

Using a conceptual change approach as a teaching strategy for improving learners' understanding of Chemical Change in Physical Sciences.

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at the University of the Western Cape

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DECLARATION

I declare that *Using a conceptual change approach as a teaching strategy for improving learners' understanding of Chemical Change in Physical Sciences* is my own work, that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

NAME: MANTUA MAVIS BIDI

DATE:

SIGNED:



DEDICATION

1. To the memory of my late grandmother, Mamoraka Mapakiso Mohlokonya, who brought me up until the age of sixteen. She is the one who laid a solid foundation by teaching me values and morals. I am the person I am today because of her teachings. Ke ya leboha moTlounge.
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KEY WORDS

Chemical change

Chemical reactions

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Cognitive thinking

Conceptual change texts

Conceptual change theory

Constructivism

Learning

Mixed Method approach

Science Misconceptions

Physical Sciences

Science Education

Eastern Cape



ABSTRACT

USING A CONCEPTUAL CHANGE APPROACH AS A TEACHING STRATEGY FOR IMPROVING LEARNERS' UNDERSTANDING OF CHEMICAL CHANGE IN PHYSICAL SCIENCES.

The purpose of this study is to investigate the use of a Conceptual Change Approach as a teaching strategy to improve learners' understanding of Chemical Change in Physical Sciences. In addition, learners' attitudes toward chemistry as a school subject and toward Conceptual Change texts were investigated. Moreover, learners' science process skills were also investigated. The study was underpinned by Conceptual Change Theory and Constructivism. The sample included 34 Grade 11 learners doing Physical Sciences. The case study is a secondary school in the Eastern Cape. For the purposes of this study both quantitative and qualitative research methods were used. Learners were given a pre- test and a post-test and an intervention in the form of a Conceptual Change text lesson. Thereafter, focus group interviews were used to examine learners' understanding in greater detail. Findings revealed that learners have several misconceptions that hinder learning related to chemical change. It is therefore imperative to find ways for remediation of these misconceptions. The results also showed that instruction based on the Conceptual Change Approach in which Conceptual Change Texts were used, caused significantly better attainment of concepts on chemical change, better remediation of misconceptions and enhanced understanding of chemical change. This study provides insight into the use of Conceptual Change as a teaching strategy to improve learners' understanding of challenging areas in Physical Sciences.

Key Words: Chemical Change, Conceptual Change Approach, Conceptual Change texts, Misconceptions, Physical Sciences.

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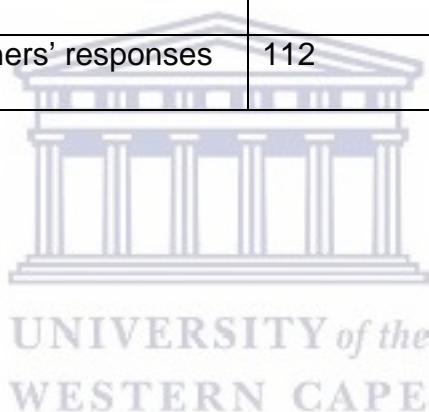
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CHAPTER 1

INTRODUCTION TO THE STUDY

1.1. Introduction

The aim of this study is to investigate how a conceptual change approach as a teaching strategy can be used to improve learners' understanding of chemical change in an attempt to improve performance in Physical Sciences as a subject. This chapter provides the background and rationale for the study. It presents the context within which the study is conducted and describes the research problem and the research question. It also highlights the significance and the limitations of the study.

1.2. Background to the study

The pass rate of learners taking Physical Sciences is currently an issue of major concern nationally and internationally (Department of Education, 2010; Redish, 2006). The problem of poor performance in Physical Sciences is however not only restricted to South Africa but also is apparent in the surrounding countries. Learners around the globe seem to struggle with understanding and learning Physical Sciences (Redish, 2006). The examination results published over the past few years reflect that there is no improvement in the performance of learners in the Physical Sciences. In view of all this, it will be appropriate to explore new strategies and ways to enable learners to achieve the desired outcomes at a higher level in Physical Sciences.

Table 1: Overall Achievement in Physical Sciences for the past 4 years

Year	No. Wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2011	180585	96441	53.4	61109	33.8
2012	179194	109918	61.3	70076	39.1
2013	184383	124206	67.4	78677	42.7
2014	167997	103348	61.5	62032	36.9

When one looks at the recent history of Physical Sciences Grade 12 results for the past four years during the National Senior Certificate (NSC) examinations in South Africa, as outlined in table 1 above, the results are not very encouraging (Department of Education, 2014). The general performance of candidates reflects a decline from that of the past two years (NSC Diagnostic report, 2014). Table 1 above, adapted from the NSC Diagnostic report of 2014, shows the overall achievement in Physical Sciences in the National Senior Certificate for the past four years. In comparison to 2013, it was noted that the number of candidates writing the subject decreased by 16 386. The number of candidates who passed at the 30% level declined by 5.9 percentage points and those who passed at the 40% level also declined by 5.8 percentage points. In 2012, the national results were 61.3%, 2013 were 67, 4% and in 2014 they dropped to 61,4%.

Overall achievement in Physical Sciences

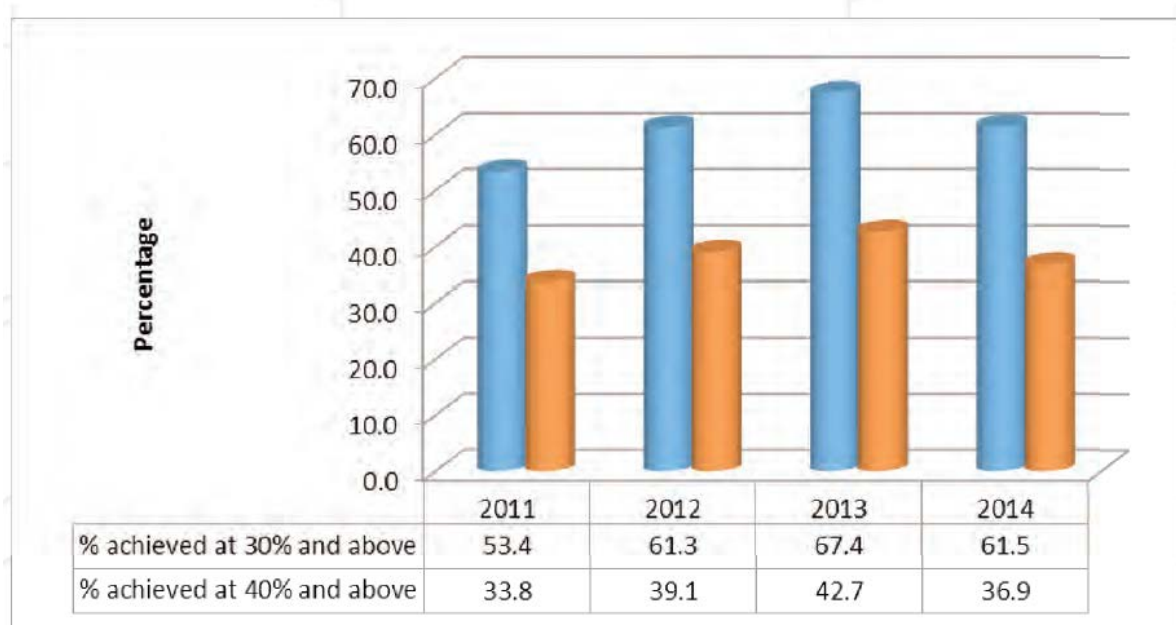


Figure1. Overall achievement in Physical Sciences (adapted from 2014 NSC Diagnostic Report)

Figure 1 above indicates percentages obtained by learners in Physical Sciences from 2011 to– 2014. From the graph, most learners obtained between 30% to 40% and the number of learners who achieved from 40% and above is less.

