. In addition, the cognitive learning theory is an extensive theory which aims to explain our thinking and the different mental processes and that influences our internal and external factors.

The ideas of cognitive learning were first introduced by Edward Chance Tolman in the years 1886-1959. Tolman has a great contribution to the ideas and the development of cognitive ideas. Tolman claimed that learning was correlated with complex mental processes and not simple conditioning processes. (Akdeniz, Bacanli, Baysen, Camak, Celikoz, Dogruer, & Yalin, 2016)

There are two vital assumptions that imply the cognitive approach to learning, the first is the human memory system being actively organized to process information and the second is the existence of processing prior knowledge as it plays an imperative role in learning (Smith, 2011). Further, the cognitive learning theory supports that for learning to take place, prior knowledge must exist on the given topic. When learners apply prior knowledge to the advanced topic, they are able to comprehend the significance of the advanced topic, thus learning occurs (Smith, 2011). Which implies that the different processes concerning learning can be explained by analysing the mental process first. With the effective cognitive process, learning can be easier and new information can be stored in the memory for a long time. On the other hand, ineffective cognitive processes result to learning difficulties that can be seen anytime during the lifetime of an individual.

According to Duke, Harper, & Johnston (2013), the cognitive learning theory has relooked at the meaning of learning, by highlighting that the conditions of cognitive learning should include; the gaining of attention, informing learners to the objective, stimulating recall of prior learning, presenting the content, providing learning guidance, eliciting performance, assessing performance and enhancing retention and transferee. This suggests that the cognitive learning theory can be seen and identified as an instructional design and approach to teaching and learning.

A theory that looks at learning as a mean to improve cognition is the cognitivism theory of learning. Since it influences psychology on the development of child-centred teaching, where learners are exposed to challenging experiences (Pollard, 2002). Piaget (1932) supports the development of the child's moral judgments as having to go through some important stages, where the learner will be required to resolve a problem by constructing their own position.

In the 1900 Piaget argued that knowledge should not be a copy of one's reality and looking at objects does not conclude that one knows (Lights & Butterworth, 2016). There has been a constant shift with the cognitive development of a child, there was a shift from the intellectual process from Piaget, which Vygotsky reassured all with the aim to examine the cognitive learning and growth of a child (Lights & Butterworth, 2016). The cognitive learning theory suggests, to understand cognitive development we need to act on the understanding of its modifications, which is being able to transform the object, and to understand the process of this transformation, and as a consequence to understand the construction of the problem or object (Piaget, 1932). Which suggests that the development of cognitive learning is concerned with the total structure of knowledge acquisition and conceptual growth.

There are key role players in the development of the cognitive learning theory, the first Vygotsky a Russian psychologist who aimed to explain the process of knowledge acquisition, according to cognition by looking at three domains for development from the mind of a child: which are the roles of social context, language, and mediation (Vygotsky 1978). This suggest that the ideas of Vygotsky focused more on how cognitive learning and development takes place from 'outside in'. He also argued for the social cultural theory of human learning as a social process and the origin of human intelligence in society or culture. The implementation of mediation can take place through social interaction between learners, where learners take charge with the help of cognitive tools to help construct possible knowledge and imagination.

Another aspect of Vygotsky's theory is the ideas for potential cognitive development called the 'Zone of proximal development' (ZPD) (Karpov, 2017). The mediation through the ZPD and potential mediators is one of Vygotsky's biggest perceptions. Where he argued that teachers, parents or care-givers are to mediate the learners though the ZPD to develop their knowledge. The important part is how does it take place and what it takes does for the learner to internally grasp concepts (Vygotsky, 1978). According to Taber (2015), there is an argument that by implementing the ZPD, it is an indication on how learners learn and respond to new ideas, which reflects their ability of logical strength and their cognitive development.

Further, cognitivism focuses on what takes place in the mind of the learner as they think and solve problems (Piaget, 1980). For an example in a Chemistry class, when the teacher is performing different types of experiments, in the minds of the learners there are a number of explanations. Some are thinking what is going to happen next, others might be thinking why is that happening and others might be thinking I want to try this for my mom. Regardless of the event is their minds some form of knowledge is being constructed. According to the cognitivism theory, new knowledge is constructed upon prior knowledge and learners require effective participation in order to learn and improve their performance (Pollard, 2002).

In addition, learner behaviour is observed in the cognitivism theory but only as an indication of what is taking place in the learner's mind (Piaget, 1980). Cognitivism uses the comparison of the mind to a computer, where information is processed in, information is processed out and therefore learning takes place (Piaget, 2001). When learners gain knowledge about something, their behaviours will change in such a way as to accommodate what they have learnt. If a learner falls down the stairs, they will be very careful the next time they walk up and down the stairs, their behaviour will be cautious, since they have learnt the effects of not being careful.

However, the cognitive theory does not agree with the behaviourism theory of learning for learner knowledge acquisition. The behaviourism theory is interested in the stimulus and response of the learner rather than the mental process that takes place in between the stages for their knowledge gain (Piaget, 1932). Further, the cognitive theory argues that learning takes place through learner mental ability and information processing and not through repetitive behavioural procedures supported by the behavioural theory (Pollard, 2002).

2.3.1 Main characteristics of the cognitivism learning theory

The cognitive learning theory is a broad theory used to explain the mental processes and how it effects both the internal and external factors of an individual. Further, the cognitive learning theory looks at how various learning approaches takes place in the human body and aims to answer the basic questions of learning (Illeris, 2018). Whereas, Kalyuga & Singh (2016) associate the ideas of cognitive learning as a framework which can enhance the acquisition of knowledge, by giving explicit instructions to reduce cognitive load.

The theory of cognitive learning is credited by the ideas of the Educational psychologist Jan Piaget, who believed and perceived knowledge as actively constructed by learners based on existing cognitive structures. Piaget disagreed with the behaviourist learning theory, since the behaviourism learning theory's main focus was on observable behaviour. Hence, Piaget was concerned with what went inside the learner's head, instead of how they reacted since it is the discipline of learning psychology (Illeris, 2018)

Whereas, the behaviourist seeks exterior methods to accepting the mind, they believed behaviour can be measured. This theory associates the stimulus with an individual's response to the stimulus. Since the behaviourists argues that measuring internal behaviour is not practical, which suggest that we cannot see the thought inside a person's mind, thus it cannot be measured (McLeod, 2015). Unlike the behaviourist learning theory, the cognitive approach believed that individual mental abilities can be scientifically studied. Which focuses on the thought process behind the behaviour.

Cognitive psychologists claim to understand behaviour, to gain an understanding of what goes inside the brain which is the result of individuals behaviour. Therefore, the ideas of the cognitive learning theory concentrates more on what goes inside the mind, which focuses on the processing aspect of what goes in, rather than just observing the behaviour (McLeod, 2015). These ideas suggest that the changes in behaviour are observed, but should be seen as indicators to what goes inside the individuals brain.

In addition, the concepts associated with the cognitive learning are used as schemes to apprehend cognitive learning, both quantitative and qualitatively (Tennyson, & Volk, 2015). By implementing principles of cognitive learning, we can focus on ones respond to stimuli. This is because ones thought processes has the ability to connect their thoughts to memories, rather than just responding to how they feel (Illeris, 2018).

The theory of cognitive learning can be understood through three main types of learning: classical conditioning, operant conditioning and observational learning. The classical and the operant conditioning are forms of associative learning, in which associations are made between events that occur together. The ideas of classical conditioning can be viewed as a procedure by which we learn to relate events or stimuli, which at most occur simultaneously and as a result we learn to foresee events. One example, is when Ivan Pavlov a Russian physiologist trained dogs by associating them with the sound of a bell and the presence of meat. With this experiment, it was gathered that when the bell was rung the dogs salivated with the anticipation for meat (McLeod, 2015).
Whereas, the operant conditioning is the learning process where an individuals' behavior can be reinforced or punished, which can either be positive or negative. Edward Thondike invented the term 'law of effect' (Thorndike, 1905) which suggests, that behaviors followed by

consequences that are satisfying are to be repeated and unpleasant behaviors are less likely to be repeated (McLeod, 2015).

Further, from the mentioned discourse was the ideas from B.F Skinner, he continued to research conditioning by showing an experiment using rats which he called ‘Skinner box’. Skinner's theory of operant conditioning was based on the work of Thondike (1905). Edward Thorndike studied learning in animals using a puzzle box to propose the theory known as the 'law of effect'. Skinner coined the term operant conditioning; it means roughly changing behavior by the use of reinforcement which is given after the desired response. Skinner identified three types of responses or operands that can follow behavior (McLeod, 2015). In Skinners experiment, the rats learnt that when they wanted to eat, stepping on the lever caused the release of food, which demonstrates that behavior can be influenced by rewards or punishment (McLeod, 2007).

Whereas, observational learning occurs when individuals observe the behaviors of others and imitate those behaviors even with no reinforcement at the end. Albert Bandura noticed that children often learn by imitating adults. In a study, he conducted by using Bob-dolls, in the experiment, Bandura learnt that when the Bob-doll were hit by parents, the children did the same thing (McLeod, 2007). This process of cognitive learning is an indication that knowledge can be constructed and learning can occur.

The ideas of the cognitive learning theory perceive learning as a reorganization of experiences, by either attaining new insights or changing the old. Which suggests that learning can be seen as a change in knowledge which is stored in memory and not just the change in behavior. Further, the cognitive learning theory applies the following examples and applications; classifying information, linking concepts (associating the old with the one), providing structure, using real world examples, discussions, solving problem, using analogies, the use and implementation of pictures and mnemonics (McLeod, 2007).

2.3.2 Related teaching strategies of the cognitivism learning theory

The main aim of teaching at any level in education is to bring a fundamental change to the learner (Tebabal & Kahssay, 2011). The cognitive theories views are focused on the internal mental process which includes an individuals' insight, the processing of information, memory and perception.

Teachers play a number of roles in the classroom, teacher are also responsible for the quality of teaching in their classrooms. Teachers are required to construct warm environments, mediate and care for their students, teachers are role models but the ultimate role is to teach knowledge to learners and assist them improve academically. According to the cognitive learning theory, teachers are seen as being the key source on building intelligence and cognitive development (Smith, 2011).

Further, the cognitive learning theory's approach to teaching uses teaching methods and techniques which allow the teachers to control what goes inside the learner's head and focuses on mental processes rather than observing behaviour only (Salkind, 2004). Teaching strategies and teaching techniques aim to improve the way in which learners acquire, recall and interpret information. Teaching strategies are methods that adjudicate to structure, learning systems, methods, techniques, procedures and processes used by the teacher when teaching. According to McDaniel (2014), these strategies are employed by the teacher to assist learners to reached academic excellence.

The science of learning can be enhanced by considering the knowledge of cognitive psychology behind effective teaching strategies (McDaniel, 2014). There exists a vast number of cognitive teaching strategies that and according to Roediger & Pyc (2012) can be organised into three general practices or principles. The first is the distribution practice, which looks at how information is distributed and presented to learners when teaching. This involves the ideas of repetition and interleaved practices, which is considered a mean to improve cognitive memory for learners. When using repetition for recalling key components, it assists learners with their long-term memory. Whereas, when old and new concepts are mixed, it supports robust learning and the benefits to recalling information (Roediger & Pyc, 2012). When problems are mixed, instead of the old fashion teaching, is can maintain authentic learning (Rohrer, Dedrick & Stershic, 2015; Sana, Kim, & Yan, 2017). For example, in the Chemistry classroom, when learners are able to answers mixed problems it indicates their understanding of the concepts previously learnt.

The second practice or principal is the retrieval practice, which inspires persistent and graceful learning to encourage learning. Since some teaching practices use the principles of recalling and the repetition of information, the retrieval practice encourages the recalling of information through a spaced period of time (Roediger & Pyc, 2012). According to McDaniel (2014), examples of such teaching strategies, include the implementation of mini quizzes throughout the school semester. When learners write constant quizzes in a subject it keeps them sharp of their cognitive growth and knowledge acquisition. Where they quickly learn to answer what is relevant and recall information in a short period of time. This teaching strategy can also assist the teacher to take note of those who are still struggling academically and the topics or concepts they find difficult. In addition to the retrieval practice, is the implementation of flash cards. The teacher can teach learners to use flash cards for further knowledge acquisition (McDaniel, 2014).

Further, the next practice or principle is the explanatory questioning teaching strategy. In this practice, there are two techniques to achieve explanatory questioning. The first is elaborative interrogation opportunities, where learners are given the platform to discover why information is true. According to McDaniel (2014), when learners get to ask 'why' they focus on using their existing information and knowledge to understand new topics and concepts, which build their cognitive understanding and improves academic success.

Elaborative interrogation, takes to mind that learners should be able to question what is the same and what is different between given information. The other practice is similar and self-exploratory, which allows learners to interrogate new information with existing knowledge. While self-exploration summons metacognition questioning, which aim to assist learners make personal connections when learning (Dunlosky, Rawon, Marsh, Nathan &Willingham, 2013). According to McDaniel (2014), an example of self-interrogation is to incorporate teaching strategies such as 'one minute paper exercise' at the end of a lesson, where learners are asked 'why's' as it can be imperative.

In addition, Piaget (2001) argues that important teaching methods used by the theory of cognitivism for the improvement of learner academic development, includes the classifying method and the teaching strategy for the linking of concepts. Whereas Vygotsky argues for mediation through social interaction, when learner takes responsibility for their own knowledge construction with an adult present (Vygotsky, 1978). In the classroom, the teacher stimulates the minds of the learners by showing them something or asking questions, to construct knowledge the teacher will guide the learners using questions, examples or past experiences to help them understand.

2.3.3 Related learning strategies of the cognitive learning theory

In the current education system learners are required to perform academically and reflect self-sufficiency in their learning (Wegner & Minnaert, 2012). It is possible for learners to achieve efficient knowledge inside and outside of school, it is made possible by how learners are able to store their information. For us to master how learners store and recall information, in learning and teaching, we need to understand the techniques called learning strategies.

Cognitive strategies are a manner used by learners to acquire knowledge better. These cognitive learning strategies include the use of repetition, organising, summarising meaning, guessing meaning from context and using imagery for memorisation. Hence, cognitive learning strategies can be seen as the manner in which information is processed by an individual. Cognition assists us to understand the way in which an individual will process information, how they will recall and interpret the information. Uttal (2004), suggest that an individual's mental process can be a measure of their knowledge growth. Thus, cognitive learning styles are vital in understanding the multiple intelligences that exist and using the cognitive learning style to maximise the potential of the individual.

The cognitive learning theory is reflected around a number of learning styles and strategies namely; comprehensive strategy, the problem-solving strategy, the organizing strategy, the writing strategy, the reasoning strategy and the self-regulation strategy (James, 1950). Learning styles are seen as information processors where the learner plays an active role independently seeking strategies to understand and process information to what they already know (Kolb, 1984). These learning styles aim to reorganize experiences, either by attaining new insights or changing old ones. Therefore, learning is a reflection of knowledge stored in memory and not just a change in behavior.

Further, the cognitivism learning theory advocates for experiential learning as a learning style which is seen as an advantage to human development (Kolb & Kolb ,2005). Individually we acquire and mature in distinct ways, which is affected by the way we react to experiences, as experience can cognitively construct ones' knowledge. The way in which we take on experiences is what guides us to knowledge development. There is an old saying that says 'old people are wise with experience', that can be true because once you have experienced something you have confidence to reason on it and how you could improve it, which is learning taking place.

Further, experiential learning can be explained as what it is not, it is not memorising information, facts and figures (Reynolds, 2009). Rather, it consists of a range of unique techniques such as including role-play, the use of simulations, structured activities, outdoors activities and inquiry-based activities (Heron, 1999). When one takes part in learning, all your sensors are working together to help you understand, you are not only focusing on the teacher or the textbook, but meaning making with the situation and environment.

With the misconceptions around Chemistry concepts, experiential learning can be a key component to assist the teacher to reflect scientific concepts in their classrooms, which builds the learning journey of Chemistry for learners and they learn to see Chemistry as relevant. This framework can change how we view Chemistry concepts with the help of teaching tools, since Chemistry occurs at a microscopic level. Research suggest that experiential learning is a powerful aura on the curriculum supported by many educational institutions (Kolb, 1984). With the complexity of Chemistry, it could improve its academic success.

In addition, based on research, another dominating type of experiential learning that is favoured in the science fields is inquiry based learning. A study was conducted in Nepal to understand the difficulties of learning science, accompanied by monotonous teaching and learning activities which leads to cultural silence. According to Williams (2013), he argues that skills such as higher-order learning, asking questions, critical thinking activities and developing metacognitive skills can be achieved by implementing inquiry. The National Curriculum Framework (NCF, 2007) in Nepal, is one of the major goals of their science education, which is to provide learners with the confidence to critically argue, reason and the ability to critique in a scientific language.

Further, ICT (information and communication technology) is a learning style implemented by the cognitive theory as a form of multimedia learning and teaching. ICT opens a new way of teaching where learners and teachers can be creative. ICT plays an important role in planning lessons and managing learner cognitive growth. With Chemistry concepts occurring at a molecular level, multimedia learning such as ICT can assist teachers in making Chemistry more relevant and a reality for learners to understand and performance better. The use of ICT can be understood in two groups, the first as a computer tool for finding information, communication, and multimedia. The second as a scientific tool for virtual laboratories, interactive simulation, computer-assisted laboratory work (Kolb, 1984). In a study conducted in Gauteng, South Africa, there was a reflected an improvement after ICT was implemented in a science lesson (Munyaka, 2008).

In addition, the use of computers in science, particularly Chemistry shows a significate advantage. Cognitive psychologists assume that the understanding of Chemistry includes the ability to think on three levels: the macroscopic level, the symbolic level and the level of particular nature (Johnstone, 1991). The cognitive theory of multimedia learning aims to help learners understand Chemistry on these three levels (Munyaka, 2008). The most complex aspects of Chemistry in understanding the sub microscopic level – which is the level of particles beyond our imagination. In such cases, interactive multimedia can be implemented as an effective tool to make these complex aspects a reality. Experiments that occur at a molecular level require virtual reality, according to Kirscher & Huisman (1998), since virtual reality helps learners analyse, synthesis, and evaluate the abstract concepts. The use of multimedia and virtual laboratories for teaching Chemistry improves teaching and learning, it allows the understanding of Chemistry through visualization and simulation of processes.

In a study conducted by Kolitsky (2014), on the use of technology for multimedia learning. Chemistry and biology learners used physical models from a 3D printer for the understanding of geometric shapes. The results showed learner improvement when 3D objects were used, the learners improved their content knowledge and their ability to connect Chemistry concepts. The idea of images such as 3D printing being a better tool to be used for learners to understand better, it is a reflection of the works of Piaget who believed that learners learn though senses. This process of generating various avenues of critical thinking of the abstract world gives learners the ability to think like a scientist (Greca and Moreira, 2000).

When learners have the chance to touch and feel what they are learning, it improves their knowledge as suggested by the experiential learning theory and the ideas of inquiry based learning. By using 2D and 3D images as tools, it makes information explicit and assist the learner in meaning making of the concepts (Liu, 2006). A study showed that the human brain contains neurons in the upper stages for faces and objects and the neurons enable the human brain to build understanding once an image has been identified (Zahavy & Mannor, 2016). The human's brain has the ability to interpret images to support knowledge acquisition by making a connection to the real world (Plass & Jones, 2005)

Moreover, the theory of cognitivism supports virtual tools as high-performance tools that are used to change the nature of Chemistry and the teaching process in the classroom (Kolitsky, 2014). Among these tools are Phet simulations, which reflects multimedia such as videos, images, diagrams or any form of technology that could be used to interpret images from the textbook and make it a reality (Plass & Jones, 2005). By using simulations, you give learners a clearer picture with the benefits of manipulating the simulations for different scenarios, this gives a broader platform to learn. This suggest that the use of molecular representations and visualizations within the teaching process in Chemistry, enhances learning, through the learners' engagement of virtual molecular structures, dynamics and the role of molecular modelling (Plass & Jones, 2005).

Meyer (2003), explains that learning from external representations, including virtual representations is a cognitive process that enhances knowledge development involving a number of processes that are mental, as explained in the cognitive theory of multimedia learning. Mnguni (2014), explains that the learning process is of external information entering the cognitive system and learners constructing mental images of the content delivered to build understanding. This cognitive process of information involves selecting information, organizing the integration of images which is referred to as visual-spatial thinking (Mayer, 2003).

Virtual representations improve learner performance in Chemistry since it has the ability to assist learners in thinking on three levels, the macroscopic (observations, like the burning of a candle), microscopic (arrangement and motion of molecules and atoms) and the symbolic level (the formulation of numbers, formulas and structures) (Plass & Jones, 2005). The symbolic level in Chemistry is one of the most complexe for learners, as these representations are invisible and abstract, therefore learner thinking relies heavily on sensory information and their imagination (Keig & Rubba, 1993). The symbolic form of Chemistry is what learners in grade 11 commonly fail which includes the atom, molecules, structures, orientations and their electrons, learners find these topics difficult to visualize let alone imagine. Thus, according to

Plass & Jones (2005), some Chemistry phenomena are not obvious without the use of appropriate visualization.

Lastly, educational computer games can be used for multimedia learning for an effective way of learning and teaching (Cogility, 2007). Since science is very abstract, using educational games or what we can call virtual reality, would allow the learners to generate or explore a reality they would have read about in their textbooks. The approach to game-based learning would allow the learner to live through their Chemistry textbook, making it possible for them to manipulate features.

With that said, game-based teaching within the science classroom can help learners be the driving force for their own knowledge development. For an example, when learners are playing FIFA on PlayStation, they are responsible for each player on their team and they control them with the joy-stick, they learn to know the strengths and weaknesses of each player and team. If the Chemistry classroom used gaming (virtual representations) to teach Chemistry, the learners would control the content by maximizing learning time. According to the cognitivism theory, this approach improves learner performance by allowing learners to make connections between verbal and pictorial cognitive channels.

2.3.4 The cognitive learning theory applied in Chemistry

For a learner to be able to fully participate in a society, they must play their role in academic achievement. The cognitive learning theory analyses learners as individuals based on their mental abilities and their cognitive skills.

Since the Chemistry classrooms require various teaching tools to cater to various learners and to assist with the challenges faced in the science department. Coffield *et al.,* (2004) argues that teaching tools and educational tools are instruments that can be valid and reliable, which impacts on pedagogy and methodology. Which suggests that if the correct teaching tools and teaching approaches are used, then learner development and learner performance can be improved.

In a study conducted in the USA different teaching tools and learning styles were used with the same group to teach Chemistry. When learners were asked to investigate concepts and use images to explain their finding, this teaching approaches improved their performance based on the tools implemented (Ballone & Czernaik, 2001). There is a need to examine the influence of teaching tools and teaching approaches in the classroom, with the intent to implement strategies to meet the needs of the different learning styles in the Chemistry classroom.

Moreover, Allen and Tanner (2003), support this argument by reflecting on common teaching tools that improve learner performance and Lederman (1992) explains, that when science tenets are supported by teaching tools, learners perform better academically. Further, Lederman (1992), argues that there is no 'one' scientific method that exists, but many methods to be implemented in a science classroom. A Chemistry classroom needs teaching tools to improve learner performance, there is no excuse for poor performance only lazy educators. Chemistry classrooms cannot be conducted or treated like traditional classrooms, Chemistry is a subject that requires more than one form of teaching method, its abstract and microscopic not difficult. Thus, to improve learner performance in Chemistry the necessary steps need to be taken, which start with Chemistry not being taught as the ordinary subject.

2.4 Constructivism learning theory

The mind is a powerful tool that the human body possesses, it has the ability to combine ideas or turn them into complex ones (Lock, 1947). The constructivism learning theory is seen as a methodology to achieve authentic teaching and learning structures on the ideas of cognition (learning) and mental construction. This suggests that learners acquire new information by suiting it together with what they already know (Bada & Olusegun, 2015).

Further, the study of psychology aims to understand the 'why' in the way people behave, the manner they do things, and what impacts their performances and their mental abilities. According to Gergen (1994), the constructivism theory is a hypothetical perception, which is seen as one of the most important fields of psychology and the role it participates in within the avenues of educational psychology. Thus, the vital limitation in education is that teachers are not able to transmit knowledge and information to learners, learners need to enthusiastically construct knowledge in their own minds (Bada & Olusegun, 2015).

Some of the biggest dominators in the fields of psychology are Bronfenbrenner, Piaget, Vygotsky and Erikson which are among those who are seen as constructivist thinkers in one way or another. They have shaped the way we see things and the way we analyse concepts based on the understanding of the human mind. We have looked at the works of some of them in this chapter.

Constructivism from an epistemological view demonstrates how knowledge is acquired, with emphasizes on knowledge construction rather than knowledge transmission and the recording of information carried by others (Suchting, 1998). Constructivism has the idea that a learner's knowledge is derived from a meaning-making search, where learner's take part in the construction of individual interpretation of experiences. This suggest that's learners are able to construct knowledge based on what they see and experience on a daily basis, which allows them to make connections and improve cognition. Driscoll (2000) argues that according to the constructivist learning theory, knowledge can only exist within the human mind, however does not have to relate to the real world.

Moreover, constructivism reflects origins in the philosophy of education, psychology, sociology, and education. It is therefore vital for educators to appreciate constructivism as it is equally vital to appreciate the repercussions for this approach that learning has for teaching and the teacher development (Tam, 2000). Constructivism is not the philosophy on teaching, it is a philosophy on knowledge and learning. Where knowledge is defined as temporary, developmental, socially and culturally mediated and thus non-objective (Brooks & Brooks, 1993). According to von Glasersfeld (1995), he views knowledge as what is in the head of a person, their thinking towards a subject, using their thinking in relation to what they know from the outside world. Constructivists pry on the ability of the human mind, to constitute or construct theory or experience into what we already know (Nola, 1998). According to Driscoll (2000), constructivism learning theory is a philosophy which enhances students' logical and conceptual growth

Prawat (1992) shares his views on the constructivism theory and argues there are several interpretations of what the constructivist theory means, which he perceives as a mean to alter teaching to a method that allows the learner to use their own efforts to understand the manner in which they construct knowledge and improve their performance. Even though there are differences between the theories of constructivism, there are congruencies between constructivists with the four central characteristics: 1) learners constructing their own learning; 2) learning being dependant on learners' existing understanding; 3) the critical role of social interaction and; 4) the necessity of authentic learning tasks for meaningful learning (Bruning, Royce, & Dennison, 1995; Pressley, Harris, & Marks, 1992).

However, to better understand the constructivism theory we can reflect it to the ides of Piaget, through cognitive development. Piaget believed ones' cognitive development is a product of maturation through the encouragement of objects/cognitive tools since learner's progress psychologically by adapting to their surrounding environment and assimilating what they already know to something new, to accommodate what does not fit. This suggests that the mental accommodation and psychological adaptation that the learner will do is a way of constructing knowledge according to the constructivist theory of learning.

Further, Piaget (1978) explains that stimulus-response towards learning, focuses on the mental progression of a child, for a learner to acquire the knowledge they need to comprehend was is going on and what is being taught, which in turn assist in constructing knowledge. Mvududu and Thiel-Burgess (2012) support the ideas of Piaget, that constructivism is methodology that aims to improve the level of understanding in children and to indicate their understanding and how to improve their levels of thinking.

The theory of constructivism is based on the idea that people are responsible for creating their own understanding of the world. How individuals are able to use what they know and what they have learnt and apply the knowledge gained to construct solutions for other problems. This is when learners use what they are familiar with and link their experiences to new information (Vygotsky, 1978). Learners use these experiences along with new information to construct their own meaning, by replacing new information with the old or improving what they know and it becomes constant knowledge construction. Amineh and Asl (2015), support the ideas of Vygotsky, by indicating that when learners replace old material with new material it improves their learning and thinking

Where the behaviourist theory is focused and concerned with the understanding of the learner influences what learners do, how their understanding changes their behaviour or how behaviour changes understanding. The behaviourist theory understands that when learning had taken place and knowledge was constructed, it would be reflected in the individual's behaviour. However, the constructivist theory is interest on what learners think, and how to improve learner development and performance (Fosnot, 2005). The constructivism theory looks at the construction of knowledge and learning being achieved when the learners are able to construct their own knowledge using what they have learnt prior.

Vygotsky's theory of cognitivism is the foundation of constructivism and Vygotsky is one of the key role players in the constructivism learning theory. He has played major roles to get people thinking about how children construct their knowledge and Vygotsky's theory can be understood from three important themes. However, Kanselaar (2002) argues that the ideas of Vygotsky can also be understood under two major strands, the constructivist perspective and the social-cultural perspective. Whereas, Amineh & Asl (2015) echoed the ideas of Vygotsky by reflecting his views through language, thought and mediation through society.

The three highlights themes that created the ideas of constructivism according to Vygotsky, the first is social interaction, seen as a fundamental role in the process of cognitive development. He explains this as a cultural interaction where experiences influence the way we build knowledge understanding and how we improve learner development (Vygotsky, 1978). The second theme is MKO (The More Knowledgeable Other) which reflects an individual who has a better understanding of concepts or is at a high ability (Fosnot, 2005). The MKO is mostly the teacher, the teacher will be the mediator for content development and for the improvement of learner development. The final theme is the Zone of Proximal Development (ZPD), explained by Vygotsky as the space between a learner's ability to perform a task under teacher guidance and their ability to solve the problem independently (Fosnot, 2005).