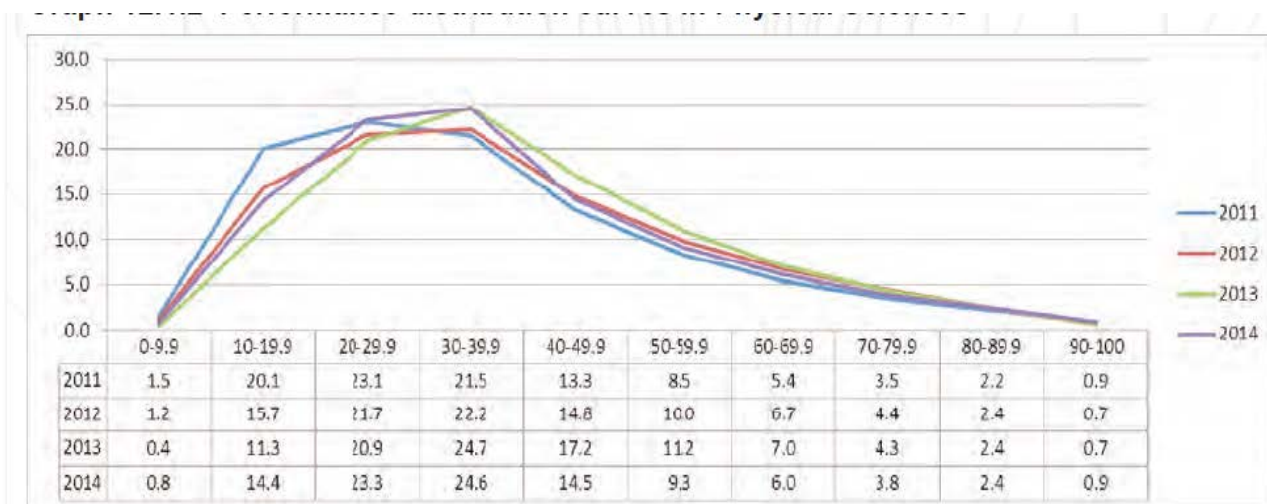


Figure 2: Performance distribution curve (Adapted: 2014 NSC Diagnostic Report)

Figure 2 above indicates national performance of Physical Sciences from 2011 to 2015. The percentage of candidates performing at the 0 - 29.9% categories increased compared to 2013. This signifies a drop in the overall performance. There is also a decrease in the percentage of candidates achieving at all levels from 30 to 80% which means fewer candidates passing.

In the Eastern Cape Province, the results show evidence of improvement though not near 70% as it was targeted by the National Minister of Education, Angie Motshega, for the 2014 matric class. In the district where the study was conducted, the results for Physical Sciences were 46% in 2012, 41.2% in 2013 and 44.6% in 2014. These results reflect negatively in Physical Sciences performance both provincially and nationally. The improvement of the results depends on the effort by both the learners and the teachers.

Due to the fact that many learners have great difficulty in successfully developing a scientifically accepted understanding of chemical change, the researcher decided to find ways in which to assist learners to develop a better conceptual understanding of chemical change. The researcher had put this theory into test to see if it surfaces the critical thinking and accommodation of new concepts to enable learners to perform better and obtain good outcomes which meet the national standards as set by the Department of Basic Education (DoE). As a Physical Sciences and Mathematics teacher, this research was done in order to use the conceptual change approach

teaching strategy even when teaching other topics in Physical Sciences and Mathematics syllabi if it yields positive outcomes.

In view of all the above and according to the Curriculum and Assessment Policy Statement (CAPS), the researcher decided to find ways in which learners' performance in Physical Sciences can be improved. To achieve this goal, the researcher has done a study which would not only broaden learners' knowledge and develop their conceptual understanding of chemical change, but also to open their minds and be informed about controversial issues relevant to chemistry and their life in general. The purpose of the study is to investigate how the conceptual change approach as a teaching strategy can be used to improve learner's understanding of chemical change and thus improving performance of learners in Physical Sciences.

The study was done in one of the provinces in South Africa, the Eastern Cape Province. Although some top achievers in Physical Sciences in the country are from Eastern Cape, overall results for Physical Sciences in the province, district and school are not good. Table 2 below shows the Physical Sciences results from national, provincial, district and down to the school level where the study was done.

Table 2: Physical Sciences Results in terms of %

YEAR	NATIONAL	PROVINCE	DISTRICT	SCHOOL
2013	67.4	64.9	41.2	50
2014	61.5	57.5	44.6	30
2015	56.6	49.5	36.9	33.3
2016	62	49.6	58.8	70

Table 2 above shows that from 2013, Physical Sciences results nationally dropped from 67.4% in 2013 to 62% in 2016. In the province, the results dropped from 64.9% in 2013 to 49.6% in 2016. In the district, the results escalated from 41.2% in 2013 to 58.8% in 2016. Although the results indicate increase in the district, they did not meet the target that was set by the Minister of Basic Education, Angie Motshega, of 70% and above. They also did not make a positive impact in the provincial results as well as the national results. This shows how bad learners are performing in Physical Sciences in the entire country. In the district the results were 41.2% in 2013 and

increased to 58.8% in 2016. Although the results are increasing, they are not reaching the required standard and target. In the school where the research is done, the results deteriorated from 50% in 2013 to 33.3% in 2015, they increased again in 2016 to 70%. Although they increased in 2016, the results in the school are not consistent, it is not guaranteed that they will stay at 70% or increase in the coming years. The poor performance of learners in Physical Sciences, the inconsistency of the increase and the decline of learners' performance in Physical Sciences at school prompted the researcher to do the study.

1.3. Context of the study

This study was performed at a school in the Northern Region of the Eastern Cape Province. The school is situated in the rural Sterkspruit District, one of the districts in the Province. This area is constituted by low income people and some of them are unemployed. There are also a high percentage of child-headed homes. The school is a senior secondary school starting from grade 10 to grade 12. It is a mixed school that consist of 60% girls and 40% boys. In all the grades, only one class per grade is doing Physical Sciences, thus constituting one third of the whole school population.

The school where this research was conducted was established in 1963, it is a quintile 3 school also referred to as a no-fee school. The school depends on fundraising to be enhanced. It has a library, a computer laboratory and a science laboratory that are non-functional because there is no equipment. It has an enrolment of about 600 to 700 learners and 21 staff members. Most learners are Xhosa speakers and few are speaking Sesotho. The school has a principal, a deputy principal, 3 heads of department and 16 post level 1 educators. The medium of instruction in this school is English. The researcher is an HOD for Science Department since 2009, teaching Mathematics. One of the researchers' major subjects is Physical Sciences. Although the researcher is not teaching Physical Sciences at present, it is her responsibility to see to it that curriculum is delivered according the statutes and policies of the Department of Education, moderate and develop Physical Sciences teachers under her jurisdiction and also to assist in teaching the subject when the need arises. The other responsibility of the researcher is to see to it that Physical Sciences is taught in such a way that learners are motivated to do the subject and achieve good results.

When moderating and analysing results for Physical Sciences ever since 2009, the researcher realised that learners are having difficulties in understanding chemistry. The hindrance to meaningful teaching is that the school is an under-resourced school. The science laboratory was built in 1963 when there was no electricity. The shelves are worn out. It is not easy to perform experiments as the equipment is also outdated. In general, the science laboratory is in a condition that does not meet the current requirements to teach sciences so as to meet the standards as set out in CAPS.

In the 2015 subject improvement plan for Physical Sciences the researcher completed a question by question analysis of 2014 Physical Sciences end of the year grade 10 and 11 examinations. Chemical reactions and energy changes was one of the sub-topics in chemical change in which learners performed badly. These findings directed the researcher to consider what needs to be done to improve learners' performance in this section of Physical Sciences. The picture witnessed after doing the subject analysis in the school provided the same picture that was witnessed in the cluster meeting where other schools in the district also presented their subject improvement plans. The study was done in order to improve learners' understanding of chemical change and to improve performance of learners in Physical Sciences in the school so as to further improve the performance of learners in the subject at district, provincial and national level.

1.4. State of science education in South Africa

Science Education involves Physical Sciences, Technology and Mathematics. It prepares learners to study science at a higher level, follow a career in science and become scientific literate citizens. Research in science education plays an essential role in analysing the actual state of scientific literacy and practice in schools, in addition to the improvement of instructional practice and teacher education (Duit, 2007). Science can be considered as a body of evidence that emphasises the integration of scientific inquiry and knowledge (Staver, 2007).

The education system in South Africa has undergone remarkable changes in the previous years with the aim of transforming it into a competent education system that can match and be equivalent to the international standards. Amongst the changes,

the introduction of the National Curriculum Statement (NCS) which was revised and is now called the Curriculum and Assessment Policy Statement (CAPS) can be regarded as the most noticeable and important change that affected all stakeholders in education.

The introduction of CAPS is aimed at equipping learners with knowledge, skills and values necessary for fulfilment and meaningful participation in society as a citizen of a free country (Department of Education, 2011). It is also aimed at meeting the challenges posed by the scale of change in the world, the growth and development of knowledge and technology as well as the demands of the 21st century that requires learners to be exposed to different and higher levels of skills and knowledge (Department of Education, 2011).

In spite of all the efforts and changes made by the Department of Education, the underperformance of learners in the National Senior Certificate (NSC) examination, especially in Mathematics and Physical Sciences is a serious challenge to all stakeholders of education. It has a direct impact on the training and supply of skilled people to the human resource of the country. The shortage of skilled people in the country affects the economic growth and the technological advancement of the nation. Burstenshaw (2006) indicated that there is evidence of a growing skills shortage with a possible shortfall of between 1,5 and 2 million skilled people over the next ten years in South Africa. Barnes (2007) maintains that South Africa produces about 1400 engineering graduates every year and this needs to be increased to at least 2400 to close the shortfall.

The statistics for Physical Sciences matric results indicates the need for improved Physical Sciences education. Learners who are unable to understand Physical Sciences concepts often label the subject as difficult and that may not only adversely affect their progress in the subject, but also discourage them from choosing Physical Sciences as a subject and consequently limit their future possibilities in a career in sciences (Mugler, 2010).

Redish (2006) stresses the importance of paying more attention to the facilitation of Physical Sciences to all learners given that, applicable skills are needed in an

increasingly technological world and demanded in the labour market. Therefore, any country, including South Africa, can ill afford not to have enough learners entering into a Physical Sciences study field. Unfortunately, the Physical Sciences curriculum is filled to capacity with limited time for learners to conceptualise difficult and related concepts (Hobden, 2005). Therefore, it becomes imperative to pay more attention to the teaching of Physical Sciences due to technological advancement and to supply in the labour market needs (Redish, 2006).

Research in science education plays an essential role in analysing the actual state of scientific literacy and the practice in schools, in addition to the improvement of instructional practice and teacher education (Duit, 2007). Another problem facing science education in South Africa is the scarcity of qualified teachers, thus in most schools, learners in the lower grades are taught science by teachers who are unqualified to teach science. For instance, it is not uncommon to find a Life Sciences, History or any other teacher with no background in science to be assigned to teach Natural Science. Students taught by such unqualified teachers perform poorly in the higher classes more specifically in grade 12 examinations.

1.5. Interventions in science education in South Africa and the Eastern Cape Province.

Since the start of the Democratic Government in South Africa, there has been great emphasis on the promotion of Science, Technology and Mathematics (STM). These fields are seen as the critical basis for socio-economic development of the country (Suping, 2003). This statement is supported by other researchers that Mathematics, Science and Technology have been national priority in South Africa as evidence for example by the national Strategy for Mathematics, Science and Technology Education (Scott & Usher, 2011).

In 2001 the Department of Basic Education established the Dinaledi Schools Project. The aim of the project was to increase the number of learners with university-entrance Mathematics and Science passes. The project started in 2006 with 400 schools and is still active and the performance of these schools is continuously monitored. The Department of Education's main objective related to the project was focused on improving the performance of learners in the Mathematics and Physical

Sciences. In 2008 a 100-hour teacher training process was undertaken with 2 400 teachers in Dinaledi schools across all nine provinces to strengthen their content knowledge, improve their teaching of Mathematics and Physical Sciences and improve learner performance. Yet despite all the support from the Dinaledi project (DoE, 2009), the results are still very bad.

The Department of Basic Education (DBE), in 2012, has worked in partnership with the Shuttleworth Foundation, to develop and distribute the Siyavula Mathematics and Physical Sciences textbooks for grades 10 to 12, to all schools offering these subjects. This project focused on increasing the number of grade 12 learners who pass Mathematics and Physical Sciences. In total 1277 550 Mathematics textbooks and 934700 Physical Sciences textbooks have reached their target groups. In 2014, the DBE provided subject advisors with CD's and DVD's with exemplars in all NSC subjects, uploaded onto the DBE website self-study guides in the ten key subjects to enhance teaching and learning. Common examinations were administered in grade 11 for Mathematics and Physical Sciences to prepare learners for the final grade 12 examinations.

The Department of Education, Eastern Cape Province, in conjunction with the University of the Western Cape initiated a project whereby teachers from the various districts were selected and trained in Advanced Certificate in Education, specialising in Physical Sciences. In this project, teachers were exposed to various methodologies as to how to teach Physical Sciences in order to improve learner performance, and also to motivate and encourage learners to take Physical Sciences as a specialisation subject in secondary school as well as at tertiary institutions. The project continued and trained these teachers up to a Masters level. The teachers are utilised by the Eastern Cape Education Department to train other teachers in fields like Natural Sciences in the General Education and Training (GET) phase.

The Department of Education in the Province also introduced Learner Attainment Improvement strategy (LAIS) programs that are in place as a form of alleviating challenges in Physical Sciences. The LAIS programme include:

1. Incubation classes which take a few learners from a large pool of learners and only cater for bright sparks whereas most learners are those who are struggling with Physical Sciences.
2. Winter and spring schools which are marked by overcrowded classes and do not cater for individual attention for learners.
3. Mini quizzes and Astro quizzes competitions that take place in March and take only two learners per school.
4. Science festival which is held in Grahamstown and not all learners are able to attend the festival as it is far from many schools in the province.
5. NMMU program for FET Physical Sciences educators which aims at developing educators in Physical Sciences.
6. Science Olympiads, SAASTA science school's debates and science week target only a few learners and other schools do not bother participating.
7. 1 + 4 program which is aimed at developing foundation phase educators in numeracy which is a base for Physical Sciences.
8. Mathematics, Science and Technology grant which is aimed at supporting schools that are struggling with Physical Sciences.

One of the aims of Science Education, according to Habtemariam (2000) is to enable learners to develop a valid understanding of science including problem solving, inquiry, information gathering, analysis, interpretation and other essential process skills needed to tackle practical problems on a daily basis.

1.6. Research problem

Physical Sciences is one of the subjects where learners perform poorly in the Eastern Cape as well as in other provinces in South Africa. The pass rate of learners taking Physical Sciences is an issue of major concern nationally and internationally (Department of Education, 2010; Redish, 2006). Redish (2006) further argued that it is of vital importance to pay more attention to the teaching of Physical Sciences due to technological advancement and to supply in the labour market needs. This is of great concern in secondary education in the whole of the country's science education system. Morais, Paiva and Barros (2007) believe chemical change is a learning area where learners present more alternative conceptions resulting in science becoming more difficult for them to understand and thus a great challenge for teaching.

Looking at the recent history of Physical Sciences grade 12 results, the general performance of candidates reflects a decline (National Minister of Basic education, 2014). The statistics for performance in Physical Sciences emphasize the need for improved Physical Sciences Education by researching learners' conceptual knowledge in South-Africa's multi-cultural environment (Meyer, 2014). The problem of poor performance in Physical Sciences is not limited to South Africa, it is globally. Learners who are unable to understand basic chemistry concepts usually label the subject as difficult. This does not only affect their performance, it also discourages them from choosing Physical Sciences as a subject at high school, thus limiting their future possibilities in a career in sciences.

Redish (2006) emphasises the importance of paying more attention to the facilitation of Physical Sciences to all learners given that, applicable skills are needed in an increasingly technological world and demanded in the labour market. Therefore, any country, including South Africa, cannot afford not to have enough learners entering into a Physical Sciences field of study.

Staver (2007) ascribes the difficulty of learning Physical Sciences to the wide range of prior knowledge, experiences, cognitive resources and interests the learners bring to the classroom. Staver (2007) further argued that, educators should integrate the core body of scientific knowledge and scientific enquiry as to clarify science and its applications. He furthermore claims that teaching is aimed at the facilitation of learning and if learners fail to learn, the educator should carry part of the responsibility. This implies that when educators plan their lessons, they have to be sensitive to their learners' needs and adjust their teaching strategies and techniques to assist learners. Once learners understand scientific principles and are able to apply their scientific knowledge to the world they live in, they gain a lifetime thirst for knowledge and the acquisition of skills that can be learned and developed on their own (Staver, 2007).

One of the problems science teachers currently face is the inability of learners to understand chemical change. The core of this problem lies in the fact that learners come to class unable to write chemical symbols and formulae for certain elements and compounds and also they come to class with existing knowledge about the

phenomena which are inconsistent with the accepted scientific conceptions. The existing knowledge of the learner plays an important role in the learning process. Often this knowledge comprises ideas which are not in agreement with those generally accepted by scientists and these have been variously termed 'alternative conceptions', 'alternative framework' or 'misconceptions' (Garnett & Hackling, 1995; Sungur, Tekkaya & Geban, 2001).