Within the philosophy of constructivism different notions of the nature of knowledge and the knowledge construction process exists. According to Moshman (1982), three types of constructivism have been reflected: exogenous constructivism, endogenous constructivism, and dialectical constructivism. Exogenous constructivism, along with the philosophy of realism, is where there is an external reality that exists, where reconstructed knowledge is formed, where one's mental structure shadows and reflects the ideas of the world. The manner in which information is processed through cognitive psychology and intellect accentuates the manner in which constructivism constructs and elaborates schemata and networks of data on the external realities of the world we experience (Moshman, 1982).

The endogenous constructivism better known as cognitive constructivism looks inside the learner's constant pattern of knowledge construction and development (Cobb, 1994; Moshman, 1982). This view evolved from the theory of Piaget (Piaget 1977, 1970), which focused on a learner's knowledge being stimulated by their inner cognitive knowledge. Learners are forever experiencing a disequilibrium where they try to understand new information with the constant attempt to negotiate their understanding (Cobb, 1994).

The dialectical constructivism or social constructivism supports knowledge construction through the social intersection with teachers and learners debating what is fiction and what is true (Rogoff, 1990). With the interactive process, the learner is able to shape their own meanings and help others find meaning in their own thoughts. Vygotsky (1978) explains this as the sociocultural theory of learning which improves learner performance. There are fundamental natures of social constructivism for social interaction in contrast to an individual investigation of cognitive constructivism. Social constructivism holds a perspective on constructivism which highlights the importance of social exchanges for learner cognitive growth and the impact on cultural growth along with historical context on learning (Brown, Collins & Duguid, 1989; Rogoff, 1990). This appreciation for the constructivist theory aims to assists learners in knowledge construct and avoiding misconceptions.

Further, learners will construct knowledge in various ways and this can be understood through the ideas of Gardner and the existence of multiple intelligences and the learning tool kit each learner will posse. The importance of what and how they think can be examined through psychological constructivism and social constructivism (or sometimes sociocultural theory) (Piaget, 1980). For psychological constructivism, the learner intellectually organizes and reorganizing new information or experiences with new concepts (Piaget, 1980). The learners organize this information by relating new experiences to prior knowledge that is already meaningful and well understood (Dewey, 1938–1998).

However, contrasting Piaget's orientation to individuals' thinking in his views of constructivism, some psychologists and educators have explicitly focused on relationships and interactions between a learner and other learners (Bruner,1960). This framework is often referred to as social constructivism or sociocultural theory (Bruner,1960). American psychologist Jerome Bruner believed learner performance could be improved if learners were guided accordingly through what was expected of them. Bruner (1960), referred to this approach as instructional scaffolding, he considered adequate learner guidance through scaffolding to provide learners with an "intellect" to perform better.

Parallel to the ideas of Russian psychologist Lev Vygotsky (1978), whose main focus was on how a learner is a novice's thinker. Where they are able to manipulate relationships with others who are more capable and he called this stage the zone of proximal development (or ZPD) (Tharp *et al.,* 1991). In contrast to behaviourism, constructivists believe "knowledge is not passively received but built up by the cognizing subject", thus constructivists shifting the focus from knowledge as a product to knowing as a process (von Glasersfeld, 1995). According to Kay and Kibble (2016), successful learning outcomes are produced when learners understand why things work.

The crucial approach to this philosophy of knowledge is the ability for the learner to makes sense of new situations by using old situations and learning to construct new meaning by connecting new ideas with their current knowledge (Naylor & Keogh, 1999). Further, constructivists believe that the development of understanding for the learner requires active engagement (Suchting, 1998; von Glasersfeld, 1989). Threads of constructivism are the ideas that knowledge growth requires the learner to actively participate in meaning-making (Jenkins, 2000).

Successful learning is a product of authentic mental processing of information that is contained with the use of different learning resources (Thompson, 1995). Psychology views humans as species with the ability to process acquired information, actively receive the information, store and use the information acquired through learning.

2.4.1 Main characteristics of the constructivism learning theory

Learners construct new knowledge through observations and interactions with their environment. Learners attain old knowledge or new experiences in which they use to organize or create new meaningful information or experiences (Kay & Kibble, 2016). This suggest that learning is goal driven, goals can be seen as obstacles required to surviving in a given environment, satisfying curiosity or solving problems. Thus, knowledge and skills are developed when there is frequent interactions and opportunities to experiment different approaches, organize concepts, make personal meaning or integrate/synthesize concepts. (Kay & Kibble, 2016).

The characteristics of the constructivism learning theory can be understood from the ideas of constructivism from the science education perspective (Duit, 2016). Further, Duit (2016) explains the characteristics of the constructivist theory can be understood from four main aspects. The first is the active construction which is the understanding on pre-existing knowledge and concepts (Duit, 2016), where students are required to advance their new knowledge freely using knowledge they already had. Which suggest that in the world of learning there is no learning from scratch and there is no simple transfer of knowledge from a certain information source to the learner.

The next is tentative construction, which looks at knowledge and the ideas that construct an individual's quality ideas of the outside world and on the ideas others have is tentative in nature (Duit, 2016). Further the viability knowledge are ideas that have been created based on the need to be viable which are useful for the individual (Duit, 2016). For a learner to construct what they like and what they are interested in, runs the risk of not being understood by others. Lastly is the social construction, according to Duit (2016) although every individual has to construct knowledge by themselves the process of construction will always has a social component. Knowledge is always constructed within a certain social setting (Duit, 2016). Thus, it is very important that children learn communication skills so they are able to construct knowledge in their societies.

Further, the understating of the characteristics from the constructivist learning theory is the aim to recognizes the manner in which the constructivism articulated literature. Situated cognition, anchored instruction, apprenticeship learning, problem-based learning, generative learning, constructionism, exploratory learning: these approaches to learning are grounded in and derived from constructivist epistemology (Jonassen, 1991).

According to Jonassen (1991), characterises that shape constructivist cognitive psychologists include, the ability to create real-world spaces for authentic learning; being focused on lifelike methods to solving problems. The teacher being analysing of the strategies used to solve these problems; being able to providing various representations or perspectives on the content; instructions and objectives should be discussed and not imposed. Further, where evaluation serves as a self-analysis tool; to provide tools and environments which assist learners interpret the multiple perspectives of the world and learning should be internally controlled and mediated by the learner.

Further Jonassen (1994) provides a summary which illustrates the characteristics of the knowledge construction according to the constructivist learning theory and how it can be facilitated. First, is to provide learners with multiple representations of reality; to show the difficulty of the real world; to focus on the knowledge construction of knowledge and not reproduction. Further, to present authentic tasks; provide real-world, case-based learning environments, rather than pre-determined instructional sequences; to foster a reflective practice. Moreover, to enable learners with context and content dependent knowledge construction and to support the collaboration of constructing knowledge through social negotiation.

2.4.2 Related teaching methods of the constructivism teaching

One of the major goals of incorporating constructivism teaching methods is because it allows learners to learn by relying on their own learning experiences. Teaching methods implemented according to the constructivism learning theory include, learners being actively involved, the environment being democratic, activities being interactive and student centered and teachers teach learners to being more responsible and autonomous (Wilson & Cole, 1991).

Wilson and Cole (1991) provide an explanation of cognitive teaching models and methods which exemplify constructivist concepts. These methods include the embedment of learning in an authentic environment to solve problems; to provide for authentic learning; provide for learner control and the use of errors as a mean to give feedback on their academic performance.

The constructivism theory believes learning is an active part of teaching through a contextualized process of constructing knowledge rather than acquiring it (Vygotsky, 1978). Where teachers are to use teaching methods that allow the learners to share ideas and their experiences while constructing knowledge. In so doing learners get the opportunity to construct their own meaning while constructing knowledge, thus improving their understanding.

The learning theory of constructivism highlights the theory of humanism as a teaching method which focuses on role play (Rockmore, 2005). Where the learner is the subject and learning is the process that assists the learner to reach self-actualization for their own improvement (Rockmore, 2005). For an example, in the Chemistry classroom if learners were required to play the role of either an atom, molecule or element in a reaction. By allowing the learners to be the subject it allows them to know the properties of each and how they act during a particular reaction. The learner will have to learn and read the properties of the assigned element and thus learning in the act. This method allows learners to take full participation in the classroom activity, while engaging in their own knowledge construction.

Further, for every learning style exists a teaching methods. There are a number of teaching methods that exist within the constructivist learning theory; expert, formal, authority, personal model, facilitator and delegator (Grasha, 1996). The expert teaching methods allows the teacher to express knowledge and challenges to the learners, as the teachers aims to maintain status as an expert. The formal authority teaching style, is when the teacher provides positive and negative feedback to their students to create positive learning goals.

Further, the personal model teaching method, is an approach that reflects the teacher's particular personal learning experience, these teachers displays to their learners how to behave and do things by following the instructor. The facilitator teaching style, is an approach concerned with teacher- learner collaboration, by guiding learners through questions, exploring content, making suggestions and promoting learners to take responsibility for their learning. The delegated teaching style reflects teachers who believe that for learners to develop positively they need to work independently and the teacher is to be a resource to learners, this style aims to produce learners who are self-directed and self-initiating learners (Grill, 2013).

The hands-on experiential activities with inquiry-based learning. In the South African curriculum, there has been a great shift towards inquiry based teaching (Department of Basic Education, 2011). When looking at what inquire means within science, it is reflected in three concrete ideas which are: learning to do inquiry, learning about inquiry, learning through inquiry (Bybee, 2000). According to Ramnarain and Kibirige (2010) the South African curriculum has emphasised on the manner in which science knowledge is transferred. Which aims to minimize teacher centred learning environments since it is seen as limiting the learners learning opportunities.

Further, there are four important aspect of inquiry based learning, within science education; confirmation inquiry, structured inquiry, guided inquiry and open inquiry (Bell, 2008). These forms of inquiry aim to develop the learner's hands-on abilities, knowledge and skills through a constructivist's way. Allowing learners to physically, construct and manipulate objects they have been taught on, for an example in the science class, manipulating shapes to explain the orientations of molecules and atoms. Gardner (2004) supports this approach of teaching as he believes in incorporating the five sensors when assisting learner acquire knowledge, where he mentions the sensor of touching as being one of the most powerful sensor to be used to teach learners.

In addition, inquiry based learning can be understood by highlighting the five E's in the classroom, which are to engage, explore, explain, evaluate and elaborate (Shulman, 1992). The following is an example of the use of the five E's in the Chemistry classroom. In the Chemistry class, you can 'engage' and 'explain' in a lesson by allowing learners to watch a video on the topic you plan to teach and let them tell you what they think is going on. The teacher can give the learners any topic and they will have to 'explore' the topic on their own. Lastly, 'evaluate' and 'elaborate' can be used in the Chemistry class for teaching and learning to take place, the teacher can explain the heating curve of water experiment and alcohol (as examples) and allow learners to evaluate the data and draw the graph. The teacher can allow the learners to elaborate using Chemistry content knowledge on why is the boiling points of water and alcohol not the same.

Moreover, Shulman (1992), promotes teaching techniques and theoretical frameworks of constructivism, inquiry-based science learning and inquiry learning in the Chemistry classroom. This advocates that Chemistry learners should not only be taught facts and theories, but taught how to argue and defend Chemistry concepts. The epistemology of inquiry-based science learning is an approach to teaching and science learning as a mean to reflect the understanding on how students acquired science and concepts learned. Freire (1993) enhances the aspect of inquiry based leaning as a belief of learner centred pedagogy being important to ensure so learners truly understand what they have learnt and not simply learn to replicate content and information.

Whereas, experiential learning is a teaching method implemented by the constructivism theory along with the cognitive theory of learning. According to the constructivism theory this approach explains learning as the process where learners are given the platform to experiencing concepts on their own (Kolb, 1984). The first stage is the stage of concrete experience and this is the *doing* stage. The second stage is the stage of observation and requires the learners to step back during the task to review what is learnt and experienced. For this phase, the learners' values and attitude can also influence learner thinking and performance (Vygotsky, 1978). Like the cognitivism theory, this form of teaching assist learners when constructing knowledge as mentioned by the constructivism learning theory. Learners will cognitively grow in knowledge and understanding while constructing and improving old knowledge through experiential learning as teaching approach.

Further, project-based learning (PBL), is another teaching method implemented by the constructivist theory. Which is a teaching framework that is an innovative approach towards teaching and learning, it permits learners to be their own leaders into research with innovative findings while developing their understanding (Bell, 2010). The teacher plays a role of a facilitator, to guarantee a more learner-centred approach to teaching and learning, to produce learners who are technologically orientated, proficient communicators and advanced problem solvers (Bell, 2010). This teaching method of PBL enables Chemistry students to develop questions and to be directed through the information and findings of their research which in turn aims to improve their performance in chemistry.

Therefore, the prescribed outcomes for PBL is a deeper understanding of a topic\subject, greater learning capabilities, higher-level reading with increased motivation to learn (Blumenfeld, Kempler & Krajcik, 2000). At times learners go to school and have no reason why they learn what they learning, they are unable to relate the concepts to the real world. Most of the time learners replicate what is on the board so they don't get detention, but that does not promote critical thinkers. In order to develop critical thinkers, the learners are expected to organize their own inquiry, through the planning of their own learning and organizing their research by incorporating a number of learning strategies (Bell, 2010).

In Chemistry education permitting learners to conduct a project, allows them no restriction on the quantity of information they are to have (Bell, 2010). For example, if the teacher is to give learners a project about geometric structure, the learners are to create their own research question, hypothesis, what they want to investigate within the geometric structure. This form of inquiry does not limit the amount of knowledge the learners acquire which improve their performance.

2.4.3 Related learning styles of the constructivism

Dewey (185-1952) emphasizes that *learning is life* and learning *prepares us for life, thus the construction of knowledge*. According to Vygotsky, the only "good learning" is learning that advances development (Kay & Kibble, 2016). When learners learn it is expected that their understanding improves, their reasoning improves and the way they view concepts. The manner in which learners will acquire knowledge and information is influence by different learning styles.

According to Ernest (1995), a number of schools have talked about their thoughts on constructivism. Which resulted to the following implications of constructivism which derives from both radical and social viewpoints when accommodating different earning styles in the classroom. These implicated principles include sensitivity toward and attentiveness to the learner's previous constructions; the use of diagnostic teaching which aims to correct learner errors and misconceptions. Further, to give attention to metacognition and strategic self-regulation by learners; being able to use various representations of mathematical concepts; being aware of the importance of learner goals, and the contrast between learner and teacher goals and being aware of the meaning of social contexts.

In the South Africa science curriculum, there are education reforms taking place. These reforms aim to change the means in which the curriculum is carried over to children. At times the way in which the curriculum is talked about, it seems like simply just as a day to day task learners need to do and not seen as a way to develop their knowledge. By understanding the different learning styles, we can make teaching and learning fun and not a day in day out task.

According to Ramnarain (2010), within the South Africa schooling system the reform of the science curriculum introduces more science investigations for the understanding of practical work. This suggests that in order for learners to build their understanding of science concepts, they are to do it practically than just reading out of the textbook. Further, methodology that supports the investigation method for more practical work, encourages a greater number of learners being more autonomous, a notion that is circulated in the South African curriculum (Department of Education, 2002:1).

Like the cognitivism theory, the constructivist theory reflects and reminds us of the existence of multiple intelligences in a classroom. Laird (1985), suggests learners learn through their senses of sight, hearing, touch, smell, and taste. This methods of teaching and learning are unique if one is teaching a practical lesson such as Chemistry, however the same is not true for a theoretical subject (Laird, 1985). Learner multiple intelligence affects the manner in which a learner will learn and acquire knowledge (Gardener, 2000). According to Gardner (2000), if a learners' domain of intelligence is not catered for, we produce learners who are demotivated. These learners will question their own intelligence or perceive subject changing as the only option because something is 'too hard', which affects their academic performance.

Constructivism theory reflects an improvement in learner performance with the use of different teaching and learning styles. Knowles *et al.,* (2005) explains the benefit of using the informal approach to teaching and learning as an art of science for learner development. Informal learning reflects the importance of what the learner is doing. This is an important aspect, since Chemistry is imaginary the teacher needs to see how the learner interprets Chemistry concepts to avoid misconceptions.

There are numerous learning styles that can be used in a classroom, the constructivism theory believes in the use of a few for learner improvement. Examples of learning styles used by the constructivist theory are, cases studies, research projects, problem based learning, brainstorming, collaborative learning, discovery learning and the use of simulations. Knowles *et al.,* (2005) suggest peer groups work as a learning style, which using experiences for content understanding by making connection, since the constructivist theory advocates for knowledge construction. Whereas Dewey (1859-1952) emphasized on incorporating various activities in the class to improve learner performance while constructing knowledge.

Further Gardner (2000) explains that all learners can use all their sensory modes in learning, one mode is often more dominant and preferred to be used by the individuals than the other sensory modes. As an example, visual learners learn through seeing and therefore prefer to learn through pictures, videos, 2D/3D graphics, assimilations, etc., and other image-rich teaching tools. Whereas auditory learners', learn better through hearing and are proficient at listening and exploring through discussions.

Learners experience different learning approaches and different classroom encounters independently, which means all learners in the same classroom will acquire and interpret, knowledge differently. The way in which the learner will transfer and interprets gained knowledge is dependent on the learners' exclusive independent style of learning, teaching and knowledge acquisition (Gardner ,2000). The various learning styles can be a sign of a defined manner in which students of all ages experience various factors, within themselves and their surroundings. These factors can include sociological needs, immediate environment and physical characteristics along with physiological and emotional inclinations.

One approach that allows learner to talk science is through the implementation of IBSE (inquiry-based education). Research has indicated the importance of teaching and learning in the classroom using IBSE for knowledge construction, it has increased student's scientific interests and concurrently simulated teacher motivation in the classroom (Ramnarain, 2010). Due to the fact that IBSE has revealed to be fully effective in the classroom with learner knowledge development, with all types of learners, from those who require more help to those who are brighter (Shulman, 1992).

In addition, inquiry-based education (IBSE) is a method that could be used to urge an interest in Chemistry and technology in education. The imperative laws involved in IBSE allows the developing of critical thinking, scientific theories, and laws, relating information into authentic contexts and stimulating metacognition, by endorsing positive attitudes towards Chemistry education (Trnova, 2014). When learners have the ability to think about their thinking in the Chemistry class they build a sense of understanding in Chemistry which improves their performance when tested. Kyle (1985) supports the use of IBSE in a subject like Chemistry, science and biology education. As a teaching framework, IBSE develops learners critical thinking, metacognition, support a positive attitude towards science and builds their knowledge development. Where Duschl (2007) believes the technique of IBSE upgrades the normal chemistry classroom turning learners into investigators, researcher making learning and teaching more meaningful.

Technological tools within IBSE crafts space for learner development by using extensive software as modelling, visualization as well as searching for information. These tools will support learner performance, enhance the curriculum for the future production of novice learners (Krajcik *et al.,* 2000). A case study, where learners were given the opportunity to make connections between the unseen microscopic world of Chemistry and the observable macroscopic world in which we live. The learners used inquiry-based learning and hands-on activities to make the connections, 90% of the learners improved in their content knowledge in the Chemistry test (Bransford, Brown, , Cocking2000).

Further, the teaching and learning approach of IBSE is explained by Blumenfeld (1994) as a challenge to both teachers and students. Where teachers are to employ an instructional methodology with the teaching style. Inquiry teaching develops new content knowledge, pedagogical techniques, new approaches to assessment and for their classroom management. However, students are challenged towards their knowledge development. This framework aims to stretch teacher and learner intellectual ability and their analysis to gained knowledge understanding, through peer collaboration and relating science content to their everyday world to break its complex nature (Ramnarain, 2010).

Further, the National Research Council (1996) aims to lessen the memorization and the decontextualized of Chemistry facts which creates misconceptions leading to poor performance. Rather have more emphasis on learners researching and investigating their everyday world. Where they can explore complex concepts through inquiry. For example, if a teacher gave leaners the task to investigate the octet rule in Chemistry, learners will learn other aspects in their journey of investigating. This includes electron configuration, types of elements and geometric shapes.

A new approach to teaching and learning Chemistry is the goal for learners to constantly finding solutions to existing problems and to show their imaginations (Krajcik *et al.,* 2000). This can be achieved in the Chemistry classroom by questioning and refining Chemistry questions, conducting and designating Chemistry investigations, gathering and analysing Chemistry data and information (Ramnarain, 2010). Making interpretations, creating explanation and drawing conclusions and to report their findings (Krajcik *et al.,* 2000).

However, Trnova and Trna (2006) stress on the value of hands-on experimental activities in the constructivism theory as being discovered through open learning, which is a learning style and a shadow of IBSE. Dewey is well known for his role in hands-on learning or experiential education, where he later prejudiced his ideas in project-based learning (PBL), where learners are commended and regarded as researchers to explore. This teaching style can be crucial if implemented in the Chemistry classroom since Chemistry attains abstract and microscopic abstracts.

2.4.4 The constructivism learning theory applied in Chemistry

The ability to changing from simple ideas to science complex ideas is not easy, sometimes not even likely. Ausubel's (1968) famous dictum is that he most important single factor influencing learning is what the learner already knows, which reflects the importance of already existing knowledge.

In an America study, bio-chemistry learners were divided into two groups. The one group was asked to write an essay about the kidney where the other group was given a 3D printout and had to describe the different parts. The learners who had the 3D print out understood the concepts better by using their sense of touch and seeing (Tharp & Gallimore, 1991). This suggest that incorporating of various learning and teaching styles in the constructivism theory draws flexibility in the classroom for the teacher and the learner since some topics are complex.

When a topic is complex for learners to understand, the constructivism theory suggests that we outsource method that can be used to simplify the concepts and assist learners in the construction of knowledge. For an example, by allowing learners to build electric circuits or to build molecular structures, it supports learner imagination to what they see in the textbook and therefore constructing knowledge. Schensul (1999) suggests, that it is reasonable to assume that imparting the meaning of scientific content and the essence of developing a scientific concept would be a way to formulate arguments". Comparably, Mayer (2004) argued that for learners to construct knowledge for concepts in science they need to learn how to create arguments, thus giving them the platform to talk science.

Chemistry can be explored in a laboratory with robust laboratory experiences for better understanding (Bybee, 1997). Chemistries abstract nature requires tools to create learner imagination. In the study conducted for learner improvement on molecular manipulation. The learners conducted experiments in a lab for element identification, molecular manipulation to improve their understanding of chemistry. The learners demonstrated a better understanding after the exercise with IBSE as a guide (Bybee, 1997), and expressed the positive results of the study due to a student-centred approach and IBSE that allowed learners to build understanding and evaluate with reasoning through IBL.

In addition, in Chemistry education permitting learners to conduct a project, allows them no restriction on the quantity of information they are to have (Bell, 2010). For example, if the teacher is to give learners a project about geometric structure, the learners are to create their own research question, hypothesis, what they want to investigate within the geometric structure. This form of inquiry does not limit the amount of knowledge the learners acquire which improve their performance.

In countries like Cuban, the education system aims to produce learner who are critical thinkers using IBE (Owen, 2008). The Cuban education system spends most of the countries budget of education. All Cuban schools are equipped with laboratories as thus the good results of learner performance. One strategy is the use of IBE technology in Chemistry and biology to assist the students in understanding the abstract concepts. In addition, a number of medical doctors in South Africa are the product of the Cuba medical education system. According to Mnguni (2014), tools used to view the unseen assists learners with the interpretation of content and in turn builds their imaginations.

Whereas in Kenya, subjects like Chemistry, physics, and biology are compulsory as they separate average learners to the 'cream of the crop' (G.O.K, 2002). The Kenya education system produces good performing Chemistry learners. The theoretical framework used is constructivism in the fields of Chemistry, physics, and biology, is inquiry (Juma, 2018). This is used for learner knowledge development and the construction of knowledge. Juma (2018) further explain that the inquiry-based assessment is accompanied by investigations, research study, and modelling imagination, thus improving learner academic performance.

The Finland education system is one of the most recognized in the world (McIntyre, 2015). In Finland subjects like environmental and natural sciences, physical science, Chemistry, biology, and health sciences are compulsory for all learners up to the age of eighteen. For this domain of studies, a great investment goes into teaching tools for good learner performance (McIntyre, 2015). In relation to Cuba, the implemented theoretical framework is cognitivism and constructivism, where learners construct knowledge with what they know in relation to what is new.

European countries have on-going research on ways of improving learner performance in Chemistry. Chemistries microscopic nature creates misconceptions about the subject and what teachers teach and how learners interpret what they are taught (Shawal, 2016). Germany is one of the countries rooting for various teaching methods such as the constructivism learning theory accompanied by teaching tools such as virtual reality and physical models, for effective learning experiences (Shawal, 2016). The change in German education seems to focus on enhancing the way learners view Chemistry through their imagination and aims to minimize the production of remote learners, to produce confident critical thinkers for the German society. German Chemistry education has influenced areas of Physics and Biology where the same methods are now applied since the year 2004 (Eurydice, 2008). Today Germany is ranked in the world's top 20 best-performing countries in education (Shawal, 2016).

2.5 Social media learning theory

The theory of learning has been critically analysed and viewed in various aspects and has reached a number of assumptions even through social media, bulletin boards, or in traditional face-to-face settings. Learning has been viewed through the ideas of Plato and through Vygotsky which have been highlighted either in their theory or their practice (Garrison, Anderson & Archer*,* 1999). The ideas of Pluto and Vygotsky reflect dialogue and social interchange as central to learning and development. In today's learning age, educational experts and learning theories also emphasis the viewpoints of knowledge construction and they hold the similar viewpoints.

In today's day and age, the term social media is defined and explained in various ways, depending on one's profession or age. According to O'Reilly (2005), the term social media can typically be defined by various characteristics and different technicalities. The term social media was invented in 2005 after the ongoing term of the Web 2.0, which was explained as a group of internet based applications that were used to implement ideological and technological foundations for the Web 2.0 (Kaplan & Haenlein, 2010). However, the term social media is an indication that reflects the existence of social space, thus an indication of individual, professional, entertainment, social networks and digital devices (Rodriguez, 2011). In addition, social media incorporates (a) social net- working sites, such as Facebook, Twitter, and LinkedIn, (b) or media sharing sites, such as YouTube and Flickr, (c) or creation and publishing tools, such as wikis and blogs, (d) aggregation and republishing to name a few.

With the ideologies and interests of social media and its ability to connect people, the world as well as the constant update on information is a powerful source for information transfer. The term used to show collaboration between social media and the internet and how it connects and teaches people, is a term called connectivism and the notion of learning. According to Siemens's (2005), the theory of connectivism and Sharples , Taylour & Vavoula (2010) notion of learning as conversation propose that learning events does not stop, rather that it continues within other networks. Networks such Facebook or Twitter provide organized and structured learning which allows individuals to share and communicate whether for a formal or informal setting.

When individuals are learning through social media, they are able to learn at their own pace and time. Social media also allows individuals to understand various perspectives from different people. For an example, learning through Facebook allows the individual to get different perspectives through the comments of the other Facebook users. Greenhow (2011) suggests that the use of social media as a learning tools encourages a more student-centred learning environment. Social media tools give individuals the ability to interact and collaborate with each other and their instructors while promoting one's personal choice (Hoffman, 2009).

The ideas of social media learning can be tracked back to the theory of social constructivism which was the highlight in the 1960s (Vygotsky, 1978). Social media has played a huge role in connecting the world and people. Through social media we have the ability to see and to learn from other people, cultures and countries at any point in time. The takeoff for social media and the internet has given us the ability to partake in worldly events. One of the advantages of the internet and social media is its ability to go back and forth with information and the ability to transfer the acquired knowledge to the next person.

According to the Horizon Report (2014), a report from the business insider indicated that approximately 2.7 billion people, which is almost 40% of the world's population has access to social media. Reflecting that more and more people rely on media more than just a mean of communicating but also a manner of sharing ideas, news and even knowledge.

Social media has become a global industry in the last couple of years. In the year 2011, statistics reflected Facebook having more than 750 million users, LinkedIn with 100 million users, Twitter having 177 million tweets a day, YouTube hit 3 billion views per day (Mazer, Murphy, & Simonds, 2007; 2009). According to Mazer *et al.,* (2009) social media has a big influence in the educational spaces, since it is not only used by varsity students but also by their instructors for many reasons.

As social media is increasingly becoming pervasive to millennium learners, educators have started to see the positive benefits of using social media tools for academic purposes in the classroom (Hughes, 2009; Nellison, 2007). In the current state, today most teens are always on their cell phones, iPad, tablets or reading something on kindle, and these devices enable them to learn from their devices.

In research study conducted in 2009 and 2010, the data gathered from the EDUCAUSE Centre for Applied Research reflected that 90% of students agreed to using social networking services, such as Facebook, Myspace, Bebo, and LinkedIn. Whereas 30% of the participants reflected only using the social networking services during courses during the quarter or semester of the annual surveys (Smith & Borreson, 2010). Whether we like it or not, social media and social media devices such as Facebook, YouTube, Instagram, Linkert in, Pinterest etc. hold more information that a teacher has. They can assist learners with spelling or show you a video on science experiments. Learning has escalated to greater highs and today's generation needs us to use devices for teaching and learning since we are in a technological era.