Learners in the Eastern Cape come from different backgrounds and communities and hence have varied experiences about the way substances interact. But whatever the differences in learners' backgrounds, they all need to develop a scientifically valid understanding of what they learn at school. Also, they need to know how the knowledge they acquire in the science classroom apply to their daily lives outside the school. The central concern of this study, therefore, is to determine how conceptual change as a teaching strategy can be used to improve learners' understanding of chemical change and also to find ways in which learners could be assisted to develop a better conceptual understanding of chemical change. The study is also aimed at broadening learners' knowledge and to open their minds and be informed about controversial issues relevant to chemistry and their life in general.

1.7. Research questions

Against the above background, the researcher wished to find answers to the following research question:

How can a conceptual change approach be used as a teaching strategy to improve learners' understanding of chemical change?

Emanating from the main research question above are the following sub-questions:

1. What were learners' initial understanding of chemical change?
2. How was the conceptual change approach implemented to address grade 11 learners understanding of chemical change?
3. What were learners' understanding of chemical change after the conceptual change lessons?
4. What were learners' perception of the conceptual change approach?

1.8. Significance of the study

The existing knowledge of the learner plays an important role in the learning process. Everyday use of certain terms, often used in non-scientific contexts, contributes to learners' confusion. This study therefore presents strategies that chemistry instructors can use to remediate misconceptions and promote conceptual change. Knowing that learners have preconceptions and some of them contradict with scientific view would help science educators to realize that learners have misconceptions and therefore to remedy that, science educators need to develop their lessons by finding ways to remediate these misconceptions. They must devise a strategic method that will help in both the investigation and elimination of misconceptions.

A method that helps in investigation and elimination of misconception is necessary in a Physical Sciences classroom. The method that uses conceptual change is based in that necessity. This study uses those methods. It will help educators to be able to investigate misconceptions and will provide ways to deal with them. Conceptual change texts developed in this study can help learners form links between existing knowledge and new knowledge resulting in meaningful learning. Therefore, conceptual change approach fosters educators to arrange a conducive learning environment in such a way that learners can express their ideas, construct their own knowledge and also realise their misconceptions.

It is hoped that the experience gained in this study would prove to be fruitful and useful in motivating the learners involved in the study to want to study not just chemical change, but other topics in chemistry as well as Physical Sciences as a whole. It is also hoped that the findings will contribute to future research on chemical change and other related topics. Conceptual change texts accompanied by models and demonstrations can provide an alternative to traditional methods to remediate learners' misconceptions. They were used in this study to remediate misconceptions learners may have with regards to chemical change. The findings in this study may also assist in understanding some of the difficulties learners experience in their chemistry classes and may help in the selection of appropriate instructional activities.

Through the findings in this study, curriculum developers could realize the effectiveness of instructional methods based on conceptual change approach and therefore develop curriculum that will cover the interests, knowledge, understanding, abilities, and experiences of learners in order to increase learners' understanding. Special attention can be given at pre-service trainings to conceptual change approach. Textbook authors could realise the effectiveness of conceptual change strategies in remediation of misconception among learners and therefore could give special attention to conceptual change approach while writing.

Learners will realise that some of the knowledge they have is inconsistent with what they are taught at school. Therefore, conceptual change texts developed can help them realise their misconceptions and remediate them thus facilitate their met cognitive awareness. Learners' attitudes towards science are a key factor in chemistry achievement since they are positively correlated. Conceptual change text instruction can facilitate developing positive attitudes towards science. This study provided instruments and procedures for conducting related research in the future.

The awareness of misconceptions allows teachers to see their views in a different way which may lead to renovation of their science knowledge as well as the instructional strategies used in the classroom. Science teachers, after knowing the misconceptions, can select science content and design lessons that will cover the interests, knowledge, understanding, abilities, and experiences of their learners in order to increase learners' understanding.

1.9. Limitations of the study

The study is done in one school that has only one Physical Sciences class per grade, therefore a case study. It will not provide results on a broader scale. In the study, only grade 11 learners were participants in the study. Grade 12 learners could not take part because they are writing an external paper and therefore they could not be disturbed.

Another challenge that was faced by the researcher was the learners' lack of enthusiasm and interest in their work as well as their negative attitudes towards Physical Sciences and education in general. As a teacher, the researcher had to

make lessons as interesting as possible. The researcher had to accommodate the learners' weaknesses without compromising the standard of the lesson. Despite these obstacles a concerted effort was made to ensure that all the learners gained enough in the exercise. The researcher had to cover concepts of chemical change, which they should have learnt in the lower grades before preparing them for the grade 11 work to be done.

1.10. Structure of the thesis

This study is outlined in the following way:

Chapter 1: Introduction

This chapter serves as the introduction to the research by highlighting the background of the study, the state of Science Education in South Africa, interventions made by the National Department of Education in the country as well as the Province of the Eastern Cape in order to improve performance of learners in Physical Sciences, the research problem, the research question, the significance of the study as well as the limitations to the study. It is in this chapter where the context of the study is explained.

Chapter 2: Theoretical Framework and Literature Review

In this chapter theoretical framework and literature related to the study are reviewed. International, national and local studies addressing this study are discussed.

Chapter 3: Research Design and Methodology

In this chapter, research design and methodology, including the quantitative and qualitative research methods are discussed. The procedures, design, population, sample and instrumentation that were used to measure the effectiveness of the conceptual development teaching strategies are discussed. Validity and reliability of the study is explained. Also the ethical aspects of the research are explained.

Chapter 4: Findings

The analysis, interpretation and synthesis of quantitative and qualitative data take place in this chapter. Based on the learning gained, the effectiveness of the conceptual change approach as teaching strategies are evaluated.

Chapter 5: Discussions

Discussions based on the findings are detailed in this chapter.

Chapter 6: Conclusion and recommendations

In this chapter, a summary is provided, conclusions and recommendations drawn regarding the effectiveness of the applied conceptual change approach teaching strategies on Chemical Change.

1.11. Conclusion

This chapter dealt with the rationale of the study. The next chapter will discuss in detail, literature related to the study and the theoretical framework of the study.



CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

The previous chapter looked at the rationale of the study and this chapter will look at the literature review and the theoretical framework relevant to the study. Various forms of literature were reviewed to establish the objectives of the research and in order to understand the nature of the incongruence between the researcher's learners' understanding and what they needed to know about chemical change or any other subject matter in chemistry. This study was underpinned by conceptual change theory and constructivism where the learners change and reconstruct their existing knowledge and concepts within the topic of chemical change in grade 11 curriculum.

2.2. Definition of terms

The following section defines terms that are commonly used in this study.

Accommodation: the creation of new schemata or the modification of old schemata which reflects the child's current level of understanding and knowledge of the world (Wodsworth, 1996).

Assimilation: the cognitive process by which a person integrates new perceptual, motor, or conceptual matter into existing schemata or patterns of behaviour (Wodsworth, 1996).

Cognitive Conflict: providing learners with confirmation that opposes with their existing conceptions.

Conceptual change theory: Theory of science instruction created by Posner, Strike, Hewson and Gerzog, (1982) based on identifying and addressing learners' held misconceptions. It is a learner based model that guides the learner through activities that directly challenge their personal misconceptions. Conceptual Change Theory is the outcome of a complex reasoning as well as a social process whereby sensible beings may alter existing conceptions for ones that are widely supported by experiential evidence (Posner, Strike, Hewson & Gertzog, 1982)

Conceptual Change Text: A text where learners are asked openly to predict what would happen in a situation before being presented with information that demonstrates the inconsistency between common misconceptions and the scientific conceptions (Çakır, Uzuntiryaki & Geban, 2002).

Science misconception: A mental model created by learners with the purpose of understanding scientific concepts that differ with the accepted beliefs held by scientists (Prokop & Fancovicova, 2006). Referred to by the research in a variety of different ways including preconceptions, alternative conceptions, alternative beliefs, alternative frameworks, private concepts, and naïve theories (Smith, Blakeslee & Anderson, 1993). Kapartzianis (2012) further explained that misconceptions are learners' conceptions that persist despite instruction, and are incompatible with the scientifically acceptable knowledge.

Conceptual change: Is described as a learning process in which learners' alternative conceptions reconstruct into the intended scientific conception (Vosniadou, 2008).

Conception: Means one's particular application or interpretation of a concept (Kaplan, 1964).

Concept: Is a general idea, usually expressed by a word, which represents a group of things having certain characteristics in common (Quillen & Hanna, 1961).

Constructivism: Is a theory of learning in which every learner constructs his or her ideas (Rasmussen, 1998).

Epistemological Beliefs: Beliefs about knowledge and how it is acquired (Charles, 2003).

Learning: Is an act or process of acquiring knowledge or skills (Colman, 2009).

2.3. Research question

This study addressed the following main research question:

How can a conceptual change approach be used as a teaching strategy to improve learners' understanding of chemical change?

2.4. Theoretical framework for the study

According to Smyth (2004) a framework within a research is a tool intended to assist a researcher to develop awareness and understanding of the situation under enquiry and to communicate. Joseph (2011) argued that the researcher needs to prepare a framework for both the theoretical as well as conceptual aspect in order to explain the different methods and strategies that are used to conduct a research. The theoretical framework of the study is a structure that can support a theory of a research work and it presents the theory which clarifies why the problem under study exists (Kozma & Khan, 2010). The researcher in this study formulated the theoretical framework based on the need to teach chemistry, which is the area of specialisation in this case. The study is underpinned by the theory of constructivism and conceptual change theory by Posner, Hewson and Hertzog (1982).

In the teaching of any topic in any subject, one has to consider what the learner already knows and how the existing knowledge may affect learning. According to Saunders (1992), there has been a definite shift in educational focus from the past to modern times. In the past the focus was placed on the external factors impacting learning, whereas today the focus is placed on the learner's understanding. This new focus includes the learner's existing knowledge, alternative concepts and cognitive style. Prior knowledge is the most influential predictor of science achievement (Lawson, 1983 & Gooding, Swift, Schell and McCroskery, 1990). The degree to which prior knowledge is consistent with the new subject matter is an indicator of the improved science learning. In this study, conceptual change theory was used as a teaching strategy where learners' alternative conceptions were reconstructed into the intended scientific conception.

One of the aims of Science Education is to develop positive attitudes towards science in learners because there is a momentous relationship between learners' achievement and attitude towards science. To motivate learners, teachers should

aim to develop learners' attitudes towards science besides their understanding of scientific concepts in science classroom and consider the factors affecting learners' attitudes towards science as is the case in this study. This study used conceptual change based instruction not only to enhance meaningful concept understanding but also to encourage learners to participate in classroom discussion through the tools used based on conceptual change method. In a study by Chi (1992) using the theory of conceptual change, the concept of chemical change has constraint-based features (e.g., random, simultaneous, uniform activities) that might prevent learners from intensely understanding the nature of the concept of chemical change. The existing knowledge of the learner plays an important role in the learning process. An equally important aspect for this study is that learners, in any grade, at any school, struggle to learn chemistry (Nakhleh, 1992). A good educator starts with what the learner knows (Carey, 2000). The discussion for this chapter is informed by Conceptual Change Theory, Constructivism, Cognitive thinking and Chemical Change. Enhancing, within the context of this study, refers to high- and low-performing learners changing their existing incorrect conceptions on chemical change, specifically on chemical reactions and energy, to scientifically correct concepts under the framework of conceptual change theory.

2.4.1. Conceptual change theory

Before conceptual change theory is discussed, one should understand what the terms concept, conception and misconception are, since conceptual change requires reconstruction of pre conceptions in order to remediate misconceptions.

2.4.1.1. What is concept and conception?

Carey (2000) defined concepts as units of mental illustration roughly equivalent to a single word, such as object, animal, heat and matter. Concepts are themselves difficult representational constructions and many properties of the units picked by a concept are characterized as a part of it and serve roles in explaining, inferring, and referring. Carey (2000) also added that:

“Individual concepts can be connected to build complex representational structures, such as propositions for example, all animals die and theories. Within a particular representational structure, concepts help us to make inferences and explain complex ideas. For example, from the proposition

“aardvarks are mammals”, one may infer that aardvarks bear live young ones. One may also explain a particular aardvark’s colouring by considering the colour of its mother and father and appealing to the concept of inheritance. Outside of particular concept system, concepts have a referential role: they pick out entities in the world that fall under them” (p. 14).

Woolfolk, (2010) defined concepts as mental categories for objects or events that are stored in the brain in a network reflecting the relationship with other concepts, known as conceptual framework. As the learners learn, new links are built in the brain between concepts, forming a conceptual framework that is comprehensible. Comprehensible conceptual frameworks, which can either be correct or wrong, enable a learner to make predictions, to explain and answer questions (Limón & Mason, 2010). Coherent wrong conceptual frameworks can lead to an explanation by the learner that is scientifically unacceptable, but in the insight of the learner correct and are known as misconceptions or alternative conceptions. These wrong frameworks are persistent and difficult to rectify. In Physical Sciences, conceptual change teaching strategies are often used to deal with persistent conceptual frameworks that are resistant to change (Treagust & Duit, 2009). In this study there were some learners that still kept parts of their original understanding of chemical change. There were learners that could not give any relationship in as far as bond energy is concerned. They still maintained the misconception they had before intervention. For an example, one of the learners maintained that bond energy is the study of strength in chemical bonding and the other learner maintained that bond energy is the amount of energy that is released during chemical reactions.

Every individual creates concept according to his or her unique learning experience and maturational pattern (Önder & Geban, 2006). Therefore, the past experiences of the individual, the way in which these experiences relate to new ones will influence the unique construction of concept network (Klausmerer, Ghatala & Frayer, 1974). Teo and Gay (2006) define a concept as a perceived combination of events and objects.

The major objective of instruction should be teaching for understanding which occurs when concepts become real part of mental structure (Önder & Geban, 2006).

Therefore, one should not expect understanding to occur in occasions where the subject is learned as isolated skills and processes (Önder & Geban, 2006). Understanding develops through interaction with environment and other individuals and when individuals have an opportunity to construct their own interpretation when they first meet a new topic (Lind, 2000). However, every individual has a unique way of learning concepts, people share common features about concepts. For an example, a teacher and a parent have different conceptions about education, but they have common attributes that they can communicate about with respect to education.

Learners create new concepts through assimilation and accommodation of new information while they are discovering the world and store those concepts in correct mental categories in their minds. Variability among concepts as explained by Klausmerer et. al. (1974) identified eight features of a concept and are discussed below.

2.4.1.2. Learnability

Learnability differs among concepts since some concepts are more easily learned than others by the same individual. For example, the concept of tablet is more readily learned compared to concept of an atom which is an abstract concept. Moreover, learning of definite concept can vary from person to person since they will probably vary in their perception of the concept.

2.4.1.3. Usability of a concept

Some concepts are used too often compared to others in solving problems and understanding principles. For an example, chemistry concept of an atom is used more often compared to evaporation in Physical Sciences.

2.4.1.4. Validity of a concept

Validity of a concept is considered when the specialists agree on its definition. Individuals' validity about a concept increases when one learns and the concept comes closer to the agreement of that of a specialist.

2.4.1.5. Generality of a concept

Concepts are arranged in a characterized manner. They are arranged from more general to more specific. An individuals' concept varies in generality if organized taxonomically.

2.4.1.6. Power of a concept

Power of a concept in this context of the study refers to how essential a concept is in realizing other concepts. For instance, without a concept of an atom, chemistry is difficult.

2.4.1.7. Structure of the concept

Concepts are structured in such a way that they show relatedness of the defining aspects. For an example, the concepts of neutron, electron and proton are related to that of an element. Thus, concepts are linked by relations to form a structure.

2.4.1.8. Instance Perceptibility of the concept

Instances that can be sensed differ from concept to concept. For instance, a cell phone has many instances that can be manipulated, seen and touched whereas electricity has less perceptible instances.

2.4.1.9. Instance numerousness of the concept

This is the number of instances that a concept varies in amount. Some of the concepts occur more than the others and the number of instances that a concept occurs ranges from one to infinity.

Kaplan (1964) describes conception as one's particular interpretation of a concept. In this study, the basic aim is to help learners acquire critical attributes of a particular concept since it is clear that concepts vary in attributes that are necessary in explaining the particular concept.

2.4.1.10. Misconceptions

From the results of thousands of studies reported in Duit (2009), research has shown that individuals are not simply passive learners but make sense of new information in terms of their previous ideas and experiences. One outcome of such learning is that

learners' knowledge is not consistent with the scientists' science, in other words, the pre-knowledge which learners bring to the classroom that make sense to them based on their daily life experiences may not match the science context and therefore may be wrong. These conceptions are referred to as children's science or misconceptions or alternative conceptions dependent on the author's philosophical position (Treagust & Duit, 2009). Treagust and Duit (2009) further indicated that these views are often firmly held, are resistant to change and present difficult challenges for teachers of science and researchers of science education.