The old methods of teaching and learning were much focused on teacher centeredness for knowledge construction. Whereas today learners are able to scaffold their own ideas and information using devices and tools. This new era reflects the gradual concentration and the power of online communication. Just as Facebook has been integrating emails, chat, and other communicative functions to its online environment, Google has been interlinking its email, chat, and productivity tools which is an approach to learning (Kirkpartrick, 2010). This is because when learners are online they are not only looking through pictures and videos, online interactions and learning is another form of knowledge construction. Where learners can join online networks, like Linkert in to communicate with people in their grades on the subject field or to find a private tutor online.

A greater pool of critical research, analysed further agreed that learning is not created around one individual acquisition activity, but requires a social discourse (Hanson & Sinclair, 2008). For an example, teachers can use WhatsApp or Facebook as a tool to send homework and send videos to assist the learners where they do not understand. This form of teaching and learning assists the teacher allowing them the ability to store all the notes and videos they take to share to the next person. The teacher can teach a certain topic and send the homework on WhatsApp, the teacher can be a mediator by seeing how the learners are responding therefor assisting them to construct their knowledge further.

According to Vygotsky (1978), the basic belief is that learners learn most successfully when they engage carefully within collaborative problem-solving activities, under the close supervision of instructors. This form of instructional guidance is called collaborative learning which as an important characteristic for social media learning. When learners are given instructions, they perform based on those instructions, but learners also have the ability to self-select what they need to know and learn to gain a better understanding of the problem. In addition, a number of studies strongly suggest that collaborative learning can be more effective than only implementing individualistic learning, it impacts motivation, raises achievement and with the ability to producing positive social outcomes (Greiffenhagen, 2012).

There are a number of educational theories that we have discussed in this chapter, just as all the other learning theories have expressed the importance of unique learning environment, so does the social media cognitive theory of learning. The learning environment should support the learner and their needs for better knowledge acquisition. The most used form of classroom and educational information transfers include YouTube and Flickr, Myspace and Facebook, as well as blogs and other environments. Through these services, the user is connected to a vast number of teachers, mentors, and other learners (Downes, 2005).

According to philosopher of technology Andrew Feenberg, argues that society is organized around technology, technological power is the principal form of power in the society (Feen berg ,2010). Today schools have websites and well ran Instagram and Facebook pages that show the public what the school can offer. In addition to the power of social media, learners can go through depression if no one likes their photos or the current outbursts of cyber bulling. If social media has so much power on learners why not use if for educational good, like teaching and sharing ideas to construct authentic knowledge and improve academic performance.

2.5.1 Main characteristics of the social media learning theory

Today's generation is permanently on their phones and they know everything about everyone because of their phones and the power of the internet and social media tools. People today run their own blogs where they share their life stories and teach people about travelling, eating healthy, going on good diets, even blogs on how to raise children or get over a relationship. But whether we agree to it or not, social media has become a way of learning and thus constructs one knowledge and abilities about certain aspects that are of interest. As a result, according to the American Society of Training and Documentation (ASTD), (Gonzalez, 2004), the amount of knowledge in the world is doubling every 18 months.

The use of social media as a learning tool cannot be overlooked since the increase of technology in the past decade. With today's social media platforms, it can be an easy and accessible way to shape the minds, behaviours of adolescents and even the world. The social learning theory has been regarded as a very important branch after the work of Albert Bandura's research. According to Bandura (1997) modelling and observational learning is a vital element for the social learning theory. Thus, suggesting that Bandura's social learning theory conveyed the components that were previously not present in the traditional methods of teaching, which suggested the added value of social elements that allow individuals to learn through the observation of others behaviours.

Like the cognitivists, the social media learning theory has been investigated by social constructivists, who perceive learning as a social, conversational and interactive knowledge construction process (Jonassen, Howland, Marra and Crismond, 2008). Further Jonassen *et al.* (2008) proposed the implementation of technology as a social learning tool to enhance learning, suggesting the use of technology for collaboration, discussions, building argument and building consensus among members and supporting communication between knowledge-building communities.

According to Zavatarro (2011), the ideas to understanding the characteristics of social media can be simplified by using the advanced definition, 'Social media technologies that facilitate social interaction, to make possible collaborations, and enable deliberation across stakeholders. These technologies include blogs, wikis, media (audio, photo, video, text) sharing tools, networking platforms (including Facebook) and virtual world. Pearson Education (2009) supports the ideas of the social media learning theory with the set norms, such as learning; explicit definitions of key terms; specific principles derived from assumptions that can be tested; and explanations of the underlying psychological dynamics of events that influence learning.

Thus, supporting the principle ideas from Vygotsky (1978) that learners will learn more effectively when collaborating through problem-solving tasks under the supervision of an instructor. The ideas of Hanson & Sinclair (2008) support Vygotsky by concurring that learning is not an individual gain, rather peer teaching and collaborative group support.

2.5.2 Related teaching strategies of the social media learning theory

In a study conducted by Banks (2007) on formal and informal teaching environments and how social media can bridge the two, the findings reflect that as learner's progress to higher level of education, teaching strategies fade and learners learn collaboratively. Which suggests that learners gain their knowledge when interacting with other partners and this interaction gives learners the platform to interact with peers and with other groups promoting knowledge construction. The ideas by Banks are supported by Chen & Bryer (2012) who argue that social connections and social networks are a way of changing the way in which we think, how we gain knowledge and manifest ideas.

The unfortunate part with the use of social media and social network is the fact that there is minimum to no form of integration in a formal school learning environment (Chen & Bryer, 2012). Teaching strategies such as Blackboard, Sakai and Moodle are a widely used teaching strategy or educational technologies mostly used in higher education (Chen & Bryer, 2012). However, these systems can be seen as more of instructional tools that can be used by the teachers or the instructor as a mean to communicate with the learners, give feedback on their school work and their performance. According to Chen and Bryer (2012), social media and social networks are technologies that can be used as a course management system (CMS), since these tools allow a small space for learners to participate in online learning, online interactions and for discussions and chats. In addition to higher education, such teaching strategies and tools are subjected to only a semester, with restriction that some content cannot be shared with any person outside the schooling environment (Chen & Bryer, 2012).

Moreover, there is limited research around the ideas on how social media teaching strategies influences learners and their learning experience, though teachers see the good of these teaching tools (Hughes, 2009; Nellison, 2007). Available research reflects that learners use social media more for personal vendettas that for education and learning aspects (Hew, 2011; Mix, 2010). The 2009 and 2010 data gathered from the EDUCAUSE Centre for Applied Research (Smith & Borreson, 2010) reflected that 90% of students admitted to using social media for networking purposes. Further in a study conducted in 50 colleges in the USA, 4600 faculty members (lectures, professors or educational instructors) were surveyed by the Faculty Survey of Student Engagement (FSSE, 2010), the data gathered reflected that 80% of the members did not know of or even use social media tools such as blogs, google docs, videos, video conferencing, video gaming and the virtual world. This is as indication that teachers and instructors are not fully clued up about what teaching strategies are available to advance teaching and learning and improve learner performance.

In a research study conducted in Cape Town South Africa, on the use of social media as a teaching tools to improve learner performance reflected that when different teaching strategies were used learners responded positively (Gachago & Ivala, 2012). In the first strategy, the engineering lecture utilized a blog to motivate his students to read, where another lectures used a blog as a course management tools for updating homework, assignments or announcements. In another teaching strategy, the lecture used a blog in their classroom where the learners were allowed to share information, tips, tasks and assist one another which encouraged peer learning (Gachago & Ivala, 2012). The obtained results reflect that technologies such as blogs and Facebook can be used as teaching strategies to improve performance (Gachago & Ivala, 2012) and they can be used to encourage learners to participate in the classroom (Kuh, Kinze, Shuh & Whitt, 2005).

Additionally, the data gathered by Minocha's (2009), argues that tools such as Facebook and blogs can be used for formal learning, especially because students have access to the internet of campus. When learners are given the necessary tools such as internet, tablets, computers, in South African a learner or student can use these tools for assignments or projects. It is up to the teachers and educational instructors to use those tools and to maximise their use in the classroom. We can never truly know how good a system or tool is if we never test it out a hundred percent. The lack of using social media and a teaching tool can also be influenced by the fact that teachers and educational instructors do not know how to use the tools or lack the creativity to implement such in their classrooms.

2.5.3 Related learning strategies of the social media learning theory

According to Chen and Bryer (2012), the use of social media as a learning tool can be a way in which we are able to connect informal teaching with the formal environment, which suggest that this learning strategies can improve learner performance. For an example, social media tools such as WordPress, Wikipedia and LinkedIn can be used to engage with learners who are outside the classroom. Learning strategies have improved so much in the years, where teachers can be in another country yet teach in their own classroom.

Further, learning styles associated with the social media learning theory allow the individual to be in charge of their own learning and knowledge acquisition (Chen and Bryer, 2012). The learner will need to be their own agent of change, they will have to research further using social media technological tools, which is an advantage since they will take responsibility and learn in the manner that suits them best. For an example, some learners enjoy talking in groups, discussing can be done on platforms like Facebook, allowing them to get help for anyone. One of the well know apps is WhatsApp, which allows individuals to share pictures, videos, voice notes and to create groups, this would allow the learners to share their ideas in a common group and having that information stored in the app.

Whereas some learners prefer learning on their own, where they gather information and make it simple for themselves, which means platforms such as Google scholar, Wikipedia, LinkedIn or Khan Academy can be beneficial with their type of learning style. According to Chen and Bryer (2012), when learning strategies connect and assist learners to interact it provides a bigger platform for learning to take place, it provides learner-learner engagement, learner-teacher\instructor engagement and learner-content interaction.

This suggest that social media can be used to create authentic environments and help learners engage with real life situations and problems, it allows helpful learning strategies that a new and meaningful to improve the traditional classroom environments. One of the benefits of learning strategies associated with the social media learning theory, is the fact that you do not have to change your teacher but you can just change the tool used to teach you.

2.5.4 The social media learning style applied in Chemistry

When learners are given the opportunity to play while learning it enables intellectual and social growth over the long term and promotes overlapping goals, continuous problem-solving skills, critical thinking and social interactions. Squire broadcasts that at any time that we turn a learner away from learning rather than developing their intellectual curiosity, we have failed (Squire, 2011).

In South Africa, we have TV channels such as Geleza Nati and Mind-set TV where learners are able to watch others teachers teach on topics they have learnt in their own classrooms. On these TV channels the teachers use different teaching tools and various teaching methods to assist the learners, the learners can further use apps like WhatsApp or Facebook where they have the platform to ask teaches further questions via social media. Educators have supported the use of Facebook, Ning, and other sites into K-12 as a form of commercial media (Davis 2010), which promotes the use of the connectivism learning theory which is a good way to empower learners. Using educational devices or social media enables the learner to have a teacher in the comfort of their own home and not having to wait till they go back to school to ask a question

One research survey conducted by the Educause Centre for Applied Research (2012), on Mobile IT in higher education echoed, that students are driven by the implementation of using mobile computing devices, such as cell phones, smartphones, and tablet computers, within higher education. From the survey 67% of the students consider the use of mobile devices as an important tool for their academic success and academic activities. This suggests that the use of media allows the individual to see what they read or are told in class, it gives the individual the ability to construct knowledge based on their experience and that of others.

Further, another method of using the ideas of social media interaction for teaching and learning is the implementation through gaming. Squire (2011), utters the importance of critical support systems that can develop good educational games for the classroom. The criteria of these critical systems involve games being collaborative for both designers and educators; the games should be entertaining and academically inclined; the games should be both fun and insightful for learners; the games should be sophisticated, the games should provide social networks, group\team interactions, temper interests and inspire creativity (Squire, 2011).

Understanding gaming can be a good way to get learners to think constructively, using games that learners like and enjoy can assist them in building knowledge, this can be a way to improve learner performance. The truth is learners learn from who they like and they learn from what they like. This suggests that instead of just having social media platforms, we can have games that acts like a social media platform but in a more controlled environment and where teachers have access and control. Through this system of teaching, it could improve learner performance in Chemistry.

According to Squire (2011) the use of gaming has a special form of teaching and learning unlike any other mediums. Relatively it plays its part in enabling the intellectual and social growth of the learner long term and infiltrates into his or her learning range. This type of learning is understood as the greater independence for the learner, but also because it changes the roles for the teachers in teaching, it alters the construction of knowledge between teacher and learner altogether through what is known as the connectivism learning (Downes, 2005).

Rodriguez (2011) argues that facile interactions are more accessible when using mobile devices in conjunction with social media and free web tools that support communication can enhance learning. These tools that can be used in conjunction with social media include Phet assimilations, online tutors, programs such as Khan Academy etc. Mottiwalla (2007) adds to say mobile learning offers combined individualized learning, where learning can take place at anytime and anywhere, just like the availability of social media.

There is minimum research and evidence for the use of social media in the Chemistry classroom and education. However, there is evidence in research which indicates the benefits of social media teaching tools for the teaching and learning environment. According to Gachago & Ivala (2012), there are strategies that are available to improve teaching and learning in general, which suggest that with further research strategies for Chemistry education can be investigated.

These strategies include teachers improving their level of understating with these tools, their creativity and choice of tools to use. When teachers implement social media technologies, they need to involve the learners, but taking note that not that all learners will respond equally.

Teachers who wish to use Facebook or blogs need to collaborate with learners online on these apps and teachers should provide and ongoing platform in order to see results in the long run. Techers who wish to use Facebook, as an example, can enhance teaching and learning by not dominating in these platforms, rather allow learners to teach each other and teachers should not dominate in the discussion (Gachago & Ivala, 2012)

2.6 Conclusion

The theories discussed in the chapter play a role in my study as to understand the influences that different teaching methods and learning styles have on the construction of knowledge to improve their academic performance. Further the theories help us understand the learning difficulties that can arise when a learner is not taught according to their mental strengths.

The behaviourist theories clarify learning as a stimulus in which the individual makes a response to it. They believe that by understanding an individual's behaviour we must first understand the relationship between the stimulus and understand the response. By implementing mental changes as a form of tool to assist learners, minimises the complexity of the problem. Thus, if we are to add tools that assist learners in the classroom, it should be tools that add further explanation. According to the behaviourist theory, there are trusted teaching methods and learning styles that are trusted but they cannot be applied to all subjects. The conclusion to the behaviourist theory on their values for educational implications on learner development is seen as not being separate but alongside theory and practice.

The cognitivism theory believes for us to understand learning we have to understand the brain as an important structure that processes information and interprets this information as we learn. Which implies that the more we learn and acquire knowledge we improve our concentration, better our critical thinking and improve the ability to perform tasks better and more effectively. Cognition influences the child's psychology and it plays a role on the development of child-centred teaching aspects that exposes to challenging experiences. It further supports the development of the child's moral judgments as it takes it through important stages where the learner will be required to resolve a problem by constructing their own position. The conclusion on the cognitivism theory looks at learning as a mean to improve cognition for learning.

The study of psychology explores human understanding and what impacts their performances and their mental abilities. The constructivism theory is a hypothetical perception which is seen as one of the most important fields of psychology and the roles it participates within the avenues of educational psychology. The understanding of how knowledge is constructed in a person's minds allows us to shaped the way in which we see things and the way we analyse, based on understanding the human mind. Further, it assists the learners to know the properties of each aspect of their thought and how their mental construction determines how they respond and how they react.

The social media learning theory, agrees by saying that when learners are given the opportunity to play while learning, it enables intellectual and social growth over the long term and promotes goals. Further, it improves their problem-solving skills, improves their critical thinking and social interactions. Facile interactions are handier when using mobile devices along social media and web tools to support communication and enhance academic learning. Another form of social media learning is the implementation of gaming in the classroom as a special form of teaching and learning unlike other medium. The incorporation of gaming in the classroom can improve learner intellect and social growth. Gaming has the ability to change the role of the teacher in teaching and alters the construction of knowledge between teacher and learner altogether through what is known as the connectivism learning.

Based on the above mentioned, it is important because in a classroom, the teacher has a fraction of seconds to grasp learner attention with new information, if not it is lost within the learners' short-term memory stages. In the processing phase of the human brain, information is enlarged, renewed and perceived as useful and therefore can be stored in long term memory. However, this phase requires more cognitive tools (virtual reality and physical models) to ensure the processing stage is more effective for a greater domain of knowledge acquisition. Since social media, social media tools and games can improve learner knowledge development and improve academic performance, it could be considered that tools such as virtual reality and physical models can be used to improve learners in their Chemistry knowledge.

All subjects require different needs, with different aims and objections to them, subjects like chemistry and biology are abstract with complex concepts one cannot see with the naked eye.

Thus, for the above research study, the rational and the aims reflect adequate teaching tools, specifically virtual reality and physical models for the Chemistry classroom. These tools can improve how learners perform in Chemistry and it can build their Chemistry content knowledge.

In other words, it explores the need to change the way teaching and learning take place and the tools that can be used in the Chemistry classroom. This is due to the existence of multiple teaching methods and learning styles that can be used in the classroom. Supporting ideas played a vital role in the integration new knowledge with understanding and this helped to structure my research design within the same line. In the next chapter a detailed description of the research design and methodology will be presented and discussed.

CHAPTER 3

3.1 Introduction

The current chapter discusses the research methods employed in the present research study which aimed to understand the effects of virtual reality and physical models on grade 11 learners' understanding of geometric shapes in the chemistry. The research study followed specific research methods, entailing both qualitative method and quantitative method (mixed-method approach). The current chapter outlines the methods that were followed during the research investigation. The approaches that were followed are also discussed. Before specific research methods employed in the present study are discussed, however, the researcher reflects on research methods in general, as an attempt to locate the research methods of the present study in the broader research methodology context.

3.1 Research Paradigms

Research can be explained in various ways, depending on one's understanding and needs. According to Burns (1997), research can be seen as a form of systematic investigation where data in gathered and interpreted. Mertens (2005) supports this ideology's by arguing that collecting, analysing and interpretation the gathered data is to reach an educational understanding, concepts of change or a phenomenon.

Research and research designs have evolved over the years, research designs are seen to be more complex today than they were years ago (Mackenzi & Knipe, 2006). Today, it is understood that the "exact nature of the definition of research is influenced by the researcher's theoretical framework" (Mertens, 2005, p.2). Which is the theory implemented to gather an understanding between variables to define or clarify a phenomenon by going through phases to gain perspective (Mertens, 2005, p.2). Thus, in research a theoretical framework is a theory that can be classified as a research paradigm (Mertens, 2005; Bogdan & Biklen, 1998) and it influences the way knowledge is studied and interpreted (Mackenzi & Knipe, 2006).

The term paradigm originates in Greek and implies patterns, it was first introduced to research literature by Thomas Kuhn (1962). Paradigms were seen as a conceptual framework used to solve problems shared by scientists for examining problems and finding solutions. Kuhn (1962) defines a paradigm as, a combined pool of fundamental opinions, variables, and problems with agreeing procedural approaches and instruments. Further, Kuhn (1962) suggests that the term paradigm implies a sophisticated set of beliefs, values, and assumptions used by researchers. Within the views of educational research the term paradigm is used to label a researcher's 'worldview' (Mackenzie & Knipe, 2006). Correspondingly, Denzin and Lincoln (2000), express paradigms as human constructions, which deals with ideas to where the researcher is coming from so as to understand the depicting ideas.

Thus, a paradigm signifies the structure and framework or the classification of scientific and academic ideas, values and assumptions (Lodwick *et al.,*1992). This suggests that epistemology is used to explain the dimensions of how we get to understand reality; how we distinguish the truth or reality; or what is perceived as knowledge in the world (Cooksey & McDonald, 2011).

There are at least two broad worldviews related to research paradigms, objectivism (or positivism) and constructivism. These two methods of viewing the world follow specific sets of guidelines related to ontology and epistemology. Each may be appropriate for some purposes and insufficient or overly complex for other purposes of a research study. This is due to the fact that a person may change their view depending on a particular time or situation (Creswell, 2003).

Ontology refers to a division in philosophy which is concerned with the articulation of nature and the world structure (Antwi & Hamza, 2015; Wand & Weber, 1993, p. 220). It refers to the ideas and nature of reality and how we perceive it to be. According to Antwi & Hamza (2015), the term ontology originated from two Greek words (*onto*, which means 'being' and *logia*, which means 'science, study or theory'. Scotland (2012), argues that ontology is a division within philosophy which is alarmed with the traditions followed to make sense of reality or the core of the investigated social phenomenon. Further, ontology is seen as a vital role in paradigms, as it aims to give an understanding of the things that establish the world as we know it (Scott & Usher, 2004).

Moreover, ontology in the positivism paradigm, which echo's the reality being real and apprehensible. Whereas ontology in the constructivism paradigm, echo's multiple constructed realities. Because of their unique perspectives on the nature of reality, these two paradigms (objectivism (or positivism) and constructivism) tend to adopt different epistemologies and methodologies. For example, positivism generally adopts a quantitative research methodology, while constructivism usually adopts qualitative research methods.

For the current research study, the paradigm of positivism and critical theory were adapted and implemented. The realism (pragmatic) paradigm is a combination of the positivism and the critical theory paradigms. According to Mackenzie & Knipe (2006), pragmatism is not only loyal to one set within philosophy or about reality. Therefore, due to no commitment to a set system, pragmatist researchers give attention on the 'what' and 'how' of a research problem at hand (Creswell, 2003, p.11). According to research theory, pragmatism can be associated with the paradigm that gives understanding to the philosophical framework for mixed-methods research (Tashakkori & Teddlie, 2003; Somekh & Lewin, 2005). Therefore, the pragmatic paradigm gives the researcher a chance to gain "multiple methods, different worldviews, and different assumptions, as well as different forms of data collection and analysis in the mixed methods study" (Creswell, 2003, p.12).

Further, a mixed-method researcher brings into line the philosophical and the transformative paradigm (Mertens, 2005). It is articulated at times, that mixed method research could be implemented with any given paradigm. According to the pragmatic paradigm, it highlights "the research problem" as the main objective central to the steps taken to understand the problem (Creswell, 2003, p.11). Which suggest that when the research question is the main objective, the data collection and analysing methods are selected as the most appropriate means to provide insights to the question with no philosophical reliability with any other given paradigm. Mackenzie & Knipe (2006) argue, for this type of research paradigm it includes tools from both positivist and interpretivist paradigms, such as interviews, observations, testing and experiments.

Whereas, the critical theory looks at a more transactional and subjective epistemology, where the investigator and that being investigated are presumed to be congruently linked (Guba & Lincoln,1982). Critical theory philosophers seek for truth in new educational reforms that aim to aggravate resistance to improving the quality and validity in education, by making it demanding to answer and amend was is acceptable (Ladson-Billing & Tate 2016). According to Giroux (2019), the critical theory paradigm focuses on the radical sense and knowledge that should be mediated between the teacher and the classroom, along with all the political exchanges and cohesions. Which suggest that critical theory is the thoughtful valuation of our society along with culture among humanity.

The paradigm of positivism is when experiments and surveys are used to verifying particularly quantitative aspects. Whereas, the ontology of critical theory focuses on virtual reality, shaped by social, economic, ethics, politics or culture over time (Creswell, 2003). The positivism paradigm explores the social reality centred on the French Philosopher August Comte's ideas (Guba *et al.,* 1994). He believed observation and reason are the best ways to understand human behavior. He trusted that knowledge is based on experience and can be acquired through experimental observation.

Further, the ontological paradigm of positivists assumes that the reality is given objectively and it can, therefore, be measurable using independent properties from the researcher and their instruments (Creswell, 2003). Which means, that knowledge is objective and quantifiable through positivistic thinking as it adopts scientific methods and quantifies the knowledge generation process. With the help of quantification, precision is enhanced in the description of parameters and the relationship among them (Guba *et al.,* 1994). Therefore, the paradigm of positivism is supported as it is concerned with uncovering the truth and presenting it by empirical means in the research investigation. Therefore, specifying the method and nature of reality and our knowledge about it.

Moreover, the positivist paradigm aims to seek for cause and effect within relationships. Thus, making it widely favoured within research, which attempts to interpret explanations with measurable facts (Fadhel, 2002). Research allocated within this paradigm trusts deductive logic, formulation origination of hypotheses, testing those hypotheses, offering operational definitions and mathematical equations, calculations, extrapolations and expressions, to produce conclusions. The intentions are to provide rationalisations by making predictions on the quantified conclusions. According to Cohen, Manion & Morrison (2000), measurable outcomes are guided by four norms, determinism, empiricism, parsimony and generalizability. By unpacking each of these norms it enables the researcher to appreciate the meaning and beliefs of the research guided inside this paradigm.

There is a blend between the positivism and the realist ontology, Walshman (1995b) argues that positivists keep the scientific concepts constant, while ontology suggests that reality requires social construction (Antwi & Hamza 2015). To further understand the importance of the two paradigms, we need to consider two worlds. One with the unchanging reality and the other where peoples reasoning is subjected to their environment. For an example, study's that consist of an unchanging reality the researcher can follow an 'objectivist' viewpoint: a realist ontology where individuals are either true or false, right or wrong. Whereas, interpretive researchers view the reality considers the individuals subjective experiences of the external world (Mutch, 2005). Thus, suggesting that reality is socially constructed within humans.

3.3 Research methodology

Having discussed the adopted realism (pragmatic) paradigm which is a blend of the positivism theory and the critical theory. The current section reflects on the research methods adopted in the present study. As mentioned earlier however, the researcher will first explain the broader context of research methods and then locate her study in these.

Researchers generally agree that there are three broad research methods that can be applied in human sciences, namely, the qualitative research methods, quantitative research methods, and the mixed methods. Each of these has some unique characteristics ranging from sampling, data collection, data analysis and reporting the findings. These are discussed in detail below. The present study adopted both qualitative and quantitative research methods, making it a mixed methods study.

3.4 Selection of the schools

For the current research study, the two schools that were part of the research study and that were selected are in Emalahleni in Mpumalanga. The participating schools fall in the Nkangala District 3 in Emalahleni and the schools were selected because of the central district between them. The district comprises of schooling communities of working (and non-working) class, where some parents are employed far, some of the learners live with their grandparents or other family members, where a large number of the participants have one or more family members working in the mining industries in Emalahleni.

All the participating schools have some or other aspect in common, the type of learners that are enrolled, the living situations of the learners and participants, the science equipment that are available in the schools, the academic pass rate (not exactly the same but a percentage or so different). As a result, the school results in Chemistry is directly or indirectly affected by the teaching approaches and the lack of equipment or usage in the school. This, however, does not imply that all the school have exactly the same problem, situations may differ to each of the participants in the schools.

In line with the Unisa policy for ethical research, the researcher followed the strict guidelines provided by the university. In this regard, all participating schools consented to participating voluntarily. School principals signed consent letters. Similarly, class teachers and learners volunteered to participate by providing relevant consent through parents and guardians in the case of learners.

3.5 Qualitative method

Most qualitative research relies on the use of multi-method strategies to collect data (Guba *et al.,* 1994). The strategies that can be implemented are in-depth interviews, participant observation, document and artefact collection, field observations and supplementary techniques (Guba *et al.,* 1994). The researcher selects one primary strategy and will incorporate other strategies to verify the important findings, increasing research credibility.

3.5.1 Characteristics of qualitative research

According to Hoepfl (1997), qualitative research aims to understand a phenomenon in a context-specific setting using a critical theory approach. It is an in-depth study which may use face-to-face techniques for the collection of data as it aims to collect rich data for the investigated phenomenon (Creswell, 1999). Qualitative research contains vast aspects of enquiring on participant behavior, experiences and opinions from the informant's points of view, where meaning is made through narratives and observations rather than the use of numbers (Zucker, 2001).

Further, Zucker (2001) supports the theoretical significance of qualitative methods with its ability to describe and discover events, phenomena, and situations within educational studies. Researchers agree that qualitative methods are best suited for studies where little is known about a particular phenomenon (Corbin, 1990). The benefits of qualitative research are the uses of multiple realities such as interviews, principles and educating teachers and students on a social situation (Corbin, 1990). The purpose of this method approach is understanding a situation from the participant's viewpoint (Zucker, 2001).

In qualitative research, there exists at least two different designs, the interactive and non-interactive method design. In the interactive design, the researcher interacts directly with participants while in non-interactive design there is no direct interaction between the researcher and the participants. The former may include the use of interviews for data collection, while the latter may rely on artefacts and document analysis.

The grounded theory is a type of interactive design which aims to generate or discover a particular theory in the study (Corbin, 1990). Whereas, the phenomenological study describes the meaning of a particular lived experience, as it wants to identify how individuals learn and interpret particular experiences (Creswell, 1990). The goal of this approach is to understand the essence of a phenomenon using long intensive individual interviews with the participants. Another example of an interactive approach is the ethnography approach, which provides descriptions of various cultural social contexts while spending time at a particular setting, with the use of interviews and participant point of view (Corbin, 1990). The researcher’s role in this context is to observe the participants and interview them to understand their point of view and therefore build reason.