Alternative conceptions may arise as a result of a variety of contacts learners make with the physical and social world or as a result of interactions with teachers, other people, personal experiences or through the media; traditional instructional language; incongruities between teacher and learner knowledge of science; the abstract nature of science concepts and textbooks portrayals (Griffiths & Preston, 1992; Soyibo, 1995). It is well known that such learners' beliefs influence how learners learn new scientific knowledge and play an essential role in subsequent learning. Misconceptions obstruct the structuring of the acquired knowledge (Ozkan, & Selcuk 2013).

Another common source of misconceptions is the language used on a daily basis. Some scientific terms are used differently in our everyday language than its scientific meaning. For example, confusion in the use of 'energy' term which has a specific meaning in chemistry but different meanings in everyday life most likely may lead learners to have the misconception, for example, bond making requires input of energy and bond breaking releases energy (Boo, 1997)

Marumure, (2012) further argued that alternative conceptions are conceptions generated which are parallel to the scientific conceptions. Dykstra, Boyle and Monarch (1992) summarized the meaning of misconceptions as:

- 1) Learners, who are confronted with a particular situation, give erroneous answers. These erroneous answers are defined as misconceptions.
- 2) Learners have ideas about a particular situation and these ideas arouse the erroneous answers. These ideas are called misconceptions.

3) Learners have some essential beliefs, which are used in variety of different situations, to explain how the world works. These beliefs are defined as misconceptions.

Misconceptions are created by different sources. Cho, Kahle and Nordland, (1985) stated that misconceptions may arise from textbooks, may arise from prior to formal instruction (Griffiths & Preston, 1992), or as a result of interaction with teachers, physical and social world (Gilbert & Zylberstajn, 1985; Valanides, 2000). For example, misconception may result from diagrams or models used in textbooks. The theoretical models used in textbooks in their explanations are figurative in nature and they are open to misinterpretations. These tools are used to gain a better understanding; however, if not properly constructed, they may give rise to misconceptions (Mayer, 2001). Additionally, Kikas (1998) showed that the diagrams used in textbooks can be interpreted incorrectly which may result in misconception.

Gill-Perez and Carrauca (1990) stated that the resemblance between learners' instinctive ideas and pre-classical conceptions cannot be accidental, but must be a consequence of the same way of approaching problems. Absence of learners' doubts may lead to alternative frameworks, and trying to find possible alternative solutions to the problems also may lead to these innate ideas (Seker, 2006).

Variety of terms has been used to define those beliefs that vary from consistently accepted scientific agreement such as, "spontaneous reasoning or conception" (Viennot, 1979), "children's scientific intuitions" (Sutton, 1980), "naïve conception" or "naïve beliefs" (Caramaza, McCloskey & Gren, 1981), "intuitive ideas" (Hynd, McWhorter, Phares & Suttles, 1994), "common sense understanding" (Hills, 1983), "naïve theories" (Resnik, 1983), "intuitive science" (Preece, 1984) "common sense concepts" (Halloun & Hestenes, 1985), "spontaneous knowledge" (Pines & West, 1986); "children's science" (Stenhouse, 1986) "preconception" (Benson, Wittrock, & Bauer, 1993; Novak, 1990), "misconceptions" (Brown, 1992; Chambers & Andre, 1997; Din, 1998; Gonzalez, 1997; Griffiths, 1994; Griffiths & Preston, 1992, Michael, 2002, Schmidt, 1997; Treagust, 1988), "alternative frameworks" (Gonzalez, 1997; Kupier, 1994; Taber, 1999), "alternative conception" (Gilbert & Swift, 1985; Niaz, 2001; Palmer, 2001; Taber, 2001; Wandersee, Mintzes & Noval, 1994; Dykstra,

Boyle, & Monarch, 1992), “folk theories” (Medin & Atran, 1999), “intuitive conceptions” (Lee & Law, 2001), and “conceptual frameworks” (Southerland, Abrams, Cummins & Anzelmo, 2001) by numerous researchers. What is common in these explanations is that learners hold explanations about science concepts which differ from scientifically accepted explanation. In this study therefore, the researcher tried to investigate if conceptual change framework as a teaching approach can assist in changing the misconceptions learners bring into a science class to accepted scientific concepts.

A review of the research relating to learners’ misconceptions of science concepts reveals that misconceptions have many common features. They are normally strongly resistant to change and learners are generally reluctant to alter these misconceptions (Driver & Easley, 1978; Sungur, Tekkaya & Geban, 2001). This study focused on learners’ misconceptions in chemical change that may hinder learning. The following are some investigations that explored learners’ ideas on science issues; Particle Theory of Matter (Doran, 1972), Gasses (Stavy, 1988), Lights and Shadows (Neale, Smith & Johnson, 1990), Dissolution (Blanco & Prieto, 1997), Chemical bonds and energetics (Boo, 1997), Solution, gas and chemical change (Çalik & Ayaz, 2004), Periodic table and elements (Schmidt, Baumgartner & Eybe, 2002).

Nakhleh (1992) studied learners’ misconceptions on chemistry education and investigated the learners’ conceptual chemistry knowledge. The results showed that 20% of the learners still held a simplistic, undistinguishable view of matter. When asked how a solution of an acid or a base would appear under a very powerful magnifying glass, these learners drew waves, bubbles, or shiny patches.

Griffiths (1994) published a review of learners’ chemistry misconceptions and identified twenty misconceptions about chemical equilibrium. In the literature, many studies have investigated learners’ understanding of chemistry concepts such as chemical bonding (Taber & Coll, 2002), acids and bases (Ross & Munby, 1991), the particulate nature of matter (De Vos & Verdonk, 1996), atoms and molecules (Griffiths & Preston, 1992), and chemical equilibrium (Hackling & Garnett, 1985).

These studies show that some learners retained many alternative conceptions and faced several cognitive conflicts when dealing with chemical concepts.

Gilbert, Osborne and Fensham (1982) reported that learners' pre-knowledge about some science concepts have an important role in comprehending and interpretation of the knowledge. Researchers emphasised that teachers should be aware of the learners' misconceptions and in order to eliminate them effective teaching methods should be used by the teachers. Even if a learner that holds a misconception is willing to struggle through the cognitive conflict, they must first be able to correct their misconception prior to forming a correct mental model. O'Brien (2010) uses the analogy of constructing a house to describe this situation.

Learning is the result of the interactions between what the learner is taught and his/her current ideas, therefore misconceptions interfere with further learning. Misconceptions make it difficult for the learners to see the 'big picture', to realize the links among science concepts and principles, and to apply these principles meaningfully to daily life. The challenge of teaching science is to ensure that learners do not leave classrooms with new ideas and explanations that they do not understand. Learners will more readily remove misconceptions that they have defended than those that they have not examined at all. Teachers should therefore encourage learners to look for contradictions between ideas they have and what their observations reveal to them. Some learners will find this frustrating and will continue reasoning in a way that justifies their old beliefs; but for others, this experience will change their thinking. Therefore, in this study, learners' misconceptions as regards chemical change were investigated, and in order to develop learners' understanding of this topic, conceptual change oriented instruction was applied.

2.4.2. The Conceptual Change Theory

This study is underpinned by the Conceptual Change Theory. The conceptual change theory is one of the effective methods for dealing with misconceptions and for understanding concepts. Conceptual Change Theory has been proposed by Posner, Strike, Hewson and Gertzog (1982). It is based on constructivist notion which asserts that learning is a process of knowledge construction. This approach represents a perspective that is based on Piaget and Zeitzgeist's views and was improved by

Posner and his colleagues. The purpose of this approach, which is an alternative strategy based on Piaget's principles of assimilation, regulation and counterbalancing, is to encourage learners to remove misconceptions in their minds, and instead learn scientific knowledge (Wang & Andre, 1991; Chambers & Andre, 1997).

Chi, Slotta, and De Leeuw (1994) defined conceptual change as learning when certain existing concepts held by learners change. Learners have an active role in a learning process. They construct their own knowledge through their existing ideas, knowledge or experiences. Meanwhile, they create their own personal meanings by using their ideas. Hence, it is possible for them to misinterpret the new concepts and to construct misconceptions by using their existing knowledge and experiences. In order to minimise and to eliminate these misconceptions, educators need to consider conceptual change approach activities. Ausubel (1968) stresses the importance of existing knowledge in the process of accepting new concepts, but according to Chiu, Chou and Liu (2002) learners struggle to do this in chemical reactions.

Conceptual change theory assists the learner in changing his/her existing concepts. When their old knowledge does not match scientific concepts; that is, when they develop misconceptions, they are unable to learn well. Conceptual change theory is defined as a process of learning science in a meaningful way that requires the learner to rearrange and replace existing misconceptions in order to accommodate new conceptions (Smith, Blakeslee & Anderson, 1993). The term "conceptual change" is used to describe the kind of learning required when the new information to be learnt comes into clash with the learners' prior knowledge acquired on the basis of everyday experiences. This situation requires prior knowledge to be taken into consideration when teaching.

The "Conceptual Change Approach" that was initiated by Posner et al (1982) is fundamentally based on four conditions; firstly, the learner must be aware that the old concept he knows is inadequate (dissatisfaction). Learners must become dissatisfied with their existing conceptions. When the discrepant event is presented, there must be dissatisfaction with the existing conception, secondly, the new concept must be understandable (intelligibility). Learners must attain an initial understanding of the

new scientific conceptions. Learners are not going to adopt a new conception unless they can first represent it to themselves. In other words, they must find it intelligible, thirdly, the new concept must make sense to the learner (plausibility) and the learner should be able to easily picture it in the mind. A new conception must appear initially plausible. It must be linked with the current cognitive framework of the concept and associated ideas and must be reliable, and finally, the new concept must be beneficial to learners (fruitfulness); that is, they should be able to solve similar problems with the new concept in the real world in future. Learners must see that the scientific conception is useful in understanding other examples of phenomena. A new concept should suggest the possibility of the fruitful research program. Figure 3 below shows the different cognitive processes involved in conceptual change theory.

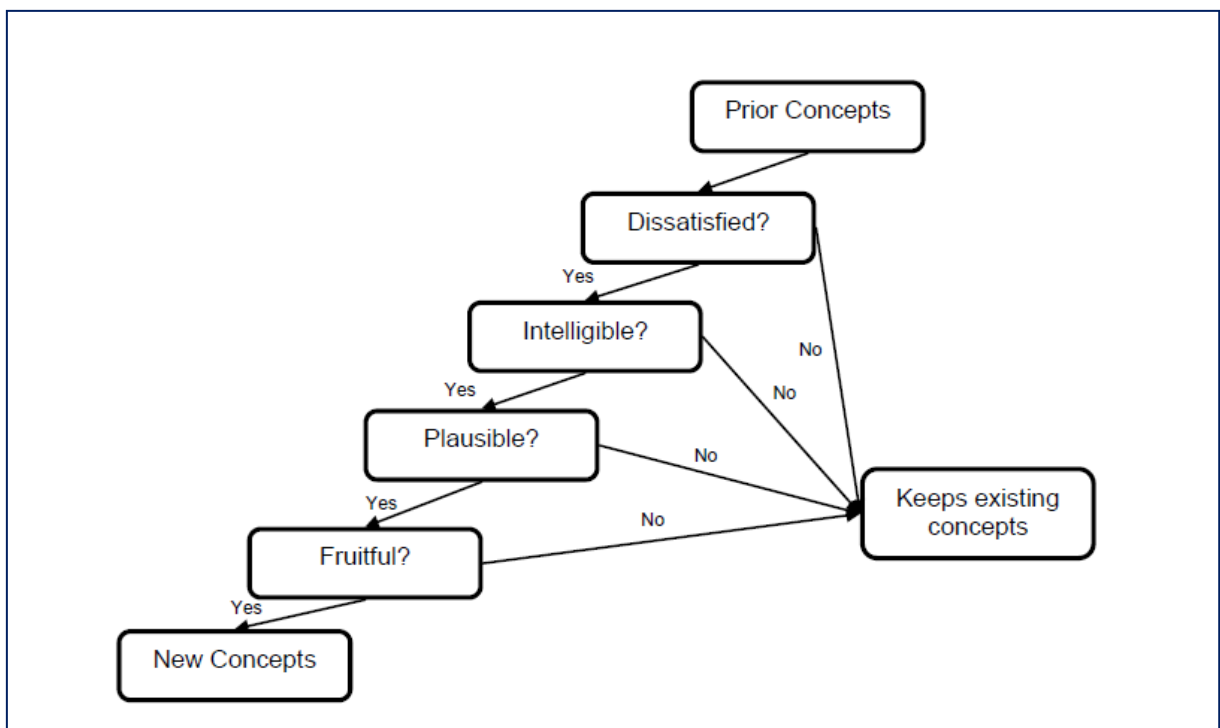


Figure3. Cognitive processes available within conceptual change (Adapted from Read, George, King, & Masters, 2006)

Treagust and Duit (2008) gave the following advice: An intelligible concept is one that is understood by the learner and it is non-contradictory. A plausible concept is one that the learner believes in addition to the existing knowledge. A concept is seen as fruitful when it is used to solve a number of problems and not just a single problem. It is also seen as fruitful when new research directions can be created. This is the way conceptual change is perceived and the order in which a concept needs to travel.

Treagust and Duit, (2008) further argued that conceptual change can be placed into different sub-categories, namely, epistemological, ontological and affective orientation. In the epistemological view the focus of the study is placed on the learning of science concepts. Epistemological perspective is the classic way conceptual change was seen for many years. Appropriate analogies help learners make connections between familiar knowledge and new science concepts (Treagust & Duit, 2009). Consequently, analogical-based instruction can stimulate interest as well as cognitive gains as measured by a conceptual change approach. Research has shown that analogical teaching approaches can enhance learning although analogies for teaching and learning can be a friend or an enemy depending on the approach taken by the teacher (Harrison & Treagust, 2006). The teacher's use of a cart with wheels moving obliquely over different surfaces as an analogy for refraction of light successfully provoked conceptual change in learners when learning about the refraction of light

Treagust and Duit (2008) also stated that the teacher makes the learners aware of the unacceptable alternative framework by creating dissatisfaction. The teacher then introduces a new acceptable framework. Introducing the new framework can limit the learners' use of the newly obtained concepts to only a small part of the context. The best that learners can come up with are a synthetic concept, where they combine only a small part of the new one with the existing one.

Other teaching strategies required for conceptual change are listed below:

- -organizing instruction in order to diagnose errors in learners thinking,
- -developing the kinds of strategies for dealing with learners' mistakes.
- -helping learners make sense of science content by representing content in multiple approaches, from one approach to another (Clement,1993)
- -developing evaluation techniques to help the teacher track the process of conceptual change in learners (Posner et.al., 1982). For example, logical interviews or open-ended questions in class would help to obtain learners' thoughts about a specific concept.

Treagust and Duit (2008) concur that if the learner was dissatisfied with the existing concept, there is an opportunity for conceptual change; however, the learner has to

be supplied with an acceptable replacement concept. The learner then needs to find the replacement concept intelligible, plausible and fruitful for accommodation to occur. Another very important step in the learning process where conceptual change is implemented is for the learners to talk about their existing or newly formed concepts (Wing-Mui, 2002), thereby becoming active members of learning in the conceptual change model (Mistades, 2009).

Learning involves changing learners' conceptions and adding new knowledge to what is already there. This view was developed into a theory of learning as a conceptual change or constructivism by Posner, Strike, Hewson, and Gertzog (1982). Learners can make sense of new information on their own terms. The conceptual change theory describes the conditions under which a learner will change one explanation for another. These conditions, in turn, point to the significance of the epistemological bases which underlie learners' responses, and to those, such as generalizability and internal consistency, which are necessary to guide changes to scientifically acceptable conceptions (Hewson & Hewson, 1992). Posner et al. (1982) and Hewson (1981) indicated that learning involves an interaction between new and existing conceptions with the outcome being dependent on the nature of the interaction. If these conceptions cannot be reconciled, learning requires that existing conceptions be restructured or even exchanged for the new.

In recent years, researchers obtained lots of information which shows that learners do not hold conceptions of science and scientific concepts that are similar to those held by scientists and science educators (Nakhleh, 1992; Wandersee, Mintzes & Novak, 1994). Sanger and Greenbowe (1997) defined conceptual knowledge that differs from commonly accepted scientific consensus as misconception. However, misconceptions are deeply held beliefs that make it difficult for new knowledge to be learnt. Hence, conceptual change process must be considered with utmost care.

To achieve the goal of learning, learners must be actively engaged in struggling with the problems or questions. Learners must willingly commit themselves to the cognitive struggle of reform. They must be motivated to challenge actively the inconsistencies and contradictions between their misconceptions and the observations. If learners perceive an inconsistency and accept the intellectual

challenge of resolving it, the teacher may be able to provoke the cognitive restructuring to more refined conceptual understanding (Hyde & Bizar, 1989).