Further, the second type of design is the non-interactive design, which uses analytical methods that only focus on analysing documents to understand the orders of past events (Corbin, 1990). Validated documents are a very important source of data with the interpretation of facts that provide explanations and clarity for this design (Creswell, 1999). The aim of this design is to use the concept analysis for operative learning with the ability of grouping, to describe the different meanings of evidence (Creswell, 1999). The historical analysis uses a systematic collection of documents and artifacts. It studies past educational programs, practices, institutions, and people in order to examine the causes that instigate the events relating to the past (Corbin, 1990).

The role of the researcher in qualitative research varies depending on the approach adopted. For example, the researcher could be a complete observer, observer as participant, participant as an observer or a complete participate. Patton's (1990) theory on the role of the researcher is for the researcher to remain "objective" as an instrument, where the researcher is only allowed to make observations, interpretations, and descriptions of the given data (Creswell, 1990).

However, Hoepfl (1997) gives more attention to the researcher's ability for being distinctive as well as pervasive, for seeking uniqueness of each research case. The role of a complete participant gives a unique understanding of the research study as one gets to engage with the culture of the participants (Patton,1990). According to Creswell (1999), participant observation reflects intuition with an intellectual grasp within a certain society and how those individuals will relate. As the researcher engages as a complete participant in a research study, it gives one the eyes of an insider.

In the present study, the researcher adopted the interactive data collection methods by directly collecting data from the participants using tools such as semi-structured questionnaires, interviews and content knowledge tests. The researcher also observed participants as a way of data collection. These are discussed in detail below.

3.5.2 Sampling in qualitative research

To determine the methodology of the research the study, it will be conducted using a sample size of 200 grade 11 learners. The sampling approach to this research study is purposeful sampling within the qualitative research approach. The participants are selected because of some defining characteristics that make them the holder of the data needed for the study. Further, the aim is to do a rich in-depth study, because the researcher wants to understand something about the cases without needing to generalize to all such cases. The selection of participants is guided by the criteria of;

1) Grade 11 learners
2) Physical sciences as a subject
3) Science background
4) Can be a boy or a girl
5) Between the ages of 15-21
6) Includes repeating learners in a grade

The set criteria provides the researchers with a good mix of students, with good exposure to different teaching approaches to obtain authentic result within the research study.

Sampling is the process of selecting participants, where a portion of the population is selected for the study at hand (Patton, 1990). Participants are those individuals who will be taking part in the research study for data collection (Creswell, 1999). Further, the group of participants chosen for the study is then referred to as the sample of that study (Patton,1990). Qualitative research usually uses non-probability or purposeful sampling whereas quantitative may use random sampling approaches (Patton, 1990).

For purposeful sampling, the participants are selected due to a defining character which aids the needs of the research study (Patton, 1990). The benefits of purposeful sampling are the reflection of rich information cases with in-depth reasoning and understanding, as it aims to explore something without generalization. Another benefit of purposeful sampling is the fact that other factors such as the setting, events, and activities for the data collection process, are also taken into consideration (Patton, 1990).

Moreover, there are different types of purposeful sampling in qualitative research (Creswell, 1999). The first is criterion sampling which decides the kind of participants as well as the number of participants, including aspects such as age or gender. The next is snowball sampling, which is when each successive person or group is nominated. However according to Creswell (1999), this approach is used to find a hidden population. However, in the current study, the researcher used stratified purposeful sampling where the 200 participants make the sample size. These participants were sampled using a preselection criteria, as they needed to be in grade 11 and have physical science as a subject in a particular school. Creswell (1999) supports this method of sampling as the participants are defined by characteristics that allow them to be the sources of the data required. For qualitative research, the sample size is generally smaller than those of the quantitative method approach. There are no guidelines or prescribed rules for the sample size in qualitative research, the size range is usually between one 1 and 40 participants.

3.5.3 Credibility and trustworthiness

Credibility is the first point that is recognised since it is an important aspect to inaugurating trustworthiness. This is because credibility is seen as a mean that asks the research to connect research findings with reality as a way to reveal the truth for the research findings. Further, credibility can be rationalised as the confidence in the truth for the findings of a research study (Holloway & Wheeler, 2002; Macnee & McCabe, 2008). Thus, credibility creates an idealistic view on the research findings represented and whether the findings interpret the participants views (Graneheim & Lundman, 2004; Lincoln & Guba, 1985).

According to Malshe (2010) and Bettinghaus (1969) credibility refers to whether the receiver views the source of information as believable or not. Thus, suggesting that credibility focuses on cognitive and affective dimensions along with trustworthiness from concepts from the recipient (Malshe, 2010; Newell & Goldsmith, 2001). Thus, research denotes that trustworthiness and expertise are the two-important aspect on the concept of credibility.

In a qualitative research study, the researcher is the instrument and therefore responsible for credibility and trustworthiness in the study (Creswell, 1999). According to Noble and Smith (2015), in quantitative research, researchers use statistical approaches to ensure validity and reliability for research findings. Concurring to the Mercator Research Group (2003), it is argued that qualitative research is an approach used to better understand with reasons and motivation, as it aims to specify perceptions in a problem and give solutions. Whereas, qualitative researchers incorporate methodological approaches to guarantee the 'trustworthiness' of the research findings.

These strategies according to Nobel and Smith (2015) include: taking responsibility for personal prejudices that can affect findings; recognizing biases when sampling with continuous reflections to confirm necessary understanding and the importance on data collection and enquiry. Further, it focuses on particular record keeping, with a clear trail of decision making to confirming the analyse to data being consistent and transparent; creating a link of similarities and differences throughout to ensure various views are represented. Followed with an in-depth classification on participants reasons to encourage findings; demonstrating clarity in terms of thought process during data analysis and subsequent interpretations. To work with other researchers to reduce research bias; allowing participant validation, as participants answer on the interview scripts concepts are to reflect the phenomena being studied and data triangulation, is various methods and perspectives which help produce a more comprehensive set of findings.

In the current research study the researcher used various strategies to ensure credibility for the qualitative methodological approach. In a sample of 200 participants, all the participants were given the content test with a Likert scale questionnaire on the same day and at the same time, both the physical model and virtual reality group participants. All the participants were given the same amount of time to complete the test and questionnaire, the participants were not allowed to get assistance from any other participants, teacher, textbook\notes or the researcher. Further, the questionnaire employed different questioning styles, such as, short questions, questions based on images and structures with further explanations. Participants in the research study, were only given 60 minutes to answer the questionnaire, this is because the researcher needed to see how well participants understood the concepts of Chemistry on their own and thus denied them to take it home.

Further, once all the scripts were collected the researcher was able to find similarities and differences from the obtained participants scripts. To ensure credibility in the methodological approach the researcher focuses on 'truth value', where the sample sizes where the same, the instructions given to the participants were clear and the same. There was good consistency from the researcher with the interaction of both groups, with transparent and clear research processes and outlies.

Once all the content tests and questionnaires we completed, the research intervened in each group. The physical model group was taught using physical biochemistry models, where the learners literally created molecular structures and atomic models. Whereas, the virtual reality group watched videos and used assimilations to create molecular structures and atomic models. Each intervention took 40 minutes for each group, where the researcher explained the concepts to the participants, then explained again using the intervention tools and the last step was to allow the participants to play and explore under the watchful eye of the researcher.

Further, after the research intervention the researcher randomly selected participants for an interview. The researcher randomly selected twenty-five participants collectively from both groups as an approach to further understand their understanding of the the pre-and post-content tests. According to Neuman (1997) interviews acknowledges the researcher and allows a platform where they can ask any form of question even those that are complex. The researcher was not bias and therefore selected participants from both groups to participate in the interview, to gain perspective on both views and experiences.

However, credibility in the quantitative phase was ensured differently than in the qualitative phase. The current research study used pre-and post-content tests to test participant improvement in Chemistry. Since the study aimed to show if learners improved when using various teaching approaches, the data was collected from two diverse groups who were tested with different teaching approaches to test the same concepts.

Both groups wrote the same pre-test on the same day, followed by a teaching intervention where one group was taught using virtual reality and the other group was taught using physical models. In the teaching intervention for both groups, the researcher covered the same topics, the same examples were discussed and illustrated and the same amount of times was allocated to each group for the intervention. Credibility allowed all participants to being able to obtain marks, no group had it easier than the other in terms of the content taught. Further, the same post-test was written by both groups on the same day, with the same time allocation for the same mark.

Further, trustworthiness in literature aims to reflect awareness, trust can be universally explained as a personal vendetta one agent has about another agent (Schmidt, Steele, Dillon & Chane, 2007). Trustworthiness in research is improved with the incorporation of various data collection methods (the use of observations, interviews, document analysis, tests, etc.) (Creswell, 1990). According to Malshe (2010), research is a reflection of trustworthiness and having experts as the two vital cores to understanding concepts.

Further, research directs that trustworthiness and capability are seen as the main ideas (Malshe, 2010). As an example, the ideas from business research indicate that trust can be seen as a measure of confidence between two partners reliabilities and their integrity along with the amalgamation of their loyalty, proficiency, truthfulness and approachability (Sirdeshmukh, Singh & Sabol, 2002). In addition, Malshe (2010) argues that experts still acknowledge the level of relevance of knowledge from the source. This because the receiver's perception on the sources level of understanding enriches their trustworthiness (and so their credibility) as viewed by the receiver (Palmatier, Dant, Grewal & Evans 2006). This suggests, the researcher should do enough research on the information collected to have credit for the receiver to have trust on the results obtained.

Trustworthiness for the research study, was achieved by first circulating the instruments among pilot participants, other researchers and the researcher's supervisor. This approach was to ensure if the questions in the Likert scale questionnaire and for the interview were going to be understood by the grade 11 participants. This methodological approach also served as a mean to determine the time that the instrument would require when being answered in the actual study. Once the methodological approach was achieved some necessary changes and corrections were made to the instruments and the critical questions were re-phrased and were made to be clearer.

On the credibility of the content test, the researcher used past DBE (Department of Basic Education) and the DOE (Department of Education) final national and provincial exam papers and compiled the content test. This was to ensure recognised knowledge level questions, the structures of the questions, the language level used in Chemistry, the expectation of the answers according to the moderated papers and the mark allocations. Further, the credibility of the instruments were taken into account, to make sure the participants were able to understand what is asked and to provide authentic responses. In addition, content validation raises theoretical concepts which emphasis on the level the instrument measures to show evidence of fair and inclusive coverage of the concepts that it aims to cover (Oluwatayo, 2012).

3.5.4 Triangulation and Crystallisation

Triangulation is an important part of qualitative research. It refers to incorporating different methods, data sources, observations or theories to better understand the phenomenon in line with the study. Triangulation is using more than one approach to collecting data on the same research topic. The use of various methods of collecting data includes different types of samples as well as the procedures in which the data is collected.

The term 'triangulation' in the field of navigation can be understood as one's angel of location, from two points (Institute of Navigation). Whereas, triangulation in research is understood as implementing more than one approach to testing a research question. This is done to increase confidence with the obtained data findings, by confirming with the different methods of testing (Tashakkori, 2003). The combination obtained from the two findings therefore provide a greater scale on the quality of the results, than using one approach alone (Tashakkori, 2003).

For the qualitative aspect of the research study, the researcher used a questionnaire, and interviews as data collection methods. By gathering the qualitative aspect of the research using the three instruments the researcher was able to gather different perspectives of the phenomena being investigated.

Therefore, suggesting that when triangulating we use, two or more methods know as mixed methods, which combines both quantitative and qualitative methods to gain understanding on a topic. The implementation of the two methods could have the following outcomes, where the results; portray the same conclusions; the results can reflect different objections or the results can be opposing or contradictory (Tashakkori, 2003).

3.5.5 Data analysis

In qualitative research, the data analysis aims to summarise the data and gain an understanding of the results obtained. Creswell (1999) explains that the end goal for qualitative data scrutiny is to see the connection between the given sets where a pattern was discovered.

Further, according to Bryman (2016), one element of analysing qualitative data is through themes and coding for each question or transcript. When analysing qualitative data, coding, themes assist the researcher in breaking down the data into components that give meaning. The coding part of qualitative data is called data reduction, since a large aspect of the data is reduced to more concentrated data (Bryman, 2016). Data analysis in qualitative research methodology is understood as the construction for collected data (Hatch, 2002).

In the present study, data were collected from the content tests, the Likert questionnaires and the interview protocol, which were designed so as to assists the researcher to collect both qualitative and quantitative data. The content test was based on Chemistry concepts and the entire test counted forty marks. The Likert scale questionnaire was designed in such a manner that allowed the participants to share their understanding and reflect to the researcher their true abilities to the subject. Further the data collected from the interview, was around twenty-five randomly selected participants from both groups. The researcher walked up to each participant and asked them to follow to a separate classroom where the interviews were held. The questions for the interview were structured in a way as to assist the researcher to gain a better perspective on the content tests results from the Likert scale questionnaire.

The researcher, organised, gathered and simplified the collected data by using codes and themes. Below is the descriptive themes the researcher used for the questionnaire, the open-ended questions and the interview,

3.5.6 Descriptive codes used to analyse participant understanding and responses.

The following criteria was used to analyse the participant responses to the content test (with the allocated memorandum), the Likert scale questionnaire and the interview questions. A criteria are principles or standards by which someone can be judged. It was set to assist the researcher to categorise the different answers provided by the participants, by having a criteria the researcher can tell in which level of understanding each participants is in. Thus, as soon as each participants has been allocated a level of understanding based on the criteria, the researcher can tally how many participates are in that level and then we can answer 'why'.

Clear knowledge **or correct knowledge** – participant responds correctly and clear with no misconceptions
Partial knowledge – **participant response is poor, lacks value or substance, a few misconceptions, however, reflects some form of understanding of Chemistry**
Poor knowledge with misconception – **participants reflects poor understanding of the contents, poor articulation of the question, shows poor evidence of understanding Chemistry**

3.6 Quantitative method

Creswell (1999) defines quantitative research as a systematic process and objectives using numerical data for a sample of a population to gather data. Quantitative research emphasizes on numbers, measurements, deductive logic, and experimentation. The process with respect to quantitative studies defines methodologies for understanding and gathering data (Libarkin & Kurdziel, 2002). Therefore, statistical techniques manage the reliability and validity of quantitative methods.

3.6.1 Characteristics

In divergence to qualitative methods, Strauss and Corbin (1990), explain quantitative methods as the quantifying, numeracy explanation of information, where findings are observed through the use of statistical means in research. Hoepfl (1997), argues that quantitative research aims to fundamentally determine, prediction, and generalise obtained findings in the research study.

The advantages of using quantitative methods is that the interpretation of quantitative research uses numbers for data analysis and it is not influenced by the researcher's opinions and beliefs. However, the major disadvantage of using quantitative methods approach is that the participants are at times forced into categories. The interpretation of the data is risky as the context from which the data was collected can possibly be lost.

Further, there are at least four main types of quantitative research designs that are used; the descriptive, correlational, causal-comparative/quasi-experimental and experimental research. In addition, quantitative research designs are sometimes clarified as the analysis of casual relationships and the association of various relationships between variables. There are two known core classes of quantitative research, the experimental design, and the non-experimental design.

Firstly, looking at the four core types of quantitative research, the descriptive research aims to seeks and explain the main aim of an identified variable, the objective of implementing descriptive research is the goal to describe a phenomenon (Nassaji, 2015). Such research tasks are intended to stipulate authentic data on a given phenomenon. Where the hypothesis is not provided at the beginning by the researcher, but developed once the data has been collected. Which means the analysis and synthesis of the data gives the reflection on the hypothesis.

The correlational research method, seeks to define the value of a relationship between two or more variables with the use of statistical data, according to MacIntyre (2014), it aims to see the correlation between existing theories. For this type of design, the relationships among a number of facts are organised and therefor interpreted. Thus, recognising the trends and patterns in data, however does not go in too deep as to prove the analysis of the observed patterns. Moreover, cause and effect is not the main point for this kind of observational research.

Further, the causal-comparative/quasi- experimental research challenges to see what is the cause and effect in variable relationships. Such designs can be related to true experiments, with a few differences. According to Bruce (2012), the quasi-experimental research designs is aimed to evaluate the effects on social programs, psychotherapy or any form of psychosocial intervention within a public space. Which means, independent variables are identified, however not influenced by the researcher and the effects of the independent variable on the dependent variable are measured.

Further the researcher does not casually allocate groups, but is required to use ones that form naturally or pre-existing groups, to identify the control group and to exposed them to treatment variables that are studied and compared to groups who are not. thus, Bruce (2012) suggests that groups that involve a comparison to another group is referred to as quasi-experimental designs.

In the experimental research design which is also referred to as true experimentation, uses the scientific approach to determine the cause and effect relationship between a group of variables that take part in the study. The true experiment design is characterised by developing various groups, some that are getting knowledge/treatment and some that are getting nothing by randomly selecting the participants (Bruce, 2012). For an example, the true experiment is often compared to a laboratory study, but this is not always the case. In a true experiment, effort is required to recognise and execute control over all other present variables except for one. Since an independent variable is influenced to reflect the effects on the dependent variables. Themes are unsystematically allocated to experimental treatments rather than recognised in naturally occurring groups.

In addition, the experimental design consists of true experimental design, quasi-experimental design and single-subject design. Experimental designs can be seen as an approach for gathering information in relation to casual relationships, which permits researchers to evaluate the relationship between one variable and another (Robson, 1993). Which suggest that a single element is influenced by the researcher as an approach to determine if there is a change

(Robson, 1993). This class allows the researcher to have control over one or more variables or factors during the research study and the purpose is to manipulate factors for the study.

Further, the true experimental design is seen as the most correct approach to experimental research design, as it trusts the use of statistical analysis to validate or invalidate a hypothesis (Gribbons & Herman, 1997). Thus, it is seen as the only kind of experimental design that can determine a cause-effect partnership in a sample. When partaking in a true experiment design there are factors which are to be fulfilled; the control group, an experiential group with variables which can be influenced by the research and unintentional distribution. According to Gribbons and Herman (199), true experimental design focuses on more than one casual assignment.

The quasi-experimental design is related to the experimental research design, however not exactly that. Therefore, in this kind of research design, an independent variable is used and manipulated and the participants of a group are not randomly appointed as per condition. Which means the independent variables are then manipulated before calculating. According to Gribbons and Herman (1997), this design approach is mostly implemented when there is no feasible approach for the researcher to randomly assign. Further, the quasi-experiment design focuses on participants in randomised conditions. Which would mean the researcher does not have full governance on the independent variables since the intervention is in progress, or the difficulty to manipulate certain the variables (Robson, 1993: 46-7), for an example, the ability to measure how a smoker affects their lives through smoking).

Another type of research designs is the single-subject design, which are structural tools used to assist a generalised reflection on how participants are to respond to a certain condition/intervention/treatment. Which in fact can act as a barrier (Robson, 1993). Therefore, this is where the single- subject design case is implemented, as it is a tool that researcher can implement to supervise the progression of their own work (Robson, 1993; Creswell & Poth, 2017).

Hence, for the current research study this design was not considered by the researcher as it can only involve a single person or a few individuals to participate. Whereas the current study required a sample size of 200 participants. The current study used the quasi-experimental design. The advantage is the participants are not selected randomly and groups used can cater for a control group and experiential group (Creswell, 1999).

The following method is the non-experimental design, which can be descriptive, comparative, correlation, casual, ex-post and secondary data analysis. Thus, for the current study the researcher did not follow the non-experimental class since it follows, the first type of design which is the descriptive design and would have limited the researcher due to the investigation of simple aspects. The comparative design only examines samples on a variable of interest, which also reflects limitations in terms of the sole purpose of the current research study.

Further, the correlative design, which investigates the correlation between two or more designs at hand. The casual comparative design which collects data on things that occurred years ago with the possibility to draw a conclusion. However, the shortfall for the survey design, it only collects data by issuing a survey or the conduction of interviews with a large number of people, usually the population, this however limits the data to be true. The secondary data analysis allows the researcher to have data access from others who have gathered it. However, this design limits the researcher as this data is to be used to draw up conclusions.

Therefore, in the current research study, the researcher implemented the quasi-experimental design where an independent variable is used and manipulated and the participants of a group are not randomly appointed as per condition. The research instrument used to collect the data for the quantitative methodological approach was a content test. Content tests are a useful way to gather data as all the participants write the same test. This approach of data collection is an advantage as the researcher controls what is on the test and what is intends to test (Oppenheim, 1966).

The content test was designed by the research using previous grade 11 examination papers, nationally moderated exams and the diagnostic reports for the last five years, for the South African curriculum for grade 11 physical sciences.

3.6.2 Sampling

A population is the entire selection of individuals that are being considered, where all members of a given group participate (Eberhard, Hassel, Baumer, Becker, Beck-Mubotter & Bomicke, 2011). However, the sample is a subset of the population which consists of a predetermined number, sample size or participants who are randomly selected. Which means the subject from which the data was collected represents a specific population (Eberhard *et al.,* 2011). Quantitative research methodology is advantageous as the results are collated from a number of participants (Creswell, 1999).

Sampling is explained by Creswell (1999) as the process used in research to select participants, where a part of the population is part of the research study. Further, the participants in the study are the people or individuals where the data will be collected (Hoepfl, 1997). Thus, collectively the group of selected participants from the population is called a sample. Qualitative research usually uses non-probability or purposeful sampling whereas, quantitative research uses random sampling approaches (Hoepfl, 1997).

For the current research study, the researcher used purposeful sampling. Further, there are different types of purposeful sampling, the first type is criterion sampling which decides on the kind of participant as well as the number of participants that will be required for the research study (such as their age, gender, etc.). Whereas snowball sampling is the successful nomination of every person or group, however, this approach is used to find hidden populations (Libarkin & Kurdziel, 2002). The last type of sampling is stratified purposeful sampling which was used for the current study.

The current study used stratified purposeful sampling where 200 participants made the sample size. The participants used to gather data for this phase of the research study were the same as the participants used for the qualitative data collection for the research methodology, however in separate groups. For the current research study, the intervention was tested and the methodological approach were used to justify the gathered results from both the qualitative approach and a quantitative approach.

Further, the selection criteria were the same as the qualitative methodology, which required the participants to be in grade 11 with physical science as a subject. Creswell (1999) supports this method of sampling as the participants are defined by characteristics that allow them to be the sources of the data required.

3.6.3 Reliability and Validity

When a research study is conducted, it is the evidence-based practices implemented to gather findings of well-organised quality research studies (Heale & Twycross, 2015). Thus, the ability to analyse quantitative research becomes and imperative skill. According to Heale and Twycross (2015), authentic research provides thoroughness, which is the extent to which the researchers operate to enrich the quality of the studies. Therefore, in quantitative research, validity and reliability is achieved through measurement of the two.

In research, the more errors that occur the less reliable the measure of the study is (Hoepfl, 1997). A reliable measure provides consistent measurements that occur from one occasion to the next. Reliability is estimated using a coefficient which ranges from -0.0 to 1.0, however, when the reliability coefficient equals 0 the score is a reflection of a measurement error (Hoepfl, 1997). Measures with reliability coefficients of 70% or greater have acceptable reliability. In quantitative research, there are different methods for assessing reliability, the test-re-test reliability, inter-rater reliability, and the internal consistency reliability.

The current study uses one of the different types of reliability. The current study uses internal reliability, however, there are three different types used to estimate the internal consistency. The first is the item-total which looks at score consistency, the split-halve reliability randomly divides elements into two subsets and thereafter, focuses on the consistency in total scores between the two subsets. The current study used the Cronbach Alpha internal consistency, which reflects the theoretical average consistency between all possible split-halve reliabilities (Cronbach, 1951).

Moreover, some of the recognized advantages of using the Cronbach Alpha in research, Eberhard *et al.,* (2011) highlights the various reports acceptable for the alpha, which range from 0.70 to 0.95. Therefore, the presence of a low value of alpha could reflect a low number of questions or poor interrelatedness between items (Cronbach, 1951). If then a low alpha is obtained the items are to be revised or discarded, this helps with the reliability and credibility of the research (Cronbach, 1951). Further if alpha is too high it may be a reflection that some items are redundant, as they are testing the similar questions but in a different manner, thus a maximum alpha value of 0.90 has been suggested (Eberhard *et al.,* 2011).

Further, a good measure cannot only be reliable it too needs to be valid. A valid measure is to measure what it was intended to measure in research. Further, validity is not the property of a ratio, rather the indication of the extent to which an evaluated measures a certain evaluation in a known context. Therefore, one measure can be valid for one aspect, but not valid for the next. A measure cannot be valid unless it is reliable, however, a reliable measure may not be valid (Cronbach, 1951).

Moreover, there are three types of measurement validity in quantitative research. The first is face validity which is when a measure seems to measure what it was intended to measure. A given measure will have face validity if people think it has. The next type of validity measurement, is criterion validity which refers to the extent to which a measure separates the participants based on a behavioural criterion (Eberhard *et al.,* (2011).

The current research study uses construct validity as it reflects scientific investigations, involving a hypothetical construct which are aspects that cannot be observed with one's naked eye. Rather requires the need for empirical evidence gathered in research through data collection. Construct validity is evaluated by studying the relationship with scores between one aspect and other, construct validity sees if a particular measure relates as it should.

3.6.4 Data Analysis

In quantitative research, the data is analysed in such a manner as to explain the research findings. Firstly, the collected data is to be summarized for the researcher's simplicity. When data is summarized we look at the variables, the effect statistics, statistical models, complex models and simple statistics (Creswell, 1999). There are different scales in which data can be organized, the ordinal scale where the numbers represent the different ranks in which variables are measured.

Further, the interval scale which looks at the equal differences among numbers which represent equal differences in the variables being measured. The ratio scale represents equal amounts from an absolute zero and the gathered data can be compared as rations (Eberhard *et al.,* 2011). The current study uses the nominal scale where numbers are used to section the different categorizes, however, the numbers do not represent the quantity of degree.

According to Byrne (2007), there are various types of data and to analyse data, the researcher is required to know the type of data that was gathered in order to analyse it authentically, such as nominal, ordinal or ratios. Nominal variables are the most basic approaches of measurement in research. They are separate levels of measurement and a category can be represented by a number (e.g. 1 = male; 2 = female). However, no mathematical calculations can be done, nominal variables are not implemented often in statistics (Byrne, 2007). When variables increase or decrease in intervals it is ordinal variables, which also have discrete categories (Creswell, 1999). An example of such research is a Likert scale: 1 = very poor; 2 = poor; 3 = average, etc. which can be explained as, the value of 1, is 'less' or 'smaller' or 'worse' than the value of 2. Hence the current research study has implemented a Likert scale questionnaire, to understand the results obtained in the content test as well as learner attitudes.

However, the disadvantage of ordinal variables is the lack of inter measurable values that lie in between the values, which means one cannot justify how bad is 1 to 2 (Byrne, 2007). Ratios are at times called scales, continuous or interval variables, which are the strongest statistical variable type. Thus, ratio variables have an authentic natural order, with the points between distances being the same (Byrne, 2007).

Hence, stereotypically when research is conducted in groups around people, usually it implements either descriptive and inferential statistics or both to analyse the results obtained to draw conclusions. Below, is a clear explanation

3.6.4.1 Descriptive statistics

Descriptive statistics is an expression used when analysing data to assist in describing, reflecting or summarize data, in a manner that will generate patterns. However, this form of data analysis does not allow us to draw our own conclusions, rather as a manner to help researchers in explaining the data.

According to Wyllys (1978), in research when the statistics aim to describe measurable characteristics of a set criteria, such as people, it is known as descriptive statistics, as it aims to explain figures. Further, when explaining the data gathered using descriptive statistic, the characteristics used are totals, percentages in subsets, the median, the arithmetic and geometric means, the range, and the standard deviation (Wyllys, 1978). The data can be better explained by characterizing the data gathered, summarizing the data, displaying in tables, graphs, charts, etc.

There are two types of descriptive statistics that can be used to explain obtained data. The first is measure of central tendency, this approach is to describe the central position of a frequency in group data. The central position implies that the frequency distribution is a reflection of patterns and the distribution of the patterns are from the lowest to the highest (Creswell, 1999). By using statistics, including the mode, median, and mean, we are able to measures of central tendency.

Whereas, the measures of speed are a method used to summarize groups of data and this is achieved by describing how the data is spread out. The measures of spread acts as guides that assist researchers to summarize the extent of how spread out the scores will be (Byrne, 2007). The ability to explain the data, we use a number of statistics, the range, quartiles, absolute deviation, variance and the standard deviation (Creswell, 1999). In addition, operations such as tables, graphical representations, charts, statistical commentary or a discussion board can used to report back or represent the collected data.

Which suggests that descriptive statistics, do not allow one to assume some conclusions beyond the collected data and obtain a conclusion with respect to the hypothesis. Descriptive statistics are just approaches used to describe our data (Creswell, 1999). There are two approaches that are used to describe statistical data.

For the current research study a Likert sale was used for the mixed method approach. For a quantitative–empirical research approaches, a successful effective application is the aid of statistical methods for data analysis. Rensis Likert's (1903 – 1981) frequently practiced method of operationalising latent variables, in a quasi-metrical manner with summated ratings X_i (i = 1, 2, . . .), which, in order to ensure effectiveness, ought to be (i) *highly interdependent* and possess (ii) *high discriminatory power*.

Other researchers support the implementation of Likert scale. Hartley and Betts (2010) and Oppenheim (2000), argue that much is known about their properties, one can work with large sample size which in turn has a beneficial increase on the validity of the findings. Another added value is the fact that is gives the researcher the leeway to perform parametric analyses to the results. Further, when various scales are used in one study, it gives the researcher a bigger picture of the issues in question (Betts & Hartley, 2012). Instead of dealing with one question at hand, it gives way to tackle the 'how' and the 'why' of that question too, by drawing on emotions, experiences or values on a given subject and the participants do not always take not

3.6.4.2 Inferential statistics

However, the methods of inferential statistics seek to examining a sample of data with a set criteria, called a population (Wyllys, 1978). This is because, when working with a population the sample can be used to show evidence, by making assumptions or interpretation about given characteristic of the population. Further, the aim to implement this statistical approach is to give the correct inferences and to avoid giving the incorrect inferences, rather a just and clear idea to how a particular inference is correct. According to Wyllys (1978), a manner to achieve the goal of making the correct inferential is to make an unambiguous statement, called a statistical hypothesis. A statistical hypothesis is concerned about clear judgements about the population when making statistical technique, as evidence used to make a decision whether to accept or reject the hypothesis.

Further, a set advantages of inferential statistics is that a number of phenomena are by nature a variable, and the experimental alterations can be nothing more than chance (Wyllys, 1978). Which means that inferential statistics use tools that assist, in deciding if and when an observed difference is significant, or not, when the significant difference is very unlikely due to chance. Thus, a change that is statistically significant does not automatically mean it is of importance. Hence, a difference can be large enough to be of importance however be in fact, non-significant because it could easily have been due to mere chance (Wyllys, 1978).

In addition, a central custom within inferential statistics is to create a hypothesis, which is called a "null" hypothesis, which can be interpreted as the observed phenomenon being reasonable to achieve to chance. In most times, the researcher wants to reject the null hypothesis, since they an explanation other than chance for the phenomenon (Wyllys, 1978).

Further, according to Byrne (2007), a t-test relates the means of two knows values. The aim of the t-test is to distinguish differences in the means and to see if they are statistically significant or can be explained by chance. A t-test can be implemented when comparing differences between two groups. Further, a t-test implicates means, which means that the dependent variable must be a ratio variable and the independent variable is nominal or ordinal.

However, there are restrictions when implementing a t-test, it can only be used for examination when there are the means of two groups. The t-test proves to be statistically significant by providing a p-value (Byrne, 2007). The current research study employed a t.test for data analysis. In addition, the t-test is a useful technique that is used to comparing the means of two sets of data values. The comparison of the two statistic values evaluates if the difference between two means is statistically significant. Thus, for the current research study, the t-test was used to compare the means of the two groups, before and after the intervention. The t-test is used to compare two independent groups (independent-samples t-test) or to compare two measurements for the same group (paired-samples t-test).

3.7 Mixed methods

Due to the nature of the study, specific methods were followed per chapter with collecting and analyzing data within the different sections of this project. In addition, the background of this chapter acknowledges and explains how the different methodological approaches were implemented. With that said, the choice of any one method used was subjected, entirely to the nature of the research being conducted at a given time since a large number of research methods exist. A number of problems and shortfalls were considered upon designing and conducting this research. With the aim to guarantee that the current research circumvents shortfall particularly with regards to data collection and data analysis.

The mixed method approach for the current investigation aims to answers the following,

- *What is the effect of using virtual reality for learner improvement in chemistry?*
- *What is the effect of using physical models for learner improvement in chemistry?*

Mixed methodology method has been explored and therefore successfully used because of the nature of individual approaches to qualitative and quantitative approaches (Bazeley, 2003). In the early years of research, the combination of research approach methods in research was inhibited, as it was regarded and supposed as a way of 'creating' war within ontology and epistemology" (Bazeley, 2003). The awareness of "paradigm war" gained intellect and wore-off in the 1990s, due to the increased demand for the use of mixed method approaches being used within research (Bazeley, 2003).

For the current research study the research has highlighted their argument to what shaped their choice in research and the manner it was conducted. Below is a structured layout that the researcher followed for using a mixed method approach, for the quality of results and work and as a mean to validate the results gathered. In addition, the researcher used their knowledge of both the qualitative and the quantitative methodologies as this approach assists the researcher to perfect both methods.

3.7.1 Characteristics of mixed methods

Quantitative research approaches in education are important for measuring the educational phenomenon, with the view for precision and to determine and evaluate the value of educational programs. This research study aims to evaluate the quality of teaching and learning with the added use of geometric structures in Chemistry. According to Philips (2009), when a researcher uses both qualitative and quantitative research, it is an important aspect of educational research in order to capture the complexity of this field.

The term quantitative is used to describe a set of approaches that analyse information and/or data such as word, expressions or experiences, in classrooms and social interactions (Wertz & F.J, 2014). Levitt *et al.,* (2018) describe qualitative methods to result in a great deal of psychology as it increases the focus on experimental and correlation research methods. According to Hoepfl (1997), the phenomenological inquiry or qualitative research aims at understanding some phenomenon in context-specific settings using a realistic approach.

Qualitative research methodologies on science education engage a number of approaches and skills for the collection of data and data interpretation. Even so, the researcher is subjected to the researcher's qualitative knowledge (Bogdan & Biklen, 1992). Because of this, a threat is parallel to the logic of the approach and on the validity and reliability of the data, as its dependencies will rely heavily on one another (Libarkin & Kurdziel, 2002). As an outcome, decisions are often applicable to very limited circumstances and contexts in such research (Libarkin & Kurdziel, 2002). With respect to quantitative studies, already-defined methodologies for understanding and gathering data are used (Libarkin & Kurdziel, 2002).

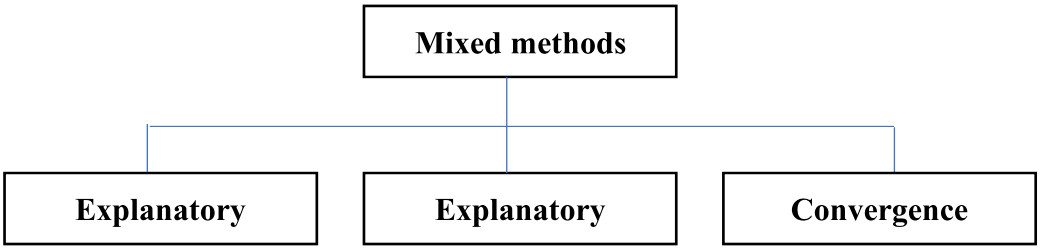
However, qualitative research will seek concept understanding, and so will a quantitative research methodology approach. Creswell (1994) further explains, that practical opinions can be successful in supporting a well-structured approach, which is followed by case divergence from such methodological needs. Therefore, statistical techniques manage the reliability and validity of quantitative methods.

The final factor to consider is theorizing or transforming perspectives, this is what guides the researcher. From theory, gender, race or a social class, in this research study, the researcher brought theories and framework to validate the mixed method approach. According to Creswell (2003), in a mixed method study, the information is gathered through the way the questions are asked, the selected participants, how the data is to be gathered and collected and the implication made from the study. In a number of mixed methods research studies, this mixed method approach and traditional approach and findings are first viewed as a discussion.

In a mixed methodological study, the researcher utilises fact when analyzing the design for this research study (Caruth, 2013). This is because both qualitative and quantitative approaches are integrated in the study, this is like creating a third research model that benefits more by using these two methods in an articulated manner. Furthermore, for this research study learner understanding, cognitive growth and learner performance in geometric structures was an objective. For that reason, more than one approach was required to explore the phenomena. Simply because the problem could not be deciphered or fully understood when only viewed from a single perspective of quantitative or qualitative (Creswell and Plano Clarck, 2011).

The research question needed to be viewed is not only how 'bad' or 'good' the learners performed, but also to why they are not performing. The researcher, therefore, aimed to view the prescribed tools in the classroom as well as the teaching approaches. Thus, a mixed method approach was vital since it can aim to explain the stats according to performance on content quantitatively and attitudes and emotions qualitatively. Therefore, the researcher analysed the various mixed method approaches and concluded in the best suitable approach for the present study. In Figure 1.1, the researcher explicitly explains the various mixed methods and seeks to make the reader aware why was the final choices made, by giving the pros and cons of each.

Figure 1.1 Representation of the structure for the research methodology



- *a. Exploratory design using sequential phases (quantitative – qualitative)*
- *b. Explanatory design using sequential phases*
- *c. Convergence design using parallel phases*
- *d. Triangulation design using parallel phases*
- *e. Complementary design using parallel phases (embedded design)*
- *f. Multilevel design (multiphase design)*
- g. *Emergent design (transformative design)*

In literature, there is two main structures considered in mixed method approaches. The first is where quantitative and qualitative approaches are not connected, integrated or combined in the research combination and structural integration of data (Bazeley, 2003). It is only done at the end of the study to answer the research question. Another approach is to combine the fields of the qualitative aspect and the quantitative aspect, this methodology approach combines and integrates the research findings and aims to magnify the data findings. According to Ponce (2011), this mixed method approach is to primarily produce more robust data findings, as it occurs in line with the philosophical positioning of the study.

Mixed method research study follows a basic research structure, namely (Figure 1.1),

a. *Research in sequential phase (sequential phase design)*

b. *Research in parallel phases (convergent parallel design)*

The researcher did not choose (a) research approach as the aim was to collect the data simultaneously from the participants. The researcher avoided having to do the first phase using another research approach to verify the findings or validate the findings of the first phase. According to the Caruth (2013), this approach to a research study is to deeply understand the research problem and so doing using the results of phase 1 to conclude phase two. The researcher followed (b) as both qualitative and quantitative methods is used simultaneously for the development of the study (Caruth, 2013). Which implies that the research did not use one methodological results to validate the other approach, rather used both to analyse and respond to the hypothesis.

Further, the choice of implementing a parallel phase (convergent parallel phase) is because for the current research study, the researcher issued out a content test for the participants to complete and attached to that was the Likert scale questionnaire with open-ended questions. This is to benefit and reason for using this approach, as parallel phases are an integration for the qualitative and quantitative methodologies.

In the two-known structure of mixed methods research, research in sequential phase (sequential phase design) and research in parallel phases (convergent parallel design). There exists a number of various approaches to creating and implementing a research design. The research continues to explain the various designs.

a. *Exploratory design using sequential phases (quan –qual)*

b. *Explanatory design using sequential phases*

c. *Convergence design using parallel phases*

d. *Triangulation design using parallel phases*

e. *Complementary design using parallel phases (embedded design)*

f. *Multilevel design (multiphase design)*

g. *Emergent design (transformative design)*

The research design mentioned above (a) was not used by the researcher as it did not meet the researcher's criteria. Creswell and Plano Clark (2011) explains that the main objective of this research design is to explore the problem within research. This design is used when the researcher needs to explore a topic using qualitative data before attempting to measure or test it quantitatively. The disadvantage of this design is the fact that takes time in conducting, the creation of instruments requires strict procedures.

This research design is used when little information about the problem is known; where (b) explanatory design using sequential is required to explore the research question in depth. Further Creswell and Plano (2011), explain it as measuring the attributes and properties of the problem in phase (l) and to qualify phase (ll). The current study aimed at collecting the data in one phase and not using one phase to explain the other, as the researcher aimed to explore why learners do not understand Chemistry concepts. The purpose of this method is to use the findings of the qualitative method to clarify the quantitative results. The disadvantages to this method are the time frame it takes to complete the task.

Further, the design(c) convergence design using parallel phases, the objective of this design is to study the researcher's problem and its dimension (Bazeley, 2003). This approach follows the quantitative approach and it is used to measure the properties and objectives aspects of the problem, where the qualitative is aimed at understanding and analyzing the subjective aspects. Explanatory mixed methods design aids to help the findings to clarify the quantitative results (Creswell, 1999). In quantitative data collection and analysis, the qualitative data collection and analysis aids to interpret qualitative results to explain the quantitative results.

Whereas, the exploratory mixed methods are used when a researcher is required to explore a topic by using qualitative data before attempting to measure or to test it quantitatively (Creswell, 1999). This methods approach is vital when the researcher does not know which constructs are appropriate or how to measure important variables. For the qualitative data collection and analysis, uses the quantitative data collection and analysis is used to interpret how quantitative results build on the qualitative results (Bazeley, 2003).

In triangulation, the mixed method used aids quantitative and qualitative methods in order to evaluate the phenomenon at hand. It uses qualitative and qualitative approaches in order to get better clarity of the phenomenon. The advantage of this deigns is the time limitation for the design (Caruth, 2013). This methods approach is most suitable when a researcher aims to collect both forms of data at the same time, on a single phenomenon to compare and contrast to produce an explanation (Bazeley, 2003).

Further is the (d) triangulation with parallel phases, as the researchers collects both qualitative and quantitative data to strengthen the findings for the research question. Authors like Bird and McCormic (1992), refer to this research approach comparison as more of a confirmation or a convergence. The disadvantage is the time and effort to collect and then analyze the two-different set of data at the same time. One other challenge is the comparing of the different sets of data. However, the research further explains how the reliability, validity, credibility, data collection and data analysis will be conducted.

Further, the embedded mixed method design is when the researcher needs to answer a secondary research question that is different from the research question at hand (Bazeley, 2003). This form of the method is based on a design to establish where the data can be collected at the same time. In the current research study, there are two methods used for qualitative and quantitative methods, though the data collection process is concurrent and happening in the same phase. However, the weight of both results obtained by the researcher is equal, which highlights the mixing of the data in this regard (Bazeley, 2003). For interpretation as well as the discussion section which requires the merging of the data findings. Where the researcher transforms one data type to another data type to easily merge, compare and integrate the data in the discussion.

Further through the (e) concurrent embedded strategy of mixed methods is seen as the order of the data collection phase, where quantitative and qualitative data is simultaneously collected. It differs for the traditional convergence design known, because with the concurrent embedded strategy. With that said it requires a primary approach to perform the secondary data, as the base is the supporting role in the entire procedure (Creswell, 2011). This approach allows the researcher to focus on one aspect at a time, the data collection is then said to be embedded or nested, this means the primary method can address a different question than that in phase one (Bazeley, 2003).

The current researcher study did not regard this research approach since the current study had a problem to answer and not an experiment to test. As Teddlie (1998) explains, when an experiment is done the quantitative data captured is then used to explain the expected treatment, while the qualitative is used to explore the process experienced by those participating in the experiment.

A researcher can choose to integrate both triangulation strategy and the embedded strategy and this is explained by Creswell (2007) as the multilevel design. For the current research approach, the researcher had to strategically approach the research question or view the question from different angles in an organization. A good theoretical approach is required as this approach can cater to a number of methods. As a mean to help the researcher gain a better perspective on a broader scale as one framework is used within another method. This method approach is unique, in a sense that it allows the researcher to adapt both quantitative and qualitative data at the same time.

It is an advantage for a research study to compare or view data from both perspectives from different data levels in the study. It can be a disadvantage through when the two data findings compared. As some faults (misunderstandings or misjudgements) may occur that might need attention to be resolved. Since the two methods are unequal in this research approach, the results are too unequal in priority. Which leads to unauthentic evidence within a study, leading to difficulties when it comes to the final stages of data interpretation.

Lastly, with the model of (g) concurrent transformative approach, it is led by the researcher's theoretical perspective of quantitative and qualitative methods, such as advocacy, critical theory on a conceptual or theoretical framework. However, with the current research study, the researcher was by led by the phenomenon is chemistry, 'why learners perform poorly in understanding chemistry concepts'. With this transformative methods approach, it being triangulated or used as an embedded design, it aims to satisfy the perspective of the researcher. The design could satisfy triangulation by conducting both qualitative and quantitative for best convergence of information as for the provision of evidence or an embedded approach where one method is embedded in another for diverse participation (Creswell, 2011).

Thus, this method approach for transformative invests in either triangulation or an embedded approach (Teddlie 1998). Where the two data findings are collected at the same time as per the collection data phase, however, the two data phases can have equal priorities or unequal priorities. If not followed and explained correctly it could lead to unclear validation of data and difficulties in the interpretation of the data.

3.7.2 Advantages of a mixed methods approach

Qualitative and quantitative research methodology approaches are two major types of methods that can be used for collecting and analyzing data, (Creswell, 1994). Among different researchers, the significance between the approaches of these two research methodologies is a source of great deliberation. Based on the research questions at hand, there is a clear distinction between the two methods, it is then up to the researcher to, therefore, find value in whichever method they prefer for a particular study (Patton, 1990). By supporting the researcher's choice there was an increase in the literature on mixed methods and multimedia learning. In the last decades and studies have shown growth with the diversity towards this research approach (Anguera, 2018).

According to Libarkin & Kurdziel (2002), both qualitative and quantitative methods are incorporated within a research study following a mixed method approach. Further, the positive argument is the strength in research through the combination of both methods to analyze data findings (Eberhard *et al.,* 2011). The mixed method approach allows the researcher to split their research into sections, to use one method approach for one section of their research and another research method for another section (Bazeley, 2003).

Additional authors (e.g. Leahey, 2006; Denzin, 1988) viewed the procedure of using a design with a mixed method approach as worthy. Since a mixed method approach aims to enhance the data with the validity and reliability of results in contrast to each method used independently (Eberhard *et al.,* 2011). Likewise, by incorporating both methods, it counters a number of weaknesses that each method might have encountered on its own (Derry, 2000). With the reasons stated above, researchers ensure a great pride to validity and reliability, by favouring mixed method designs to conduct their studies. As incorporating a mixed method approach allows them for more accurate results and to assist with the shortfalls each research methodology might have encountered (Leahey, 2006; Tashakkori & Teddlie, 2003; Alford, 1998).

The mixed methods research approach is widely used and implemented as it has the capacity to incorporate another approach such as action research, which benefits a solid methodological foundation and creating an integrated approach for addressing complex practical problems (Anguera *et al.,* 2018). Furthermore, the mixed methods approach enables researchers to be justifiable and to allow possible integrations. As in the current study, mixing the two methods allowed the researcher to make possible integrations. According to Anguera *et al.,* (2018) when the two methods (Qual-Quan) are combined, it can provide results that a scientifically sound and transferable results through integration.

Furthermore, an added advantage to using a mixed methods approach, it allows the researcher to evaluate similarities between the two approaches. This ability to preview research by minimizing the disadvantages that come with a methodology approach is an illustrated advantage (Anguera *et al.,* 2018). What makes a mixed method approach liable is taking into consideration the timing, the weighting of the results, values and the final stages of theorizing the data collected. Creswell *et al.,* (2003) view this as the four important aspects in a mixed method research approach.

The first is timing, which allows the researcher to choose if the phases of qualitative and quantitative are sequential or gathered at the same time (concurrently). Or the researcher can choose to gather data quantitatively and then follow with qualitative methods for data validity (Bazeley, 2003). In the current research study, the researcher collected the data sequentially, beginning with the quantitative method and followed by the qualitative method approach. Creswell *et al.,* (2003) support this approach as this approach allows the researcher to expand their understanding through the second phase. Furthermore, collecting the data sequentially and concurrently makes the data collection process more manageable.

The next important focus is the weighting, in some studies the weight and timing are equal and in some studies, it might emphasize or help predict the one or the other (Creswell *et al.,* 2003). In the current research study, the researcher used equal parts of weighting between the two methodologies. The first part the participants fill in a Linkert scale, open-ended question air, as well as a follow-up interview. The quantitative part of the research being the content test. This is for the validity and fairness of the research study. Take into consideration the quantitative research approach will be the qualitative analysis of the study, aimed to validate the results gathered in the quantitative research approach. Creswell *et al.,* (2003) support the researcher choice by explaining this framework as a deductive approach (i.e., testing a theory), as the research deliberately uses one form of data collected to support the other.

Further, the next important aspect is the mixing of the data in the methodology with the research question, the philosophy and with particular interpretation (Creswell et al, 2003). Therefore, the mixing of the two types of data (quantitative and qualitative) is to occur in several stages namely; when collecting the data, the data analysis, data interpretation or in all the three phases. For the current research study, the mixing of the data will occur in all three phases. As this research study is following equally sequential research methodology, the importance of the two-research methodology is needed for the fairness of this study.

Creswell (2003) supports the researcher's choice by viewing qualitative and quantitative data as the end of the spectrum combined in some way between the two. As the researcher used the written test for quantitative data analysis, further the researcher used the Linkert scale as the qualitative aspects of the researcher study, the open-ended questions were to validate the information gathered from the Linkert scale. For further authentic data validation, a questionnaire was conducted between 200 randomly selected participants, with open-ended questions, the interview was conducted by randomly selecting participants for follow up questions to understand and clarify the results of the content test.

Whereas the qualitative results, statements, and quotes are used to support or disconfirm the quantitative aspects of the results (Creswell, 1990). Furthermore, the advantages of this method approach are its ability to meet researchers halve way and to present well-validated findings. In addition to that, the time period required for concurrent triangulation mixed method approach is less than that of the sequential approach where there are different phases to collect the data for qualitative and quantitative (Bazeley, 2003). For the current study, the researcher chose to do both phases at once so as to minimize irregularities in the research paper. When data is not collected on the same day, one might not find the same participants in their return or their mood that day might just affect your results.

3.7.3 Justification for the choice of mixed method research approach

The researcher aimed to gain an in-depth understanding to why learner perform poorly and how tools can improve performance. The current research study supported the convergent parallel design which is a mixed-methods designs. Further, the research process is understood as qualitative and quantitative (QUAL+QUAN; Morse, 1991). Thus, when conducting a convergent parallel design, it required the researcher to concurrently conduct the quantitative and qualitative aspects of the research study at the same phase of the research process, weighs the methods equally, analyzes the two components independently, and interprets the results together (Creswell & Pablo-Clark, 2011).

Further, due to corroboration and validation, for the current research study the researcher triangulated the two methods by directly paralleling the quantitative data findings and qualitative data findings. For the current research process, two datasets have been obtained, analyzed separately, and compared to answer to the hypothesis. The researcher choice in implementing the parallel phase was led by the determination of the study and its research question, with the great support from literature and methodological discussions in the literature (Morse 1991; Morgan 1998; Tashakkori and Teddlie 1998; Creswell et al. 2003).

Further, the current research study followed an explanatory design using sequential phases, the researcher's reason to support the choice of selected design was for the researcher to study and describe the research problem at hand in depth. Explanatory research aims to understand and interpret the 'why' questions.

Further the integration of the explanatory sequential design is a process that requires the mixing of quantitative and qualitative methods (Green, Caracelli, and Graham 1989; Tashakkori and Teddlie 1998; Creswell et al. 2003). In addition, the mixed-methods sequential designs, requires that the quantitative and qualitative phases are connected (Hanson et al. 2005) when analysing and interpreting the collected data from various phases. In the sequential explanatory design, it is also true that a researcher can merge the two phases and appoint participants for a qualitative follow-up from the first phase (Creswell et al. 2003). Another approach can be connecting be the development of the qualitative data and support the results from the first quantitative phase. For the current research study, both qualitative and quantitative data was analysed and interpreted to see if the same interpretations were gathered.

The main aim for the researcher to implement the convergent parallel mixed-methods study was to conclude whether various teaching tools can impact and influence learner performance in Chemistry. In other words, the current study seeks to answer whether virtual reality and physical models as educational tools and as teaching approaches can change learner metacognition, improve Chemistry knowledge and change their attitudes towards the subject.

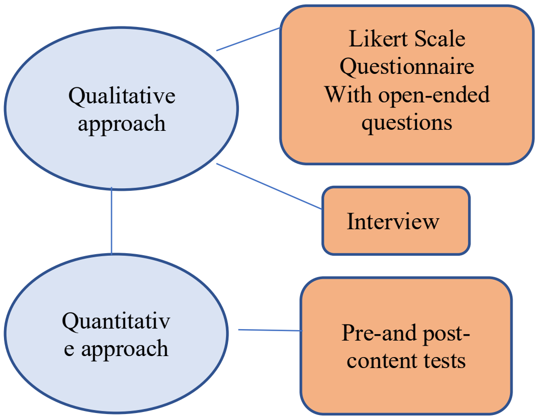


Figure 3.1 *Procedure followed for the current research study*

3.7.4 Procedure followed in the present study

Two groups of learners were exposed to a number of teaching methods (virtual teaching methods and physical-models teaching). The learners completed a test (see appendix 1) based on chemistry concepts. The test was structured using the Department of Education (DoE) physical sciences Diagnostic report for the years 2010-2016 and the prescribed CAPS curriculum document and previous past papers. Further, the learners responded to a Likert scale with an open-ended questionnaire (see Appendix F).

For this to be achieved, the quantitative aspect of the research study was used as the measure and for the properties of the problem (phase). The qualitative aspect of this study (phase 2) was to strengthen and to deepen the finding for phase 1. The researcher issued a test and quantified the results (phase 1), followed by the participants answering questions from a Likert scale. The questionnaire aimed to find out the level of teaching and learning and how it can be improved, as well as how the methodology approach helped, using a scale of 1 to 3. Where 1 being agree and 3 being disagree along with open-ended questions for all the participants to elaborate (quantitative aspects) on weaknesses in teaching and learning on the perceived phenomenon and the interviews. The quantitative phase is to measure the pride and levels of teaching and learning

There was a total of two hundred participants in the study who that were divided in to two groups, each group with one hundred participants. All two hundred participants participated in the qualitative and the quantitative research methodology, it was the interventions used that separated the two groups. The current research study consisted of three phases, phase one was the pre-intervention (which tested learner performance), phase two was the interventions (virtual reality and physical models that were used to teach the participants) and phase 3 was the post-intervention (which looked at how learners performed after the teaching intervention)

For the first phase of the research study, both groups completed the content test with the questionnaire and the given time was thirty minutes. Once all content tests and Likert scale questionnaires were handed back to the researcher, they were kept separate according to the designated groups. For group 1 and group 2 (the virtual reality and the physical model group) the researcher collected the scripts and gave each script a number from 1 to 100 e.g. P1, P2 which stand for participant 1, participant 2, which was written on the script, this was done to keep record of the number of scripts. This phase of the research the researcher aimed to observe;

a) *The individual performances of the two groups*
b) *The performance of each individual*
c) *Participant attitudes towards Chemistry*

After one week, the researcher went back to the participants and in their designated groups intervened. Group was taught Chemistry concepts and knowledge using virtual reality. Various videos and animations were showed to the participants as an approach to improve their Chemistry understanding. The other group, group two was taught using physical models, participants were given the opportunity to design and make atoms and molecules in tier 3D appearances.

Further, another week later, the researcher visited the participants. This phase of the research study, the participants wrote the same test and Likert scale as before. This was to see if their understanding would have improved from phase 1 which was before the teaching intervention. For this phase of the research the researcher also randomly selected twenty-five participants to participate in an interview. The questions in the interview were structured around the hypotheses of the current research study.

In collecting the data, the researcher aimed to answer:

How do teaching methods improve academic performances in Chemistry?

- *a) Change in results from before and after the intervention*
- *b) Learner attitudes about the intervention*
- *c) Learner attitudes about understand chemistry*

Further, to prove the hypothesis that lead to the current research study:

- *a) What are the effects of using physical models to improve learner performance in geometric shapes?*
- b) *What are the effects of using virtual reality to improve learner performance in geometric shapes?*

The figure below is a summary of the research methodological procedure for both groups and the phases followed by each group.

Figure 1.2 *Summary of the research structure and procedure for the methodology approach*

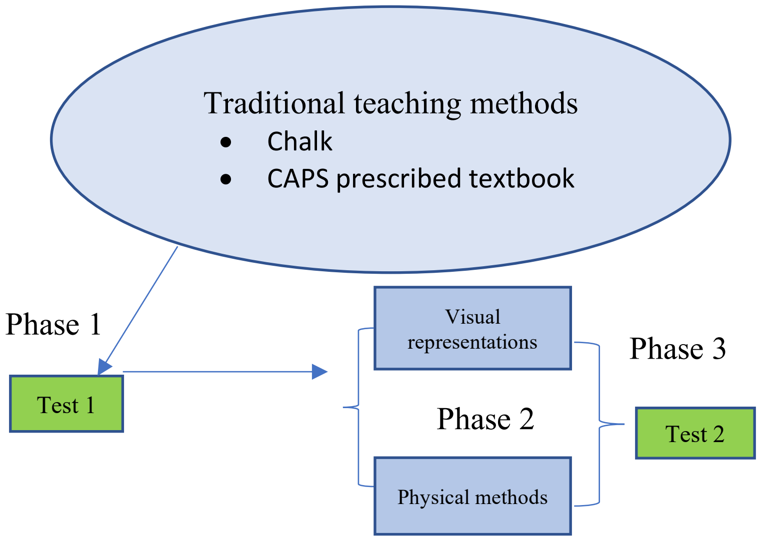


Figure 3.2 *Phases followed by each group as per phase*

The first and second phases are a reflection of the quantitative approach to the mixed method methodology. Phase three of the research study had both groups complete a questionnaire on their views, experiences, and opinions (Appendix F) in their understanding of the chemistry concept of geometric shapes. The researcher hosted interviews with learners selected randomly from each group. This was done by the researcher to gain a better understanding of the answers and reasoning provided from the questionnaires completed by the participants for their pre-and post-tests.

Table 3.1 below explains the procedure of the research study in terms of phases and results.

Table 3.1 *Representation of the methodology and the activities each group will take part in***.**

Groups	**Pre-test**	**Visual representation**	**Physical models**	**Post-test**	**Questionnaire**
Group 1	All	Visual representations	No	All	Yes
Group 2	All	No	Physical models	All	Yes

Data was collected from the tests as well and the questionnaires and were analysed quantitatively and qualitatively following rules and criteria. Moreover, qualitative data analysis relies on inductive reasoning processes from the Likert scale and the closed and open-ended questionnaires. This is for the understanding and structure of scientific meanings to be derived from the learners' test data (Libarkin & Kurdziel, 2002) (Table 3.1).

From these analyses conclusions are drawn on the students' response to the different teaching methodologies and cognitive tools in the Chemistry classroom. The statistical (quantitative) analysis was done using the t.test (Statistical Software), such an analysis reflects the relationship between two means (of the pre-test and post-tests). This was measured using the paired data t-test by testing the hypothesis that the two means are to be different. This relationship would be descriptive of the effect of the visual representations and physical models on students' understanding. Such that if the two means are not different (i.e. accepting the null hypothesis) then the teaching methodologies and tools had no effect on the students' understanding.

In addition, for the collection and the analysis of data in a qualitative research methodology it avails an array of instruments available that can be utilised for any empirical investigation as instrument validity requires careful attention (Creswell, 1999). Further, Heffner (2004) explains content validity as the instrument's capability to represent clearly and appropriately on the content of a particular construct. In this regard, the content domain represented is defined by experts according to how well it is able to cover such content domain. Whereas, concurrent validity communicates the measure of the same variable of two different occasions to two different instruments (Heffner, 2004). The instrument used was a content test structured instrument which allowed the researcher to view the learner conceptual understanding and cognitive development within chemistry. The test incorporated a mixture of grade 10 and 11 chemistry concepts for the understanding of chemistry knowledge, geometric shapes and geometric orientation. The questionnaire is structured so as to enquiry on the students' understanding on chemistry concepts, opinions and comments about the teaching tools suitability for this research.

3.7.5 Instrument description

Further, the content test (see Appendix E) is the quantitative part of the research investigation, where numerical results will be used to explain data findings. The test had a total of 40 marks to be obtained by the learners, question 1, looked at the Lewis notation which is a topic covered in grade 10. The Lewis notation is where learners are taught electron arrangement, through the Aufbau diagram and the electron configuration (sp notation). Where question 2, required the learners to use the name of the molecule given and provide the molecular formula. When the learners have to use the name and molecular formula to draw the Lewis structure, it helps check whether they understand the coloration of the name and the molecular formula because this requires them to visualize the molecule and the electron behaviours along with it.

Further, in question 3, the learners had to answer by using two atoms and how they bond to form a molecule. The introduction to this topic is done in grade 10 but covered in depth in grade 11. Question 4, is grade 11 content; the aims is to tests the background on learners understanding. In this question, the participants were expected to apply the rules on what determines bond type. They had to applying their knowledge and understanding of the Lewis structure, molecular shape and the molecular polarity. The final question is question 5, and this content is done in grade 11. This question was similar to question 4 but did not require the participants to use any methods, however requires them to determine the answer by looking at the molecular formula.

Furthermore, the qualitative part of this research is where valued attitude and perception is used to analyse the data findings of the participating learners. This section forms part of the third phase of the research investigation which requires the learners to complete a Likers scale questionnaire (see Appendix F). The questionnaire is structured in a manner that will allow the researcher to investigate learner attitudes towards chemistry, their perception on Chemistry and how they perceive themselves as Chemistry students.

Part of the Linkert scale questionnaire that was written by the participants included closed and open-ended items (Appendix F), which used three options, 'Agree', 'Neutral' and 'Disagree' which were converted into three-point rating scales, agree-1, neutral-2 and disagree-3 (Hyrkäs, Appelqvist-Schmidlechner, & Oksa 2003). The open-ended questions aimed to explain the responses provided by the participants to the closed questions. For example, if the participant agreed with a statement in the Likert scale questionnaire, the participant was then asked to elaborate on his/her reasoning in spaces provided below. The researcher went through all ten questions of Likert scale and tallied all the values and gave each participant a mark out of ninety (and a percentage) to see their level of understanding. This was done for all 200 participants.

3.7.6 Data analysis

Qualitative research contains a vast aspect of enquiring about participants' behaviours, experiences, and opinions. This includes the informant's points of view from human reasoning and the understanding of social sciences such as science education (Zucker, 2001). In the current research study the research inquiries to understand participant reasoning on performance and understanding of geometric shapes in chemistry.

In addition, the researcher used a Likert scale questionnaire with open-ended questions to gain understanding. Further Zucker (2001) supports this methodology approach with theoretical significances that qualitative methods are often used with the aim in describing and discovering events, phenomena, and situations within educational studies. However, when little is known about a particular phenomenon, researchers (e.g. Hoepfl, 1997; Strauss & Corbin, 1990) agree that qualitative methods are best suited for situations where little is known.

In addition, to such cases, the qualitative method is used to express certain variables that can later be confirmed over quantitative methods, even though quantitative methods may not constantly trail qualitative methods (Hoepfl, 1997). In the current study, the researcher uses the content test for the quantitative approach and clarifies with reasoning using the qualitative method through the Likert scale. Because of this, the researcher acquires a role where they remain "objective" as an instrument where they are only allowed to make observations, interpretations, and descriptions of the given data (Patton, 1990). With this said, the qualitative research approach is on discovering the meaning of events resulting in the research being very descriptive in nature (Hoepfl, 1997). Attention is paid towards qualitative researchers for being distinctive as well as pervasive for seeking uniqueness of each research case (Hoepfl, 1997, p. 3).

3.8 Conclusion

For the current research study the design of the study was explicitly indicated with all advantages and disadvantages of the selected approaches, further explaining their issues of validity and reliability. The chapter also underlined the procedures that were monitored during data collection process. The instruments used for both the qualitative approach and the quantitative approach, with details of their structures and aims of the instruments.

The procedure with descriptions includes research methodology; how the participants were selected and divided; the groups in which they were placed into; the intervention; the entire data collection procedure; and how the instruments were therefore utilized; the study design. In the next chapter of the study the collected data and results are presented.

CHAPTER 4

4.1 Introduction

The present chapter aims to provide a discussion on the data that was obtained from grade 11 chemistry learners. Since the current research employed a sequential mixed method (qualitative and quantitative) the discussed results follow the following sequence; the content test, the questionnaire with open-ended questions and the interviews. The quantitative methodology is further validated by the qualitative methodology approach.

For the current study, a t-test and Mann-Whitney test were used to analyze the quantitative results of the content test. The researcher calculated the reliability content test and questionnaire was acceptable (Cronbach alpha value was over 0.7), which is an acceptable level in statistics (Maree, 2007). Other results are presented below.

4.2 Physical model group

The first set of data that was analysed relates to the group of students who accessed the physical model as an intervention. Students' performance in this group are discussed below.

4.2.1 Students content understanding prior to experiment

The results of the study show that, prior to exposure to the intervention (physical model and virtual model), both sets of students had poor content understanding related to the geometric structures. For example, students in the physical model group and virtual model group scored highest in the questions testing knowledge of the Lewis structure of ammonia, where the mean score was 40% (see Table 4.1). However, the two groups scored lowest in the questions testing their ability to interpret Lewis structures. In this instance, the average score was 4.5%. The overall poor performance in the pre-tests is evident in that the overall average score for the physical model group was 27.33% (S.D. = 20.21%). Similarly, the average score for the virtual reality group was 24.26% (S.D. = 19.37%). These scores suggest that the students had major difficulties learning geometric structures.

Table 4.1 Students' content understanding prior to exposure to the animation. Physical model group (n = 100), virtual model group (n = 101).

Group		Mean	Std. Deviation	Std. Error Mean
Valence electrons in nitrogen	Pre-Test Physical Model	38,0000	43,29835	4,32984
	Pre-Test Virtual Model	26,7327	40,96606	4,07628
Lewis structure of ammonia	Pre-Test Physical Model	40,0000	45,50502	4,55050
	Pre-Test Virtual Model	40,0990	41,24306	4,10384
Geometric shape of ammonia	Pre-Test Physical Model	33,5000	43,84027	4,38403
	Pre-Test Virtual Model	29,7030	40,11123	3,99122
Interpreting Lewis Structure & Ball and Stick structure	Pre-Test Physical Model	23,0000	35,83069	3,58307
	Pre-Test Virtual Model	20,2970	34,04278	3,38738
Interpreting Lewis Structure & Ball and Stick structure	Pre-Test Physical Model	16,5000	32,60957	3,26096
	Pre-Test Virtual Model	17,8218	35,06006	3,48861
Interpreting Lewis structure	Pre-Test Physical Model	8,5000	21,38512	2,13851
	Pre-Test Virtual Model	6,4356	20,81270	2,07094
Interpreting Lewis structure	Pre-Test Physical Model	4,5000	20,21975	2,02198
	Pre-Test Virtual Model	4,4554	18,84013	1,87466

Content Knowledge	Pre-Test Physical Model	27,3331	20,20824	2,02082
	Pre-Test Virtual Model	24,2568	19,36886	1,92727

A t-test comparing the performance of the students in each of the sections of test revealed that learner performance was at times significantly different between the groups and sometimes not (Table 4.2).

Table 4.2. A test comparing student performance in the physical model group and virtual model group, prior to exposure to the interventions.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Valence electrons in nitrogen	Equal variances assumed	1,871	0,173	1,895	199	0,060	11,26733	5,94508	-0,45611	22,99076
	Equal variances not assumed			1,895	198,155	0,060	11,26733	5,94672	-0,45965	22,99431
Lewis structure of ammonia	Equal variances assumed	5,696	0,018	-0,016	199	0,987	-0,09901	6,12469	-12,17662	11,97860
	Equal variances not assumed			-0,016	196,707	0,987	-0,09901	6,12769	-12,18341	11,98539

Geometric shape of ammonia	Equal variances assumed	3,136	0,078	0,641	199	0,522	3,79703	5,92607	-7,88893	15,48299
	Equal variances not assumed			0,640	197,083	0,523	3,79703	5,92870	-7,89481	15,48887
Intepreting Lewis Structure & Ball and Stick structure	Equal variances assumed	0,793	0,374	0,548	199	0,584	2,70297	4,92954	-7,01786	12,42380
	Equal variances not assumed			0,548	198,259	0,584	2,70297	4,93080	-7,02057	12,42651
Intepreting Lewis Structure & Ball and Stick structure	Equal variances assumed	0,514	0,474	-0,277	199	0,782	-1,32178	4,77710	-10,74202	8,09846
	Equal variances not assumed			-0,277	198,229	0,782	-1,32178	4,77538	-10,73884	8,09528
Intepreting Lewis structure	Equal variances assumed	1,504	0,222	0,694	199	0,489	2,06436	2,97651	-3,80520	7,93391

	Equal variances not assumed			0,693	198,726	0,489	2,06436	2,97692	-3,80604	7,93475
Intepreting Lewis structure	Equal variances assumed	0,005	0,946	0,016	199	0,987	0,04455	2,75634	-5,39082	5,47993
	Equal variances not assumed			0,016	197,718	0,987	0,04455	2,75731	-5,39295	5,48206
Content Knowldge	Equal variances assumed	0,000	0,988	1,102	199	0,272	3,07627	2,79192	-2,42927	8,58181
	Equal variances not assumed			1,102	198,455	0,272	3,07627	2,79251	-2,43053	8,58307

The Levene's Test for equality of variances (Table 4.2) show that there was generally no significant difference in the student performance in the different sections of the test ($P > .05$). There was however a significant difference in the performance related to the knowledge of the Lewis structure of ammonia ($p = .018$). these results suggest that the was generally equal variance between the two student group performances prior to exposure to the interventions. A similar pattern was also observed in the t-test for equality of means. In this regard, results showed that in different sections of the test, there was no significant difference in the average student performance ($p > .05$). These results suggest that there was similarity in how students responded to the tests prior to exposure to the interventions.

4.2.2 Students content understanding following exposure to the interventions

Results from the posttest suggest that student performance improved significantly, even though the standard deviation was high (see Table 4.3. For example, the average score in the physical model group was 80.85% (S.D. = 28.02%), while in the virtual reality group it was 76.73% (S.D. = 33.67%).

Table 4.3 Students' content understanding prior to exposure to the animation. Physical model group (n = 100), virtual model group (n = 101).

Group		Mean	Std. Deviation	Std. Error Mean
Valence electrons in nitrogen	Post Test Physical Model	62,8713	44,52722	4,43062
	Post Test Virtual Model	69,3069	46,35207	4,61220
Lewis structure of ammonia	Post Test Physical Model	62,8713	43,38978	4,31744
	Post Test Virtual Model	75,2475	40,38797	4,01875
Geometric shape of ammonia	Post Test Physical Model	60,8911	46,69259	4,64609

	Post Test Virtual Model	61,8812	46,98325	4,67501
Interpreting Lewis Structure & Ball and Stick structure	Post Test Physical Model	73,7624	42,77503	4,25627
	Post Test Virtual Model	68,3376	42,81720	4,26047
Interpreting Lewis Structure & Ball and Stick structure	Post Test Physical Model	44,0594	47,05695	4,68234
	Post Test Virtual Model	59,4059	46,21302	4,59837
Interpreting Lewis structure	Post Test Physical Model	64,8515	45,02475	4,48013
	Post Test Virtual Model	53,9604	47,26688	4,70323
Interpreting Lewis structure	Post Test Physical Model	61,8812	46,44810	4,62176
	Post Test Virtual Model	57,4257	46,03593	4,58075
Content Knowledge	Post Test Physical Model	80,8582	28,02616	2,78871
	Post Test Virtual Model	76,7322	33,67168	3,35046

Comparing the two groups' post test results (Table 4.4) however showed that with regards to individual sections of the test, there was no significant difference in the variances (Levene's Test for Equality of Variances, $p > .05$). However, the t-test showed that there was a significant difference in the learner's performance related to Interpreting Lewis Structure & Ball and Stick structure ($p = .020$). Looking at the overall post test results, there was significant difference in the variances (Levene's Test for Equality of Variances, $p > .027$), but no significant difference between the mean scores ($p > .05$). Analysis of the performance in the physical model group suggest that there was significant difference between students' performance in the pre-test and posttest ($p < .001$) (Table 4.5). These results suggest that students' content understanding following exposure to the physical models improves significantly. For example, the lowest mean difference in the individual sections of the text was 22.87% for the knowledge of the Lewis structure of ammonia, and the highest mean difference was 57.38% for interpreting Lewis structures. A similar trend was also observed for the virtual reality group (Table 4.6).

Table 4.4. A test comparing student performance in the physical model group and virtual model group, prior to exposure to the interventions.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Valence electrons in nitrogen	Equal variances assumed	0,322	0,571	-1,006	200	0,316	-6,43564	6,39553	-19,04697	6,17569
	Equal variances not assumed			-1,006	199,678	0,316	-6,43564	6,39553	-19,04710	6,17581
Lewis structure of ammonia	Equal variances assumed	3,473	0,064	-2,098	200	0,037	-12,37624	5,89836	-24,00720	-0,74527
	Equal variances not assumed			-2,098	198,981	0,037	-12,37624	5,89836	-24,00756	-0,74491

Geometric shape of ammonia	Equal variances assumed	0,037	0,847	-0,150	200	0,881	-0,99010	6,59104	-13,98695	12,00675
	Equal variances not assumed			-0,150	199,992	0,881	-0,99010	6,59104	-13,98695	12,00675
Interpreting Lewis Structure & Ball and Stick structure	Equal variances assumed	0,299	0,585	0,901	200	0,369	5,42475	6,02225	-6,45050	17,30000
	Equal variances not assumed			0,901	200,000	0,369	5,42475	6,02225	-6,45050	17,30000
Interpreting Lewis Structure & Ball and Stick structure	Equal variances assumed	0,267	0,606	-2,338	200	0,020	-15,34653	6,56272	-28,28754	-2,40553
	Equal variances not assumed			-2,338	199,935	0,020	-15,34653	6,56272	-28,28757	-2,40550
Interpreting Lewis structure	Equal variances assumed	1,767	0,185	1,677	200	0,095	10,89109	6,49553	-1,91743	23,69961

	Equal variances not assumed			1,677	199,530	0,095	10,89109	6,49553	-1,91761	23,69979
Interpreting Lewis structure	Equal variances assumed	0,131	0,718	0,685	200	0,494	4,45545	6,50722	-8,37611	17,28700
	Equal variances not assumed			0,685	199,984	0,494	4,45545	6,50722	-8,37612	17,28701
Content Knowledge	Equal variances assumed	4,990	0,027	0,947	200	0,345	4,12604	4,35918	-4,46981	12,72189
	Equal variances not assumed			0,947	193,623	0,345	4,12604	4,35918	-4,47154	12,72362

Table 4.5. A comparison of student performance in the physical model group prior and after exposure to the physical models.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Valence electrons in nitrogen	Equal variances assumed	0,483	0,488	-4,014	199	0,000	-24,87129	6,19586	-37,08925	-12,65333
	Equal variances not assumed			-4,015	198,936	0,000	-24,87129	6,19499	-37,08756	-12,65501
Lewis structure of ammonia	Equal variances assumed	1,341	0,248	-3,647	199	0,000	-22,87129	6,27126	-35,23794	-10,50464
	Equal variances not assumed			-3,646	198,343	0,000	-22,87129	6,27275	-35,24113	-10,50144

Geometric shape of ammonia	Equal variances assumed	3,116	0,079	-4,287	199	0,000	-27,39109	6,38995	-39,99180	-14,79038
	Equal variances not assumed			-4,288	198,443	0,000	-27,39109	6,38794	-39,98805	-14,79413
Interpreting Lewis Structure & Ball and Stick structure	Equal variances assumed	5,885	0,016	-9,116	199	0,000	-50,76238	5,56853	-61,74328	-39,78147
	Equal variances not assumed			-9,124	193,697	0,000	-50,76238	5,56365	-61,73550	-39,78925
Interpreting Lewis Structure & Ball and Stick structure	Equal variances assumed	58,581	0,000	-4,821	199	0,000	-27,55941	5,71600	-38,83112	-16,28770
	Equal variances not assumed			-4,830	178,188	0,000	-27,55941	5,70598	-38,81939	-16,29942
Interpreting Lewis structure	Equal variances assumed	146,303	0,000	-11,315	199	0,000	-56,35149	4,98006	-66,17195	-46,53102

	Equal variances not assumed			-11,351	143,249	0,000	-56,35149	4,96435	-66,16434	-46,53863
Interpreting Lewis structure	Equal variances assumed	224,341	0,000	-11,336	199	0,000	-57,38119	5,06192	-67,36307	-47,39930
	Equal variances not assumed			-11,375	136,878	0,000	-57,38119	5,04470	-67,35682	-47,40555
Content Knowledge	Equal variances assumed	11,478	0,001	-15,517	199	0,000	-53,52512	3,44937	-60,32712	-46,72311
	Equal variances not assumed			-15,542	181,925	0,000	-53,52512	3,44393	-60,32029	-46,72994

Table 4.6. A comparison of student performance in the virtual model group prior and after exposure to the virtual models.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Valence electrons in nitrogen	Equal variances assumed	6,278	0,013	-6,917	200	0,000	-42,57426	6,15536	-54,71199	-30,43653
	Equal variances not assumed			-6,917	197,024	0,000	-42,57426	6,15536	-54,71310	-30,43541
Lewis structure of ammonia	Equal variances assumed	0,395	0,531	-6,119	200	0,000	-35,14851	5,74385	-46,47480	-23,82223
	Equal variances not assumed			-6,119	199,912	0,000	-35,14851	5,74385	-46,47483	-23,82220
Geometric shape of ammonia	Equal variances assumed	14,752	0,000	-5,235	200	0,000	-32,17822	6,14699	-44,29945	-20,05699
	Equal variances not assumed			-5,235	195,199	0,000	-32,17822	6,14699	-44,30126	-20,05517

Interpreting Lewis Structure & Ball and Stick structure	Equal variances assumed	16,767	0,000	-8,826	200	0,000	-48,04059	5,44298	-58,77358	-37,30761
	Equal variances not assumed			-8,826	190,331	0,000	-48,04059	5,44298	-58,77690	-37,30429
Interpreting Lewis Structure & Ball and Stick structure	Equal variances assumed	36,572	0,000	-7,205	200	0,000	-41,58416	5,77195	-52,96584	-30,20248
	Equal variances not assumed			-7,205	186,468	0,000	-41,58416	5,77195	-52,97087	-30,19745
Interpreting Lewis structure	Equal variances assumed	214,153	0,000	-9,248	200	0,000	-47,52475	5,13899	-57,65830	-37,39121
	Equal variances not assumed			-9,248	137,372	0,000	-47,52475	5,13899	-57,68650	-37,36301
Interpreting Lewis structure	Equal variances assumed	225,694	0,000	-10,702	200	0,000	-52,97030	4,94950	-62,73021	-43,21039
	Equal variances not assumed			-10,702	132,583	0,000	-52,97030	4,94950	-62,76051	-43,18009
Content Knowledge	Equal variances assumed	33,754	0,000	-13,576	200	0,000	-52,47535	3,86522	-60,09717	-44,85353
	Equal variances not assumed			-13,576	159,647	0,000	-52,47535	3,86522	-60,10891	-44,84178

Table 4.7. A comparison of student performance in the post test comparing the physical model group and the virtual model group.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Valence electrons in nitrogen	Equal variances assumed	0,322	0,571	-1,006	200	0,316	-6,43564	6,39553	-19,04697	6,17569
	Equal variances not assumed			-1,006	199,678	0,316	-6,43564	6,39553	-19,04710	6,17581
Lewis structure of ammonia	Equal variances assumed	3,473	0,064	-2,098	200	0,037	-12,37624	5,89836	-24,00720	-0,74527
	Equal variances not assumed			-2,098	198,981	0,037	-12,37624	5,89836	-24,00756	-0,74491

Geometric shape of ammonia	Equal variances assumed	0,037	0,847	-0,150	200	0,881	-0,99010	6,59104	-13,98695	12,00675
	Equal variances not assumed			-0,150	199,992	0,881	-0,99010	6,59104	-13,98695	12,00675
Interpreting Lewis Structure & Ball and Stick structure	Equal variances assumed	0,299	0,585	0,901	200	0,369	5,42475	6,02225	-6,45050	17,30000
	Equal variances not assumed			0,901	200,000	0,369	5,42475	6,02225	-6,45050	17,30000
Interpreting Lewis Structure & Ball and Stick structure	Equal variances assumed	0,267	0,606	-2,338	200	0,020	-15,34653	6,56272	-28,28754	-2,40553
	Equal variances not assumed			-2,338	199,935	0,020	-15,34653	6,56272	-28,28757	-2,40550
Interpreting Lewis structure	Equal variances assumed	1,767	0,185	1,677	200	0,095	10,89109	6,49553	-1,91743	23,69961
	Equal variances not assumed			1,677	199,530	0,095	10,89109	6,49553	-1,91761	23,69979
Interpreting Lewis structure	Equal variances assumed	0,131	0,718	0,685	200	0,494	4,45545	6,50722	-8,37611	17,28700
	Equal variances not assumed			0,685	199,984	0,494	4,45545	6,50722	-8,37612	17,28701

Content Knowledge	Equal variances assumed	4,990	0,027	0,947	200	0,345	4,12604	4,35918	-4,46981	12,72189
	Equal variances not assumed			0,947	193,623	0,345	4,12604	4,35918	-4,47154	12,72362

The results presented in Tables 4.5 and Table 4.6 suggest that the physical model and virtual models had a significant positive impact on students understanding of geometric structures. The researcher was however interested in determining if either of these two had a greater impact. In this instance, the post test results of the two groups were compared. As shown in Table 4.7, there was no significant difference in the overall content knowledge performance ($p = .345$). However, there was significant difference in some sections of the test. For example, in the items propping knowledge of the Lewis structure of ammonia and interpreting Lewis structures and ball and stick structures there was a significant difference ($p < .05$). Overall however, the observation made was that both the physical model and virtual models have a significantly positive impact on learners' understanding of geometric structures.

4.3 Learning difficulties associated with physical and virtual models

While the overall performance was positively high following exposure to the physical and virtual models, the researcher did investigate potential learning difficulties associated with these models. It was observed in the physical model group that generally, students reported more learning difficulties in the pre-test than they did in the post test (Table 4.8). For example, 46% of the participants reported in the pre-test that they have difficulties using given information to predict the shape of a molecule.

Further, this number dropped to 8% in the post test. Similarly, 53% reported in the pre-test that they have difficulties illustrating the different molecular shapes and geometric orientations. This number however dropped to 5% in the post test. Interestingly, when asked if they have difficulties in following instructions and interpreting pictures in computer simulation on geometric structures, 55% of the participants in the pre-test said yes. However, 100% of the participants said yes in the post test. This was the only case in which more participants reported learning difficulties in the post-test than in the pre-test. The Mann-Whitney test actually revealed that there was a significant difference in percentage learning difficulties reported in the pre-test compared to those reported in the post-test ($p < .001$).

Table 4.8. Learning difficulties reported by students in the physical model group.

Difficulty	Group	Frequency	Percent	Cumulative Percent
difficulties using given information to predict the shape of a molecule	Pre-Test	46	46,0	100,0
	Post Test	8	7,9	100,0
difficulties illustrating the different molecular shapes and geometric orientations	Pre-Test	53	53,0	100,0
	Post Test	5	5,0	100,0
difficulties synthesizing information to predict the shape and structure of a molecule	Pre-Test	41	41,0	100,0
	Post Test	9	8,9	100,0
difficulties relating the molecular shape to the name and properties of the molecule	Pre-Test	44	44,0	100,0
	Post Test	6	5,9	100,0
difficulties understanding chemistry concepts and information from the textbook alone	Pre-Test	43	43,0	100,0
	Post Test	6	5,9	100,0
difficulties explaining chemistry concepts to other people	Pre-Test	38	38,0	100,0
	Post Test	4	4,0	100,0
difficulties in following the pictures in a computer simulation on geometric structures	Pre-Test	58	58,0	100,0
	Post Test	1	1,0	100,0
difficulties in following instructions and interpreting pictures in computer simulation on geometric structures	Pre-Test	55	55,0	100,0
	Post Test	101	100,0	100,0
difficulties in following the computer simulation on geometric structures for its entire duration	Pre-Test	55	55,0	100,0
	Post Test	12	11,9	100,0
difficulties in identifying different molecular orientations when	Pre-Test	42	42,0	100,0
	Post Test	11	10,9	100,0

learning through a computer simulation				

Looking at the virtual model group, it was observed that the number of students reporting learning difficulties was relatively higher on both the pre-test and post-test (Table 4.9). For example, 45.5% and 47.5% of the students reported, in the pre-test and post-test, respectively, that they difficulties using given information to predict the shape of a molecule. Similarly, 61.4% and 50.5% of the students reported, in the pre-test and post-test, respectively, that they had difficulties relating the molecular shape to the name and properties of the molecule.

Table 4.9. Learning difficulties reported by students in the virtual model group.

	Group	Frequency	Percent	Cumulative Percent
difficulties using given information to predict the shape of a molecule	Pre-Test	46	45,5	100,0
	Post Test	48	47,5	100,0
difficulties illustrating the different molecular shapes and geometric orientations	Pre-Test	65	64,4	100,0
	Post Test	22	21,8	100,0
difficulties synthesizing information to predict the shape and structure of a molecule	Pre-Test	56	55,4	100,0
	Post Test	23	22,8	100,0
difficulties relating the molecular shape to the name and properties of the molecule	Pre-Test	62	61,4	100,0
	Post Test	51	50,5	100,0
difficulties understanding chemistry concepts and information from the textbook alone	Pre-Test	56	55,4	100,0
	Post Test	47	46,5	100,0
difficulties explaining chemistry concepts to other people	Pre-Test	58	57,4	100,0
	Post Test	23	22,8	100,0
difficulties in following the pictures in a computer simulation on geometric structures	Pre-Test	63	62,4	100,0
	Post Test	41	40,6	100,0

difficulties in following instructions and interpreting pictures in computer simulation on geometric structures	Pre-Test	61	60,4	100,0
	Post Test	36	35,6	100,0
difficulties in following the computer simulation on geometric structures for its entire duration	Pre-Test	64	63,4	100,0
	Post Test	28	27,7	100,0
difficulties in identifying different molecular orientations when learning through a computer simulation	Pre-Test	50	49,5	100,0
	Post Test	24	23,8	100,0

The Mann-Whitney test revealed that, there was no-significant difference ($p > .05$) in the number of students reporting that they had learning difficulties related to using given information to predict the shape of a molecule, difficulties relating the molecular shape to the name and properties of the molecule, and, difficulties understanding chemistry concepts and information from the textbook alone. There was no significant difference with regards to the other items.

The researcher also compared the number of students reporting that they had learning difficulties in the two posts tests (Table 4.10). It was found that in six out of eleven instances, there was not significant difference ($p > .05$). However, in the other five cases, the difference was significant. For example, 4% of the students in the physical model group reported that they and difficulties explaining chemistry concepts to other people while 22,8% of the students in the virtual group reported the same. The difference in this regard was significant ($p = .003$, see Table 4.10).

Table 4.10 Learning difficulties reported by students in the physical model group and the virtual model group in the post test.

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)

difficulties using given information to predict the shape of a molecule	4654,500	9704,500	-1,038	0,299
difficulties illustrating the different molecular shapes and geometric orientations	4552,000	9602,000	-1,369	0,171
difficulties synthesizing information to predict the shape and structure of a molecule	4150,000	9200,000	-2,383	0,017
difficulties relating the molecular shape to the name and properties of the molecule	4104,500	9154,500	-2,525	0,012
difficulties understanding chemistry concepts and information from the textbook alone	4469,500	9519,500	-1,529	0,126
difficulties explaining chemistry concepts to other people	3934,500	8984,500	-2,939	0,003
difficulties in following the pictures in a computer simulation on geometric structures	4689,000	9739,000	-1,008	0,313
difficulties in following instructions and interpreting pictures in computer simulation on geometric structures	4520,000	9570,000	-1,450	0,147
difficulties in following the computer simulation on geometric structures for its entire duration	4424,500	9474,500	-1,723	0,085
difficulties in identifying different molecular orientations when learning through a computer simulation	4188,000	9238,000	-2,249	0,024
Difficulties	3816,000	8866,000	-3,249	0,001

The researcher concluded that participating in the physical model group, and perhaps exposure to the physical model reduced the learning difficulties significantly. However, participating in the virtual model group did not always reduce learning difficulties.

4.4 The interview results from both participants of the physical model group and the virtual reality group

The participants were randomly selected by the researcher from their respective groups. The interview process was to get a better understanding of their views after the post content test on the learning difficulties experienced in the teaching and learning of Chemistry. In Table 4.13 there is a reflection of the important themes that contribute to learning difficulties. The researcher only selected the themes mentioned in Table 4.13 theme (there were more others) as the most necessary to understanding the learning difficulties.

The result suggests that there are learning difficulties that affect learners in improving their performance in Chemistry, there learning difficulties are a barrier can affect the entire process of understanding other Chemistry concepts. More than 50 percent of the participant's echoed the difficulties on valence electrons, valency electrons, understanding atomic mass, electron configuration, and the Aufbau diagram. These topics are topics done in grade 10 topic, which suggests Chemistry teaching and learning is too lacking in grade10. As reflected in the content test, a large fraction of the participants experienced difficulties in the interpretation of images, more than 50 percent required assistance in the topic of geometric understanding.

The further analysis reflects that the participants had difficulties with understanding concepts for the textbook. More than 70 percent said the images of the textbook lacks explanations and they fail to understand. As reflected in the results from the content test, participants did perform poorly on these question, before the intervention (Figure 4.3). Participants were asked their views on the effects of teaching tools such as physical models and virtual reality. More than 60 percent agreed to use physical models, as it provides the ability to touch the actual figures, the ability to see a clear representation of the atomic figures and the ability to build the atomic structures.

Lastly, a very large number of participants agreed to support the use of virtual reality in the classroom (Table 4.4), even those who were part of the physical model group. More than 80 percent of the participants agreed to more benefits of virtual reality in support of the textbook. They supported the benefits of seeing the structures, the ability to learn more concepts as the speaker talks, with the ability to remind and to play back the videos. The interview results suggest that there are learning difficulties and there are teaching tools that can assist the understanding of Chemistry concepts. An average of more than 70 percent of the participants agreed that the textbook requires assistance since there are gaps in the performance of Chemistry concepts.

Table 4.12 ***Results from the interview from both participants of the physical model group and the virtual reality group***

Theme 1	Difficulties	Valence electron	Valency electron	Atomic mass	Electron configuration	Aufbau diagram
		P10, P2, P9, P1	P7,P6, P12, P2,15	P1,P18, P3, P6	P1, P4, P17, P12, P10	P10, P12, P2, P7
Theme 2	**Image interpretation**	**3D models**	**1D models**	**Naming the shape**	**Geometric orientation**	
		P17,P16, P2, P10,P15	P20,P19, P7, P8,P13	P1,P6, P12, P5,P14, P7,P16	P7,P6,P10, P2,P13,P18,P1,P4, P17, P12, P8	
Theme 3	**Difficulties understanding from the textbook**	**Images illustration**	**Minimum examples**	**Not like exams**		
		P1,P6, P12, P5,P14, P7,P16, P17,P16, P2, P10,P15	P20,P19,P7, P8,P19, P1,P18,P3, P6,P5,P9,P7, P8,P13	P7,P6,P10,P2,P13,P18, P20,P19,P7, P8,P13		
Theme 4	**Benefits of physical models**	**Touching**	**Clear representation**	**Building the atomic structure**		
		P20,P19, P7, P8,P19, P1	P7,P6,P10, P2,P13,P18,P11,P17	P10,P16,P11, P12,P3,P8,P16		
Theme	**Benefits of**	**Seeing the**	**Ability to learn**	**Ability to rewind and**	**Detailed explanation**	

Several learners were collectively and randomly selected from the virtual reality and the physical model groups to participate in an interview session with the researcher (Appendix G). The selected learners were not representing a certain group or based on their performance, rather that the researcher aimed to understand learner poor performances in Chemistry and their attitudes towards Chemistry. The data collected through the interviews were examined qualitatively and other quantitative variables such as percentages were used to assist the researcher to validate the results that emerged from the pre-and the post-tests.

For the interview session that took place, all the participating learners communicated the causes of poor results in Chemistry, their attitudes towards the subjects, the use of virtual reality and physical models in the Chemistry classroom.

When the learners were asked if they enjoy Chemistry, most of the participants agreed to loving the subject but argued that it was a bit complex for them to understand. Some of the learners said:

"I enjoy Chemistry but I prefer physics because Chemistry can be confusing',

"I enjoy doing Chemistry calculations in stoichiometry but not when we have to dissolve or dissociate stuff, that's not nice" and another learner said,

"Chemistry sucks because we are taught based on imagination'

Looking at the results obtained from the pre-test obtained, the virtual reality group obtained an average of 5,50% where the physical model group obtained 5,15%. These results reflect that a learning barrier exists within the understanding and teachings of the Chemistry subject. Also, reflecting on the test written by the participants most of them performed poorly when they had to identify the shape and structures of the elements.

Most of the interviewed learners stressed that not all Chemistry concepts are difficult or complex, rather that they found more of the imaginary aspects a bit more challenging. When asked 'what they found as complex or difficult', the learners pointed out that when elements or molecules undergo change (physical or chemical) it becomes a challenge. Some of the learners said:

'I find the periodic table challenging by understanding elements and their charges. The idea of the element accepting or donating electrons and the concept of dative bonds is hard' ,

'I really have a challenge with the chapter on VSEPR because I really struggles to see the shape of the molecule'

'electronegativity and the periodic table trends are a challenge for me, all I know is that the elements get smaller from left to right and bigger as we move down, but why I don't know' and

'I still don't get intermolecular forces and the intramolecular forces'

For the interview session 97% of the learners agreed that after the lesson intervention, they saw Chemistry in another light, only 3% said they were still a bit confused. They agreed that the physically working with the molecules and seeing the elements and molecules broadened their views. One of the learners said:

'when we watched the videos we all had the same picture in mind'

I think when a teacher introduces a topic or concepts they should aim to have all the learners to be on the same page, this will decrease lesson misconceptions and misunderstandings. As a result, to the intervention the post test results for both groups improved, the virtual reality scored 11,06% and the physical model group scored 8,60%.

Further, another question that was posed to the learners was what they though could help them understand Chemistry better. The learners agreed that using sensors like seeing and touching really helped them. Some of the learners responded:

'I would love to watch a video for every topic or chapter we do in Chemistry and even physics'

'one of my teachers in primary school made us bring clay to school and we build elements such as water, methane and carbon dioxide, it was fun and I still remember the structure till today'

The idea of using different sensors in teaching has been reflected as good practice from the teaching and learning strategies explained in chapter one. The use of the textbook alone for subjects like Chemistry is not enough, as seen in the pre-test. The post-test gives us a clearer picture of what change a textbook assistance can do for learner performance.

The researcher posed a question to the participants and asked whether the participants found it difficult to name geometric shapes and drawing the 3D shapes. All the participants had an opinion on how the topic on 3D geometric shapes can be explained in their classes. One of the arguments was, how to name things we don't understand. For question 2 in the test 76% of the learners failed to identify the two diagrams to being identical, which implies a lack of understanding and 7% said they guessed the answer.

'different textbook uses different diagrams, which confuses us more',

'when the video showed how electronegativity attracts the elements, leaving one more positive and the other one more negative and forming a compound or molecule helped',

'I won't lie I cram the drawing, since I go through a number of past papers' and

'having to imagine the one bond at the back is difficult, but watching the video helped'

For the above question, the learners were asked in relation to the pre-tests as the lesson intervention. When the researcher asked the learners how they felt when answering the questions in the post-test after the lesson intervention, the learners gasped with admiration. The learner responded by saying:

'when I was writing the tests after the intervention, I was relating the questions based on the videos we were watching',

'it felt like the textbook was paging inside my head',

'the fact that I was able to build these structures using the Biochemistry set made it easier for me to remembered what was being asked'

Using the post tests as a reference point, more than 80% of the learners improved in the questions where they were asked to identify the shapes and molecules. Further, the learners reasoning improved when they had to motivate why the shapes looked the same or why they were different, reflecting to a better understanding of the concepts.

Further, the next question was, what would make chemistry more fun and understandable? The participants used their sensors as a mean of improving performance in their Chemistry knowledge. In the current research study, in chapter one, Gardner's views on how sensors can assist in teaching and learning was examined. All the participating learners agreed on the idea.

'when we went to Sci-Bono last year, it was fun and having to see real dry ice made it exciting since we got to see something we have learnt about, because we heard about absolute zero'

and

'I think schools should have science labs where we can do experiments and make things blow up. We are always told some chemicals are dangerous but be have never seen it'

As a result, from the post test, the learners improved on their performance when they have to reason for question two and three of the different elements in different dimensions. Resulting in a percentage improvement when teaching tools that incorporate sensors are used.

The next question was whether the use of actual molecular shapes could assist in making chemistry less challenging. All the participants agreed to the statement, some of the learners said:

'anything to assist the textbook can be really helpful',

'if they could get to see and feel the molecules and their shapes it can assist her when answering questions' and

'in the exam, some questions are based on practical wok we have not done and we have to guess or cram, so the actual molecules can help'

The next question asked was what they found interesting about the visual/virtual reality used by the researcher to teach chemistry. the participants loved watching the videos and they felt they could remember the concepts more. Sone of the participants said:

'I loved the sound effects, they had me actually feel what was going on'
'having to see how the elements on the periodic table bond and some of the funny faces made by the atoms was really nice',

'When we watched the part about electronegativity seeing the cartoons made it interesting, it was like watching a really funny show',

'love the fact that the researcher played the movies several times and stop in between and explained what was happening. Sometimes teachers talk too fast, but being able to stop and play the video made it so much better' and

'I love how the same concept could be explained so differently and easy'

The second last question for the interview was, what did the participants not like about using the molecular shapes in the lesson. Not much was said for this question, however some of the participants said:

'I wish we each had our own box of molecules and not have to share with others' and

'I think we could have practiced more problems and also be given time to play and figure some of the concepts ourselves'

Based on the above data that was collected from the interview, it is clear that an interactive lesson can be a positive mean to improve learner Chemistry performance. When learners can rely on a number of sources for learning is broadens their understanding and they are able to make connections. A total of 89% of the participants wanted the use of virtual reality and physical models in every lesson. Whereas 11% thought the use of virtual reality and physical models can be good to introduce a lesson only.

4.5 Conclusion

As justified in the above sections, the research study relied on both quantitative methods as well as qualitative methods, following a sequential mixed method approach. The researcher trusts that based on validation procedures undertaken to prepare the instruments, the findings and conclusions drawn are acceptable responses to the research sub-questions. The researcher believes that the processes taken to strengthen the methods as described above were adequate for study, though there were some limitations. Researchers in literature argue that in qualitative research, findings are true only within the lens of the researcher and their instrument (Nicholls, 2003). Findings of the methods applied are presented in Chapters 3 of this thesis.

The evaluation and discussion of results recorded in this chapter show that teaching tools such a virtual reality and physical modes can improve learner understanding of Chemistry concepts. The research study also shows that learning difficulties do exist in relation to chemistry content, providing results from the questionnaire. A few learners indicated that they do know what is being asked of them but cannot explain their line of thinking, or have limitations when responding to the question because of the language barrier. Not English as a language barrier but the science and Chemistry language a whole. A majority expressed the lack of imagination towards the subject, based on limitations to relating the abstract concepts.

The content test addresses the performance and the results from the study show that before the intervention there was poor performance. Whereas, after the intervention the number of achievement increased. Some learners elaborated on their understanding of Chemistry and its difficulties when answering the Likert scale questionnaire. What needs to be taken note of, if the fact that their first point of contact for Chemistry information is the teacher and the second point is the textbook. Which can limit their understanding and cognitive growth if they lack a relation to the abstract nature of chemistry? In the following Chapter, the assumption from the study, suggestions, and proposals are discussed.

CHAPTER 5

5.1 Introduction

This chapter discusses and reflects the study to where it originated, from the beginning to the end. The target population was grade 11 chemistry learners since grade 11 chemistry is the foundation for the final grade12 chemistry paper reviewed at a national level. The discussion is extended to qualitatively understand why learners perform poorly in chemistry and how different teaching and learning tools can assist.

This chapter begins with the i.e. results that echo literature, results that contradict literature and results that are new. Further, the researcher discusses results that respond to the research question and highlights where further research and recommendations are required. The limitations of the study are then presented as well as the conclusion.

5.2 Results that echo literature

As stated primarily in chapter 2, the current research study looks at the effective use of virtual reality and physical models to improve the understanding of Chemistry on grade 11 learners. With the use of data, the researcher used the information to conclude whether virtual reality and physical models can be used to improve the understanding of chemistry concepts. Findings that support existing literature indicate that teaching tools are important when assisting learners to better understand Chemistry concepts, this is because i) Chemistry is abstract and cannot be seen, ii) learners who have difficulties imagining concepts in Chemistry perform poorly iii) and the understanding of Chemistry is limited when using the textbook alone.

When learners lack the ability to create a memory based on the abstract nature of Chemistry, learning does not take place. The theory of human learning combines principles of human memory and learning in order to explain and predict concepts (Atkinson and Shiffrin, 1968). The results obtained in Chapter 4 from the pre-test reflect poor performance, especially for questions 2 and 3, and 6 to 9. For these questions, learners performed poorly as they lacked the application of the knowledge of Chemistry concepts. With the gathered results, one can see the poor learner performance is a cry for help in improving the subject. For learners to have been able to answer the questions, they required the basic foundation of molecular structures. These are concepts learned and gathered from observing elements and understanding trends on the periodic table. The structures are shown in 3D on the content test and are in 1D in the textbook. The participants failed to make the connections even though both structures were in actual fact the same thing. When learners lack the ability to link abstract concepts with reality they fail to apply any learned concepts or make connections (Bruner, 1960).

According to the ideas of multimedia learning, students learn better from words that are accompanied by a variety of pictures relating to each other, rather than words alone (Zoller, 1990). With that said if learners were taught using the textbook alone, then a clear explanation should be given to explain the actual reality of the images and pictures in the textbook. Hence, the chemistry concept limitations in the classroom occur as the only reference being the textbook. The textbook as a reference point fails to explain the reality of the images and pictures, resulting in poor performance. As a reflection of the results obtained, the participants failed to make connections with the given images, when using the textbook as a frame of reference.

Moreover, as an example the children song, 'Old McDonald had a farm' adds many animals even 'old MacDonald had a cat'. The overall idea is the similarities, children add detailed aspects that make logic to them given the general idea of the story. Note that this does not only apply to children but adults too, as they too add and subtract information when rebuilding ideas and concepts (Atkinson, 1974). The point of reconstructive memory is that we do not remember the exact replicas of experience or what we have learned.

Rather we tend to remember the general ideas or concepts that have occurred or what was said and with that, we can fill in details as needed (Atkinson and Shiffrin, 1968). Thus, if the participants had constructed the Chemistry concepts before, they could have answered the questions that required an application. For example, if they had previously watched a video or modeled an atom, they would have been able to answer questions that were based on the interpretation or synthesis of elements. For an example in English, teachers are more likely to allow learners to watch a movie on Othello or Mack Beth for learners to remember when asked questions in exams. People seem to remember better and are better story tellers from what they see rather than what they read alone.

Relating to the question asked on the valence electrons of nitrogen, the participants lacked the ability to imagine the structure of nitrogen from the periodic table. If there was ever experience or memory created using tools in the classroom on the understanding of valence electrons, electron configuration or the Aufbau diagram, they would have achieved. The topics mentioned are the basic building blocks for Chemistry education and when well understood, an individual can make connections and assumptions using the topics as a reference or a guide.

Which means the participants could have had the ability to reconstruct new knowledge based on the old knowledge created in their Chemistry classroom. When learners experience multiple perspectives and explanations for a particular Chemistry theory or phenomenon, it provides the learner with the raw materials necessary to develop multiple representations, therefore, building chemistry understanding (Bruner, 1960). Therefore, if the use to teaching tools along with the textbook was used learner performance could improve since the learners have multiple reference points to answer questions.

Chemistry is seen as an important branch in other fields of science, as it assists learners in knowing what is happening around them (Nahum et al., 2004). Results from the pre-test reflect that 68% (136 out of 200 participants) had difficulties synthesizing information to predict the shape and the structure of a molecule. The lack of content amalgamation with abstract thinking affects learners understanding, especially because Chemistry concepts occur at a molecular level (Mnguni, 2014). A total of 59,6% (119 out of 200 participants) failed to name the molecular structures. According to Gilbert (1997), when the applied teaching method is unclear and complicated, learners misinterpret the point and no Chemistry knowledge is acquired, resulting in poor performance and misconceptions. This is a clear indication that suggests the use of the textbook alone is limiting.

Further, in the questionnaire 62% (124 out of 200 participants) agreed to have difficulties understanding Chemistry concepts with the use of the textbook alone. This is due to the fact that the abstract nature of Chemistry makes it challenging for learners to processes a mental picture of Chemistry molecular shapes with only a textbook as a frame of reference (Al-Balushi, 2009). According to Gardner (2004) using multiple representations such as tools, figures or images provide learners with various directions to retrieve knowledge and the ability to respond to more complex questions in tests and exams. Thus, a student's understanding and compliance are improved when he or she is able to assess concepts from multiple perspectives.

Further, teachers provide for unique and various ways for content acquisition in chemistry, to help learners interpret the same Chemistry information in different settings (Mayer, 1992). For the current study, the participants had difficulties predicting, synthesizing and interpreting concepts. Learners build knowledge of the experiences created by their teachers in the chemistry classroom (Mayer, 1992). Based on the results of the questionnaire, a majority of the learners do not use model tools or virtual reality in their classroom, or any other tools to assist their understanding.

Thus, good teaching and learning experiences are created using adequate teaching tools are used to bridge the gap in the molecular nature of Chemistry. When teaching tools are used, learners have the ability to acquire Chemistry knowledge and to improve their performance. According to Juma, (2018) teaching tools are a guide to the curriculum which helps to expand the classroom textbook, correcting concepts and creating analytical thinkers and problem solvers.

Based on the poor performance the participants shared the lack of equipment in their schools. One of the participants pointed out how they are made to cram certain aspects of Chemistry but are not taught, due to the lack of teaching tools. Classroom tools along with activities are important for learner content development and activities should aim to foster the construction of mental structures and imagination (Fosnot, 1996). During the interview, some of the participants admitted to not fully understanding grade 11 chemistry, but by watching the videos they were able to link everything together. This is because classroom tools and activities should be used in environments that promote and facilitates learning (Garrison, 1998).

In addition, participants shared that their teacher uses examples they know nothing about. Learning is limited when learner experiences are not the same, which will result in a variation in the construction of new knowledge in the Chemistry classroom (Mayer, 1992). Teachers should not only expect students to build Chemistry knowledge on their own, rather create the same idea and imagine for all students in the classroom. According to Sirhan (2007), when a learner cannot see or relate to concepts in Chemistry, they lack an understanding of chemistry principles and laws. Every individual is different in the chemistry class, in regards to how they learn.

5.3 Results that contradict literature

Literature suggests teaching tools assist learners in understanding concepts since it uses multiple representations to provide learners with various directions to retrieve knowledge (Gardner, 2004). However, learners might not require teaching tools to improve performance, rather than learners remember more of what they see than what they hear, but learners will always remember more of what they experienced. Based on this literature, subjects like chemistry cannot always be experienced due to the abstract nature, however, this may be true for other fields.

The literature on the use of ICT and multimedia learning, suggest that technological tools will always be better for learners as it allows them the ability to see and build on imagination (Fosnot, 1996). However, based on the results obtained from the questionnaire, 61% (122 out of 200) of the participants agreed to have difficulties following computer simulation on the geometric structure for the entire duration. Whereas 69% (138 out of 200) had difficulties identifying molecular orientations when learning through a computer simulation.

Learners can acquire their chemistry knowledge using different resources along with the textbook (Fosnot, 1996). Literature shows that teaching tools are popular in schools to improve performance. However, in a study conducted learners were given eight substitutes on how they best acquire knowledge and the most favored resource option was teachers, followed by the internet, media presentations and then teaching tools (Gergen, 1994). In the current study, the results gathered from the interview shows a number of participants supporting the use of physical models and virtual reality as the first option over their teacher and textbook. After the intervention participant results improved, therefore supporting the use of these tools to improve performance.

On the contrary, in a study conducted in Britain, Hunther, Shafer, Holzner & Kemmler (2003) argued that the most mentioned source of information that can improve performance in chemistry education is TV and documentaries, where teaching tools are seen as tertiary options.

This could probably have resulted from the fact that South African learners depend more on their teachers already, as certain technological equipment may not be freely available to the majority of learners. Whereas Britain is already a technologically innovative country, in terms of technology and as a result bypassed the teaching tools. Which mean a majority of the people are up to date technologically and hence are able to use other foundations to improve their performance.

According to literature, the teacher is an assessor, instructor and a bridge in the classroom to improve understanding. However, the results gathered during the interview show that students are forced to believe what their teacher saying, which reflects the teacher as a dictator and not a bridge. However, scholars argue that learners cannot fully depend on what the teacher says. Leaners must learn to build their own understanding so as to discovered and understand more about their own learning, researchers call this metacognitive awareness (Duckworth, 1987). It is believed that this manner of content acquisition brings better insights into understanding also promoting more of what students need to know.

Further cross-cultural research in teaching supports the idea that discrete differences among learners can be resources rather than common teaching tools (Lampert, 2001). Unlike the contrast in counties like the United States, Japanese teachers see individual differences as a natural and beneficial teaching tool (Lampert, 2001). This is the idea that by allowing each individual to explain a concept based on their belief, teaching tools are not required, rather the use of indigenous knowledge systems. Participants responded to interview questions by saying their teachers use examples they know nothing of, which means they do not relate to the examples used. But by using their own cultural or native experiences as examples they could improve in performance and gain the ability to apply and explain the concepts.

For example, in South Africa different cultures do things differently, the brewing of "umqombothi' (traditional African beer) can be explained as an exothermic reaction. According to Stigler and Hiebert, (1999) distinct differences result in a range of opinions and problem-solving approaches for learner improvement, content application, discussions, and reflections. Understanding these cultural differences is supported by scholars, to say it assists teachers to better conclude on learner engagement in the classrooms (Lampert, 2001). It is believed that teaching tools require time and skills whereas, indigenous knowledge systems are already in place and practiced. This approach improves learner performance in the abstract nature of chemistry due to the connections already being associated with the learner's communities.

Moreover, Jackson (1986) argues that Chemistry concepts cannot be instructed or simplified using tools and teachers cannot assure learners will pass. Literature focuses so much on improving chemistry performance using tools, but teaching tools are a small fraction of what improves chemistry understanding. Teachers are forced to motivated learners, use appropriate instructional strategy, make the learners interested in the subject on a daily, make the classroom and school conditions conducive for learning, build learner-teacher parents support, plan for time to digest the ideas and practice new skills, be aware of any peer pressure or bullying in your class and the list goes on.

Thus, all these facts need to be addressed before the teacher can even touch teaching tools. The results reflect improvement with the use of teaching tools, however, Jackson (1986) argues that on a daily basis it is not feasible. Though the results show improvement, it is suggested that it could be due to the setting being outside the classroom environment. Which suggests if all social issues were taken into consideration the results might have not improved. Which implies that a closer focus should be based on the social issue affecting learners to automatically improve Chemistry performance.

5.4 Results that are new

As indicated previously, findings in the research study suggest that teaching tools such a physical models and virtual reality improves learner performance in chemistry. In this regard, the research study displays the findings in the research study and suggest that the success of teaching tools depends on the attitudes and behaviors of the learners. The study displays the informal curriculum has a greater impact on learner attitude and behavior than the formal Chemistry curriculum. These views are supported by other scholars' observations (e.g. Askew, Hodgen, Hossain, & Bretscher, 2010: Medeiros-Domingo, Bhuiyan, Tester, Hofman, Bikker, van Tintelen & Ackerman, 2009.).

However, what emerged as new insight in the research study is that concepts recommended in the formal Chemistry curriculum do not support and relate learner attitudes and behaviors possibly because students rely on the perspective of the teacher causing difficulties in relating Chemistry concepts taught in Grade 11 Physical Sciences to real life, (see Chapter 4).

Suggestions to this statement are that learners i) do not understand why they learn Chemistry ii) have no level of commitment to the subject iii) do not take ownership of their own performance but instead shift the blame to teachers, parents and the school. The researcher reasons that if learners had knowledge of Chemistry concepts based on how Chemistry contributes to societies. Their attitudes and behaviors to the subject would have had a different ideology. Such misleading behaviors and attitudes to the subject is the cause of poor performance and the lack of commitment to the subject.

5.5 Responding to the research questions

For the current study, the main conclusions are structured according to the two research sub-questions. The researcher first examines the results before the research intervention. The conclusions are drawn after the research interventions for both groups. The separate findings and the effects are argued in detail in the following subsections.

5.5.1 Conclusion before the research intervention

Chemistry education is one of the poorly performed subjects in South Africa (Department Of basic education, 2000). As a result, the poor performance in grade 11 chemistry in the output of the final grade 12 national results. In the current research study, the researcher argues in Chapter 2 for the use of physical models and virtual reality to improve Chemistry performance for grade 11 Chemistry learners. Further, in Chapter 2, the researcher points out the abstract nature of Chemistry, Chemistry being microscopic and cannot be seen with the naked eye (Mnguni, 2014).

In addition, Chemistry concepts occur at a microscopic level making it complex for learners to imagine and comprehend (Roehrig & Garrow, 2007). The lack of imagination in chemistry concepts adds to poor performance. The chemistry textbook is the guide to understanding

Chemistry, however, the textbook alone does not solve chemistries complexity, its abstract nature or its occurrence at a molecular level.

a) The effects of using physical models for chemistry understanding

Physical models and Chemistry labs are tools that can be used to clarify the abstract nature of Chemistry. Quality teaching and learning is achieved by implementing various approaches to teaching and learning. Achieving a greater number of learners cognitively growing their Chemistry knowledge lies in the incorporation of multiple intelligences (Gardner, 2000).

The results show that before the intervention, participant confidence in chemistry was limited. Table 4.1 is a reflection of poor performance. As we move the question to question, the cognitive level of the questions changed. Moving from identifying concepts to applying to understand, the lack of Chemistry knowledge application is seen for questions 6-9 (Figure 4.1). However, for the intervention, the use of physical models supported the teaching of abstract concepts, which improved their knowledge application. The use of physical models allowed the participants to build atoms, see their geometric structure, use their knowledge of Aufbau to determine electron orientation. This display changed their understand and perceptions of atoms.

Findings of the research study point out that participant performance for this group improved after the intervention. Based on the pre-test the participants performed poorly as the reference point to their understanding was the textbook. Chemistry education requires more support than other subjects, the use of the textbook alone is insufficient. As discussed in Chapter 2 other scholars suggest that teaching tools and multimedia teaching and learning improve poor performance for subjects like Chemistry. Since Chemistry is abstract, the use of physical models allowed the participants to build on their imagination and understand the complexity of the subject. For improvement to occur different tools should be implemented for continuous improvement (Tsi, 2002).

Language limitations for the understanding of concepts is a major factor in poor performance. The chemistry language is not correctly articulated in the classroom to learners making is difficult to understand Chemistry as a subject. When the use of a language has not been fully

maximized, the ones using the language fail to express concepts in that language (Blumenfeld, 1994). For example, participants had difficulties understanding valency and valence electrons. During their intervention, participants were made to see what is the difference between the valency and valence. The research demonstrated using figures how the electrons are aligned in the different energy levels, the electrons on the highest energy level are referred to as the valence electrons.
Whereas, the numbers of atoms required by the elements to complete its outer orbital it referred to as the valence electrons. The limitation is that the textbook gives diagrams and definitions but does not explicitly explain how the words come about. Further, the gap in language to explain chemistry concepts and phenomenon's is a lack of understanding. Participants failed to explain concepts to others, because how do you explain what you do not understand in a language you do not cognize (Table 4.3).

Thus, the study shows that physical modeling aims to improve what is not seen and brings it to reality (Magussoon et al, 1999). For example, the use of 3D printing is a big hit in Chemistry education, biochemistry, and medicine. For one to have the ability to explain concepts that are microscopic, one is required to see it. Results show that having an image in sight improved learner performance (Table 4.2). The ability to explain, identify, synthesis and interpret concepts will also improve.

However, though some of the learners were unable to use the correct articulation of language after the intervention but could explain the chemistry behind it. For example, before the participants did not know that the two pairs of electrons on nitrogen atoms when displayed using the Lewis structure are called lone pairs in chemistry and not just electron pairs. Participants could further explain how the two lone pairs from the nitrogen atom come about and the importance when naming the molecule.

Further, participants corrected their Chemistry knowledge in observing that trigonal planar and trigonal pyramidal is not the same thing. Therefore, the overall study shows evidence to indicate those physical models used in the chemistry class improve learner performance. The physical models did not improve other factors like languages or social dilemmas but improved the understanding of chemistry concepts.

5.5.2 The effects of using virtual reality for chemistry understanding

One of the best ways to teach complex concepts in any field of study is the use of visual reality (Gardner, 2000). Literature proves that for learners to understand complex concepts, they need to visualize it and create a memory (Fosnot, 1996). In Chapter 2, the researcher argued for the use of virtual reality for the improvement of Chemistry in grade 11. Poor performance is a result of the complexity of Chemistry as a whole. Further, limitations are due to the fact that school relies mostly on the textbook as a frame of reference. However, most Chemistry concepts are not still motions as the textbook perceives it to be. Grade 11 Chemistry education includes branches of molecular bonding, electrostatic attraction, molecular shapes, and orientation. Such a topic requires motion and virtual explanations as in their actual reality. Due to the lack of imagination, visualization and the molecular occurrence learners perform poorly.

The evidence is shown in Table 4.4 that learners experience difficulties in the understanding of Chemistry concepts with the use of the textbook alone. As with the physical model group, there is evidence that learning and teaching of Chemistry have limitations when learners are taught with only a single frame of reference. The learners experience difficulties when having to apply their Chemistry understanding further as in the content test because of the gaps in their Chemistry foundation (Figure 4.2). According to Wiley (1990) when learners fail to answer questions, they tend to not give their all as they move along texts and exams. For the current study, it could be a result that as the learners answered the questions, when they came across questions they could not answer it demotivated them as a whole, thus failed to even try.

Scholars give evidence that the use of virtual reality improves the understanding of chemistry as it improves the manner in which instructions are articulated (Clark, 1983). Resulting in clear and less clustered explanations provides evidence that learners understand better (Clark, 1983). The explanation is done in the classroom when the teacher refers to the textbook makes it hard for learners to maintain concentration. The simplicity of explanations through virtual reality is what improves performance. In Figure 4.5 there is a clear indication of improvement from each participant.

The virtual reality videos and assimilations used by the research followed a step by step articulation of concepts. The videos explained why nitrogen is the seventh element on the periodic table, it also presented the electron alignment of the element and the molecular shape. This allowed the participants to see the relationships between the atomic number, the molecular shapes and the concepts of valence electrons. This aids as evidence that the use of virtual reality improves learner understanding of chemistry concepts.

The chemistry language is a learnings barrier for good performance (Blumenfeld, 1994). Virtual reality is one of the most supported teaching tools to be used in the classroom because it uses a number of multiple intelligences and senses resulting in a wider pool of understanding (Gardner, 2000). Results of Figure 4.6 show an improvement in language use. The virtual reality allowed the participants to watch while listening to the speaker using chemistry terminologies while touching or pointing to what is being explained.

Thus, this allowed the participants to put a 'name to the face', which is hard to do in a classroom with the use of textbook alone. Sung, Chang, & Liu (2016), suggest that the textbook is the manual to Chemistry, it only supplies a general understanding of Chemistry concepts. However, the use of tools such as virtual reality will strengthen what the textbook cannot explain. Hence, results reflect evidence that virtual reality improves learner performance and virtual reality improves language but did not improve other social difficulties.

b) Reflection of results from the physical model group and the virtual reality group

The use of physical models and virtual reality showed improvement in the participants' development in Chemistry understanding when the textbook was supported by the tools. There is a great improvement from both groups when these tools are used, most of the participants improved with 10% and more (Figure 4.4). The overall performance rate improved in both groups. Any teaching tools used to improve learning builds a deeper understanding, intelligence and gives the individual a sense of logic (Gardner, 1994).

Between the two groups once can see that the virtual reality group performed better (Figure 4.4). This is a reflection that the use of virtual reality utilizes and supports a number of multiple intelligences found in a given classroom creating a bigger space for improvement. The use of virtual reality is also one of the best modern methods of teaching since the generation today is all about technology. By incorporating virtual reality, the teaching of complex and microscopic

Chemistry concepts corrects the language barriers in the subjects. Therefore, in the content test for questions that required language acquisition, the virtual reality group was able to articulate in the correct Chemistry terms. Whereas the physical model group performed better than the pre-test results but still experienced difficulties.

The physical model group performed better when it came to questions in the naming of the geometric structure and orientation of the molecule. The ability to create the molecules physically enabled them to remember the structure (Figure 4.4). Further, the physical model group reflects understand of the 3D concepts in relation to the 1D concepts provided in the textbook. One of the biggest challenges in chemistry education is the idea that Chemistry occurs in 3D and not in 1D (Trna, 2014). Results show that the physical model group had the skill and were able to apply their 3D knowledge to the 1D figures and conclude it to being the same. For questions 1.1, 1.3 and 2.2 the physical model groups performed the best. Whereas questions 2.1, 2.3, 3.1, 3.2 and 3,3 the virtual reality group performed better. The questions where each group achieved better are a reflection of the output of the tools that were used and the tools ability to correct certain concepts.

In conclusion, both teaching tools are a good way to engage learners to improve their performance. As we have discussed both findings have advantages. But one can incorporate the use of both tools because physical modeling improved content application whereas virtual reality improved the language learning barriers.

5.6 Further research required

Although the results of the study are important the researcher believes that further research is needed to better understand the effects of using physical models and virtual reality to improve Chemistry performance. Some possible research areas are discussed below.

Firstly, it would be significant to do a cross-sectional research study between the three grades in the FET phase using grade 10, grade 11 and grade 12 Chemistry students. This will benefit and improve our knowledge of the use of physical models and virtual reality for improving performance.

Secondly, there is a need to investigate how understanding the Chemistry language can be used to improve performance. The study showed that performance in Chemistry education is affected by language. However, it remains imperative that the chemistry language is a great part of the performance of the learners which contributes to learner development and empowerment. Therefore, it is critical that research is conducted to determine how the Chemistry language can be used to improve performance for the reconstruction of the subject while fostering conceptual understanding. This means there is a need to explore the possibility of introducing the language of Chemistry as a separate subject so as to teach the concepts of Chemistry with the required language.

Thirdly, the research study displayed that the content in the Chemistry textbook is not understood. Which mean besides the fact that teaching tools are required, Chemistry textbooks are not at a standard as to explain or present the actual nature of Chemistry, thus the poor performance. It is, therefore, necessary to investigate the power of the textbook on learners' concept understanding, especially in schools where there are textbook shortages. Hence, the research may seek to compare South African chemistry textbooks with international textbooks to see if the standard in South Africa is in line with the rest of the world. This approach could determine which chemistry concepts should be covered using the textbook, which concepts require teaching tools and which should use both.

Fourthly, the study establishes that there may be other factors that cause poor performance in Chemistry. The chemistry knowledge of the teacher needs to be investigated. Such factors were however not identified, but participants highlighted that educators use examples they do not understand. Given their apparent impact on learner improvement the researcher considers that research is needed to identify these factors and improve performance.

5.7 Limitations of the research study

With any field in research, the current research study had limitations due to conditions beyond the researcher's control. Such influences may result in risks in the validity of the findings and conclusions gathered from the findings. The limitations of this study and the required steps taken to minimize the limitations are debated below. It is vital for the reader to be aware of the limitations so as have the limitations taken into consideration when regarding the conclusion.

In my research study, I designed a content test since I was unable to source content tests that were previously used in a study. However, the questions in my content test were imperative to use as the pre-test and post-test for the research study. Questions were generated using the Department of education Diagnostic reports and past exam papers. The limitation is the constraint to using prescribed questions since I could not create my own questions, which resulted in not fully taking the different learners and their abilities into consideration.

In this research study, a large concentration of the learners in the groups were from the same schools. Although they did not discuss the instrument, the variation of performance was the same since they were taught by the same educator.

5.8 Conclusion: there is a need for the use of teaching tools

As justified in the above chapter, the research study used both qualitative methods as well as quantitative methods, making the desired methodology a sequential approach. The researcher considers that based on processes of validation undertaken to plan instruments, the results and conclusions drawn are satisfactory answers to the research sub-questions. The researcher admits to some limitations with the instrument and the organization of the participants as a sample size. The researcher believes that the gathered results would have been more practical had an additional opinion been accessible. The researcher feels that by not creating the content test might have limited the learners to good performance. This is because all the questions were national level questions used for final November examinations.

The researcher believes that if the content test was self-designed it could show a true reflection. Further by organizing the purposeful sample (the participants are selected due to a defining character which aids the needs of the research study) personally into groups and not by schools would have rendered the findings more trustworthy. However, the researcher believes that the procedures taken to advance the methods as described above were sufficient for firmness in the study. These views are supported in the literature by other scholars (Nicholls, 2003). Bogdan

& Biklen (1992) suggest that for qualitative research the findings are true only when viewed through the lens of the researcher and their instrument.

The findings of the methods used in the research study are presented in Chapters 3 in this thesis. In conclusion, a broad discussion is presented in Chapter 4 and 5 as a response to the main research question. on theories and assumptions on chemistry. The use of teaching tools can bring all learners into one movement, where all examples relate to all of the learners and not just based on what the teacher knows.

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APPENDIX A: PERMISSION LETTER TO SCHOOL

PERMISSION LETTER TO SCHOOL

Re: <u>Request for permission to conduct research at your school.</u>

Research title: ‘The effects of virtual reality and physical models on grade 11 learner understanding of geometric shapes in the chemistry classroom’

The Principal: Mr Ras

School Address: 7 Dixon Road Reyno Ridge Witbank

Insert contact person’s telephone number and email address: 079 499 6443

Dear Principal,

I, Thobile Precious Nkosi (student number 61995088) am doing research under the supervision of Lindelani Mnguni, a professor in the Department of Science and Technology towards a Master’s Education degree at the University of South Africa. The study is not funded. We are inviting you to participate in a study entitled “The effects of virtual reality and physical models on grade 11 learner understanding of geometric shapes in the chemistry classroom’

The aim of the study is to investigate the extent to which virtual reality and the use of physical models can improve Grade 11 learners’ understanding of geometric shapes in Chemistry.

Your school has been selected because the school falls under Witbank which is the area where the study has its focus.

The study will entail requesting learners to write a pre-test, followed by a lesson intervention where the learners will be taught by me using various teaching tools. This will be followed by a post-test as part of assessing their response to the use of virtual reality with simulation and using biochemistry tools. I will also observe lessons where teachers will be teaching Physical science concepts using computer simulations or interactive boards. Finally, I will carry out interviews by randomly selecting learners.

The benefits of this study are that teachers will be equipped with innovative teaching strategies that will benefit learners especially in cases where practical activities could not be done due to financial constraints. Learners will also be exposed to simulated concepts which are hoped that it will improve their understanding and retention of concepts which under normal circumstances are considered to be abstract.

In this study, there are no foreseeable risks

Feedback procedure will entail me sharing with the teachers the best possible strategies of using computer simulations for their adaptation into their day to day teaching.

Yours sincerely,

Thobile P. Nkosi

Student: UNISA (Student No 61995088)

APPENDIX B: CONSENT LETTER TO PARENTS

Research title: ‘The effects of virtual reality and physical models on grade 11 learner understanding of geometric shapes in the chemistry classroom’

Dear Parent

I would like to request your child to participate in my research project being undertaken at your child’s school. My research topic is ‘The effects of virtual reality and physical models on grade 11 learner understanding of geometric shapes in the chemistry classroom’

This research will entail the observation of your child inside the classroom during Physical science lessons. Your child will be part of the children in the class I will be observing for a month. I will be teaching your child only once and I will be present in class when his/her teacher teaches them. I will be a passive participant who will do audio recordings and take field notes while the teacher and the learners are busy in class. Your child will participate in pre-test and post-test, questionnaires, as well as an interview.

I would like to promise you that the information obtained from this study will be treated in the strictest confidentiality possible, and it will be used for this research purposes only. Your names and the child’s names will not be revealed instead pseudo names will be used.

The information obtained from this research will be made available to your child’s school and can be used by the teacher to help your child during science lessons. In conclusion, I would like to thank you most sincerely in your assistance in this research, and I hope that this research makes a contribution towards meeting the needs of diverse learners found in science classrooms.

Yours sincerely

Thobile P. Nkosi

If you are willing to allow your child to participate in this study, please sign this letter as a declaration of your consent, i.e. that your child participate in this project with your permission and that you understand that he/she may withdraw from the research project at any time. Under no circumstances will the identity of participants be made known to any parties/organizations that may be involved in the research process.

Any information that is obtained in connection with this study and can be identified with your child will remain confidential and will only be disclosed with your permission. His or her responses will not be linked to his or her name or your name or the school's name in any written or verbal report based on this study. Such a report will be used for research purposes only.

There are no foreseeable risks to your child by participating in the study. Your child will receive no direct benefit from participating in the study; however, the possible benefits to education are that the study seeks to improve the teaching and learning strategies through use of computer simulations. Neither your child nor you will receive any type of payment for participating in this study.

Your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusal to participate will not affect him/her in any way. Similarly, you can agree to allow your child to be in the study now and change your mind later without any penalty.

The study will take place during regular classroom activities for the lesson and pre-tests/post-test while interviews might be done at times convenient to your child with the prior approval of the school and your child's teacher. However, if you do not want your child to participate, an alternative activity will be available.

In addition to your permission, your child must agree to participate in the study and you and your child will also be asked to sign the assent form which accompanies this letter. If your child does not wish to participate in the study, he or she will not be included and there will be no penalty. The information gathered from the study and your child's participation in the study will be stored securely on a password locked computer in my locked office for five years after the study. Thereafter, records will be erased.
If you have questions about this study please ask me or my study supervisor, Prof Lindelani Mnguni, Department of Science and Technology, College of Education, University of South Africa. My contact number is 0726277991 and my e-mail is thobileking@gmail.com The e-

mail of my supervisor is mngunile@unisa.ac.za. Permission for the study has already been given by UNISA faculty of Education and the Ethics Committee of the College of Education, UNISA.

You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the study. You may keep a copy of this letter.

Name of child: ____

____

__

Parent/guardian's name (print)   Parent/guardian's signature   Date

____

__Researcher's name (print)   Researcher's signature   Date

APPENDIX C: CONCENT LETTER TO TEACHERS

Research title: 'The effects of virtual reality and physical models on grade 11 learner understanding of geometric shapes in the chemistry classroom'

Dear educator

Re: Educator- Request for your participation.

My name is Thobile Nkosi and I am a Master's student at the faculty of Education student at the University of South Africa. I would like to conduct my research in your Physical Sciences classroom on the above-mentioned study. I hereby request your permission to administer a pre-test and post-test, questionnaire and conduct interviews with a selected number of learners, as well as, analyse your lesson plans.

Your participation in this research process is voluntary and you may choose to withdraw from this process at any time. If you choose not to participate or withdraw from the research process, there will be no penalty. Furthermore, written consent will be obtained from you and the findings will be discussed with you.

For the purposes of anonymity and confidentiality the names of both your school and yours will not be mentioned throughout the data and findings of the case study. Pseudonyms (another name instead of your name) will be used in the writing of the final assignment. The collected data will be for the purpose of this study. This information will be treated with the strictest of confidentiality. Should you so require, please do not hesitate to contact me on: 0726277991 or send my supervisor Prof LE Mnguni an email: mngunile@unisa.ac.za.

Thanking you in advance.

Yours sincerely

Thobile

I hereby confirm that I understand that Thobile Nkosi is conducting her study on the effectiveness of virtual reality in improving the understanding of grade 11 geometric shapes. I hereby state that I will allow her to conduct the research in this in my Life Sciences lessons to use the findings for the purpose her studies.

_________________________ _________________________

Educator's Name Date

____

Signature

APPENDIX D: ASSENT LETTER TO LEARNERS

Dear learner

I am doing a study on 'The effects of virtual reality and physical models on grade 11 learner understanding of geometric shapes in the chemistry classroom' as part of my studies at the University of South Africa. Your principal has given me permission to do this study in your school. I would like to invite you to be a very special part of my study. I am doing this study so that I can find ways that your teachers can use to virtual reality better. This will help you and many other learners of your age in different schools.

This letter is to explain to you what I would like you to do. There may be some words you do not know in this letter. You may ask me or any other adult to explain any of these words that you do not know or understand. You may take a copy of this letter home to think about my invitation and talk to your parents about this before you decide if you want to be in this study. I would like you to write a pre-test and post-test, respond to a questionnaire and engage you in an interview for approximately fifteen minutes.

I will write a report on the study but I will not use your name in the report or say anything that will let other people know who you are. You do not have to be part of this study if you don't want to take part. If you choose to be in the study, you may stop taking part at any time. You may tell me if you do not wish to answer any of my questions. No one will blame or criticise you. When I am finished with my study, I shall return to your school to give a short talk about some of the helpful and interesting things I found out in my study. I shall invite you to come and listen to my talk.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about this study, you can talk to me or you can have your parent or another adult call me at: 0726277991. Do not sign the form until you have all your questions answered and understand what I would like you to do. You may also contact my supervisor Prof LE Mnguni on 0114294614 or send an email: mngunile@unisa.ac.za.

Do not sign written assent form if you have any questions. Ask your questions first and ensure that someone answers those questions.

INTERVIEW ASSENT AND CONFIDENTIALITY AGREEMENT

I____ grant consent/assent that the information I share during the interviews may be used by Thobile P. Nkosi for research purposes. I am aware that the discussions will be digitally recorded and grant consent/assent for these recordings, provided that my privacy will be protected. I undertake not to divulge any information that is shared in the interview to any person outside the group in order to maintain confidentiality.

Participant's Name (Please print): ___________________________________

Participant Signature: ____

Researcher's Name: (Please print): __________________________________

Researcher's Signature: ____

Date: ____

APPENDIX E: PRE-POST TEST

Test

Total 40

Time 1 hour

Name and Surname: **Group:**

Gender: **Age:**

Question 1 (NSC: Grade 11 Exemplar - DBE/2013)
Please answer the following question

Ammonia (NH_3) is an important gas used in the preparation of fertilisers. An ammonia molecule is formed when electrons are shared between three hydrogen atoms and a nitrogen atom.

1.1 Name the type of chemical bond formed between a hydrogen and a nitrogen atom.

____ (2)

1.2 How many valence electrons does a nitrogen atom have?

____ (2)

1.3 Draw a Lewis structure for an ammonia molecule.

____ (4)

1.4 For an ammonia molecule, write down the:

1.4.1 Number of electron pairs surrounding the central atom.

____ (2)

1.4.2 Number of atoms surrounding the central atom.

____ (2)

1.4.3 Name the geometric shape of an ammonia molecule.

____ (2)

(Total 14)

Question 2 (DBE/November 2014)
Please answer the following question

Both aluminium fluoride (AlF_3) and phosphorous tri-flouride (PF_3) contain fluorine. Aluminium fluoride is a colourless solid used in the production of aluminium, whilst phosphorous tri-flouride is a poisonous, colourless gas.

2.1 Explain the difference between a covalent bond and an ionic bond.

____

____(2)

2.2 Name the type of chemical bond between particles in:

2.2.1 AlF_3 -

____(2)

2.2.2 PF_3 -

____(2)

2.3 Draw the Lewis structure for:

2.3.1 AlF_3 –

(4)

2.3.2 PF_3 –

(4)

2.4 Draw molecular shape of PF_3

____(2)

(Total 16)

Question 3 – Use the diagrams provided to answer the questions

3. Consider the following images, and then answer the questions that follow.

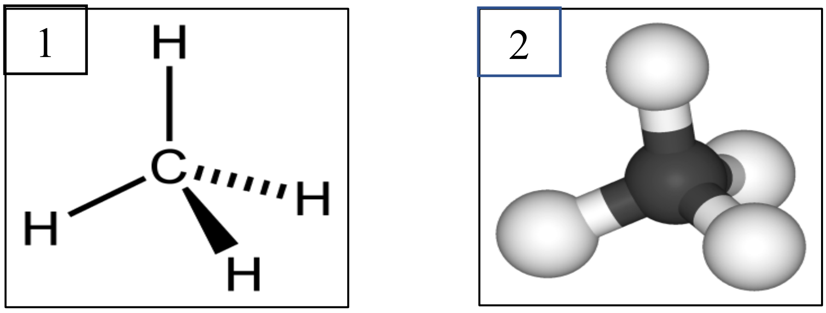

Figure 1

3.1 Pictures 1 and 2 in Figure 1 above represent the same molecule.	True	False
3.2 Explain your reasoning in 2.1 above.		

(2)

(Total 2)

Question 4 – Use the diagrams provided to answer the questions

4. Consider the following images, and then answer the questions that follow.

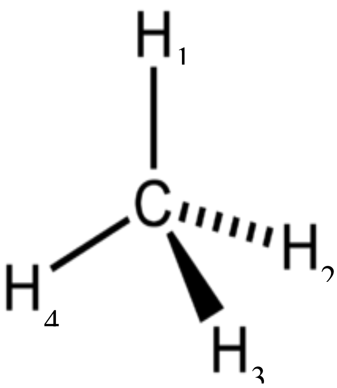

Figure 2

4.1 H_1 and H_2 in Figure 2 are on the same plane.	True	False
4.2 Explain your reasoning		

(3)

4.3 H_3 and H_4 in Figure 1 are on the same plane.	True	False
4.4 Explain your reasoning		

(2)

(Total 3)

Question 5 – Use the diagrams provided to answer the questions

5. Consider the following images, and then answer the questions that follow.

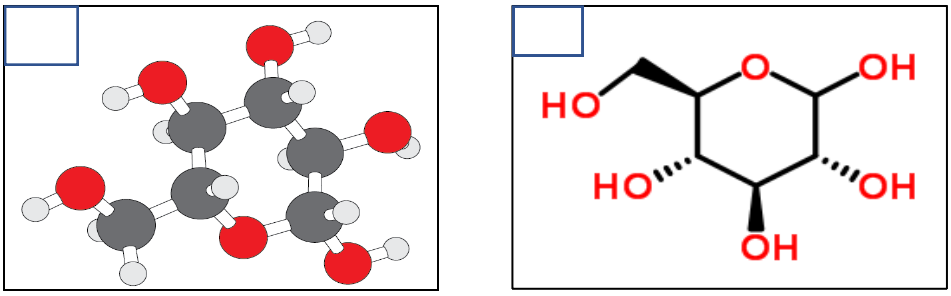

Figure 3

5.1 Pictures 1 and 2 in Figure 3 above represent the same molecule.	True	False
5.2 Explain your reasoning in 4.1 above.		

(3)

(Total 3)

Question 6 - Indicate whether you agree or disagree with the following statements.

3.1 I have difficulties using available information to predict outcome of chemical processes.			
Strongly agree	Agree	Disagree	Strongly disagree

3.2 I have difficulties illustrating using simple diagrams and drawings.			
Strongly agree	Agree	Disagree	Strongly disagree

3.3 I have difficulties synthesising information cognitively to predict outcome of Biomolecular processes.			
Strongly agree	Agree	Disagree	Strongly disagree

3.4 I have difficulties relating the orientation of two different ERs representing the same amino acid			
Strongly agree	Agree	Disagree	Strongly disagree

3.5 I have difficulties explaining chemistry concepts to other people.			
Strongly agree	Agree	Disagree	Strongly disagree

3.6 I have difficulties understanding chemistry concepts when I study using diagrams and pictures.			
Strongly agree	Agree	Disagree	Strongly disagree

3.7 I have difficulties understanding chemistry concepts when I study using lecture notes			
Strongly agree	Agree	Disagree	Strongly disagree

3.8 I have difficulties understanding chemistry concepts if I missed a lecture.			
Strongly agree	Agree	Disagree	Strongly disagree

APPENDIX F: THE QUESTIONNAIRE

Dear learner

Thank you for your willingness to complete the following questionnaire. The purpose of this questionnaire is to determine what your views are on the use of computer simulations and models in learning how molecules form their shapes. There are no right and wrong answers. Your real name will not be revealed when I report on my findings.

Name: ______________________________

Age: ________________________________

1.1 I have difficulties using given information to predict the shape of a molecule?		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

____
____
____
____
____

1.2 I have difficulties illustrating the different molecular shapes and geometric orientations.		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

____
____
____
____
____

1.3 I have difficulties synthesizing information to predict the shape and structure of a molecule.		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

____
____
____
____
____

1.4 I have difficulties relating the molecular shape to the name and properties of the molecule.		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

1.5 I have difficulties understanding chemistry concepts and information from the textbook alone.		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

1.6 I have difficulties explaining chemistry concepts to other people.		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

1.7 I have difficulties in following the pictures in a computer simulation on geometric structures.		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

1.8 I have difficulties in following instructions and interpreting pictures in computer simulation on geometric structures.		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

1.9 I have difficulties in following the computer simulation on geometric structures for its entire duration		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

1.10 I have difficulties in identifying different molecular orientations when learning through a computer simulation		
Agree	Neutral	Disagree

Please explain your response in the lines provided below.

APPENDIX G: INTERVIEW QUESTIONS

INTERVIEW

Below are the questions to be used for this research study. These questions will be for the randomly selected participants, where there will be 10 taken from each group. The interview is to be guided by the researcher. The interview will be done face to face with the participants and during break in their schooling environment. The participants can answer honestly and there are not wrong or correct answers, this is based on opinion and\or understanding

Questions

1. Do you enjoy chemistry?
2. What do you find difficult about chemistry?
3. What do you think can help learners to understand chemistry more fun?
4. Do you find naming geometric shapes challenging?
5. Do you find drawing the 3D shapes challenging?
6. What would make chemistry more fun and understandable?
7. Do you think using molecular shapes could assist in making chemistry less challenging?
8. Do you think the aid of videos could assist in making the naming of shapes easier?
9. How do you think playing with molecular shapes help you into understanding the geometric orientation of the shapes?
10. How do you think watching a video will helped you understand the geometric orientation of the shapes?
11. What do you find interesting about the molecular shapes used by the researcher to teach chemistry?
12. What did you find interesting about the visual/virtual reality used by the researcher to teach chemistry?
13. What did you not like about using the molecular shapes in the lesson?
14. What did you not like about the visual\virtual reality used in the lesson?

APPENDIX H: RESEARCH ETHICS CLEARENCE CERTIFICATE UNISA

UNISA university of south africa

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2018/09/12

Dear Miss Nkosi

Decision: Ethics Approval from 2018/09/12 to 2021/09/12

Ref: 2018/09/12/61995088/33/MC
Name: Miss TP Nkosi
Student: 61995088

Researcher(s): Name: Miss TP Nkosi
E-mail address: thobileking@gmail.com
Telephone: +27 76 267 7991

Supervisor(s): Name: Prof L Mnguni
E-mail address: mngunle@unisa.ac.za
Telephone: +27 12 429 4614

Title of research:

The effects of using virtual representations and physical models on Grade 11 learners understanding of geometric shapes in the chemistry classroom.

Qualification: M. Ed in Science and Technology Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2018/09/12 to 2021/09/12.

*The **low risk** application was reviewed by the Ethics Review Committee on 2018/09/12 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

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APPENDIX I: LANGAUGE EDITING CERTIFICATE

EDITING AND PROOFREADING CERTIFICATE

29 Sparrow Street
Tasbet Park Extension
Witbank
1040
24 September 2019

TO WHOM IT MAY CONCERN

This certificate serves to confirm that I have edited and proofread the report for T.P Nkosi's dissertation entitled, "**The effects of virtual reality and physical models on grade 11 learner understanding of geometric shapes in the chemistry classroom'**

I found the work easy and intriguing to read. Much of my editing basically dealt with obstructionist technical aspects of language, which could have otherwise compromised smooth reading as well as the sense of the information being conveyed. I hope that the work will be found to be of an acceptable standard.

Hereunder are my particulars:

Chanel. E. Roarty

Contact number 082 797 9542

Shady92@mweb.co.za