Conceptual change involves some techniques such as accommodation, reconstructing, replacing a concept (Taylor, 2001). Different models have been developed for conceptual change. Scott, Asoko and Driver (1991) have identified two main groupings of strategies to promote conceptual change. The first grouping was of strategies which are based upon cognitive conflict and the resolution of conflicting perspectives. The second grouping was of strategies which build on learners' existing ideas and extend them through for example, metaphor or analogy, to a new domain.

Underlying these two groupings were different stresses on where the balance of responsibility for promoting conceptual change in learners may lie. Strategies which emphasise conceptual conflict and the resolution of that conflict by the learner, may be seen to derive from a Piagetian view of learning in which the learner's active part in reorganising their knowledge was fundamental. The strategies which build on learners' existing knowledge schemes, extending them to new domains, may be seen to place less emphasis on the role of accommodation by the learner and instead focus on the design of appropriate interventions by the teachers to provide scaffolding for new ways of thinking.

The teacher can provide these principles using conceptual change model. Conceptual change cannot be obtained through regular instruction. In order to elicit it, teacher should use some instructional strategies. One of them is conceptual change text model. In this approach; teacher asks learners to predict what would happen in a given situation related to science concepts, before presenting new information that reveals the inconsistency between common misconceptions and scientific conceptions (Chambers & Andre, 1997).

The following explains how a teacher may help facilitate the process of conceptual change:

Step 1: Acknowledging Information

The teacher has to assure that the new ideas are addressed sufficiently so that they get noticed and preferably also so that the learner is initially fascinated by them enough to want to know more.

Step2: Assimilating Information

The natural phenomena ought to be presented in such a simplified technique that the learner can follow every part of the opinions clearly. The learner should have the feeling that something makes sense. Meaningful associations are useful, because they might help the learners make meaningful connections. Suggesting to learner how to chunk the information might be another way a good teacher might be able to assist.

Step3: Accommodating Information

A good teacher will confront the learner with why his/her prior beliefs no longer work. What is important here is that the learner thinks aloud and articulates the problem in his or her own words. The teacher can guide the learner by challenging him/her with the correct questions.

Step4: Familiarising Information

A good instructor can now provide meaningful examples that go beyond repeating the problems, examples that involve applying the new knowledge and testing it. Also suggesting how to transfer the newly acquired concepts to other areas might also help. Clearly, the last step of making original findings is in the hands of the learner himself. All a good teacher can do is to challenge the learner to go beyond his or her limits.

Posner et al. (1982) has shown that it is not enough for an educator to clarify ideas or present knowledge; he or she must also become a Socratic tutor to confront the learners' thinking and be a model of scientific thinking. The educator therefore needs to:

- create a lesson, class, demonstration and a problem that causes a cognitive conflict with learners' existing concepts;

- organise instructions to shift the attention toward the learners' alternative thinking and identify the cautious mechanisms they use to obstruct accommodation;
- develop strategies to help with these alternative ideas and obstructions; and
- help learners to make sense of the science content.

Saunders (1992) suggests that the educator cannot change the learner's cognitive structure; only the learner can change it. Wing-Mui (2002) supplies the following teaching strategies to help learners with their conceptual reconstruction:

- Firstly, identify the learner's views.
- Create certain opportunities for learners to discover their own ideas. This is done to test the learner's ideas on events or situations.
- Provide enough stimuli for learners to further adjust their ideas; or change the wrong idea into the correct one.
- Provide enough support for learners to reconstruct the ideas.

Other studies on conceptual change emphasise the importance of the role of the learner, suggesting that the learner can play an active intentional role in the process of knowledge restructuring (Sinatra & Pintrich, 2003).

Another important aspect of conceptual change is a learner's conceptual status (Treagust & Duit, 2009). They further argued that when a competing conception does not generate dissatisfaction, the new conception may be assimilated alongside the old, when dissatisfaction between competing conceptions reveals their incompatibility, two things may happen: i. If the new conception attains higher status than the prior conception, conceptual change may occur. ii. If the old conception retains higher status, conceptual change will not proceed for the time being. It should be remembered that a replaced conception is not forgotten and the learner may wholly or partly reinstate it at a later date because the learner, not the teacher, makes the decisions about the status of the new concept and any conceptual changes.

Learning for conceptual change is not merely accumulating new learning skills. In conceptual change, an existing conception is fundamentally changed or even

replaced, and becomes the conceptual framework that learners use to solve problems, explain phenomena and function in their world (Taylor, 2001).

2.4.2.1. Related studies on conceptual change approach

The common aim of all science education researchers is to help learners learn science subjects in the most suitable and relevant way and also to stimulate learners' interest towards taking Physical Sciences as a subject at school. There had been many investigations in science teaching strategies and curriculum development in order to improve the effectiveness of science teaching as well as improving performance of learners in Physical Sciences. Several research studies have been carried out in order to find out the effect of conceptual change approach on learners' understanding of scientific concepts. These studies indicated that conceptual change approach provided a better acquisition of scientific conceptions and removing alternative conceptions (Hewson & Hewson, 1983, Suits, 2000, Sungur, Tekkaya & Geban, 2001, Ceylan 2004, Özmen, 2007, Ceylan & Geban, 2010, Kaya & Geban 2011, Kaya & Geban, 2012, Mckenna 2014, Kapartzianis, 2012, Meyer, 2014).

Hewson and Hewson (1983) employed a conceptual change approach to promote conceptual change in learners regarding density, mass and volume concepts. The study showed that the use of instructional strategies taking learners' misconceptions into cognisance results in a better acquisition of scientific conceptions. For example, in this study cognisance learners' prior knowledge was deliberate tested for to provide a basis for the conceptual change approach.

Suits (2000) studied conceptual change and chemistry achievement. In the study, three qualitatively different achievement groups; rote learners, algorithm memorizers, and conceptualizers were formed according to the results of a chemistry achievement test. In addition, two-dimensional achievement model was formed based on the chemistry achievement test. In the first stage, the memorize line, learners only accumulate knowledge. In the second stage, the conceptual line is the stage where learners were able to see connections between their knowledge fragments and restructuring. Results of this study indicated that the rote learners were blocked in stage one. Algorithm memorizers showed a form of weak restructuring. Conceptualizers, tended to possess an intelligible set of aspects that

allowed them to create new knowledge structure. This indicated the positive influence of conceptual change on achievement.

Sungur, Tekkaya and Geban (2001) used concept mapping strategy to promote meaningful learning. They conducted a study where they investigated the effect of conceptual change text accompanied by concept mapping instruction on 10th grade learners' understanding of the human circulatory system. In the study, interview technique was used for the identification of misconceptions in the related topic. The experimental group consisted of 26 learners who received conceptual change text complemented by concept mapping instruction and the control group consisted of 23 learners who received traditional instruction. It was found that learners in the experimental group performed better than those in the control group. Item analyses were utilized to determine and compare the proportion of correct responses and misconceptions of the learners in both groups. The average percentage of correct responses of the experimental group was 59.8 and that of the control group was 51.6 after the treatment. In the present study concept mapping was incorporated into the conceptual change texts in order to promote meaningful learning and in order to consolidate important concepts about chemical change.

The study by Ceylan (2004) investigated the effectiveness of the conceptual change oriented instruction through demonstrations and traditionally designed chemistry instruction on 10th grade learners' understanding of chemical reactions and energy concepts. The findings indicated that demonstrations based on conceptual change approach were effective in decreasing learners' misconceptions regarding the chemical reactions and energy concepts as is the case in this study.

Özmen (2007) investigated the effectiveness of conceptual change texts in remediating high school learners' alternative conceptions concerning chemical equilibrium. The subjects for the study consisted of a total 78 tenth-grade learners, 38 of them in the experimental group and 40 of them in the control group. The experimental group received a conceptual change text instruction whilst the control group received a traditional style instruction. The results of the study indicated that learners in the experimental group showed expressively greater levels of achievement than learners in the control group. Moreover, in both groups the

percentages of learners' alternative conceptions decreased. In this study learners' misconceptions' percentage was decreased although some few still retained their misconceptions even after the treatment.

Ceylan and Geban (2010) investigated the effectiveness of the conceptual change oriented instruction through demonstration over traditionally designed chemistry instruction on 10th grade learners' understanding of chemical reactions and energy concepts and their attitudes towards chemistry as a school subject. The participants were 61 tenth grade learners from two classes instructed by the same teacher. One class was assigned as experimental group and instructed with the demonstrations supplying the conditions of conceptual change, while the other class was assigned as control group and instructed with the normal consistent chemistry teaching. In the study, concepts were explained through the use of demonstrations related to the concept of chemical change. A concept test and attitude scale was administered as a pre- and post-test. The results of the study showed that conceptual change oriented instruction caused significantly better acquisition of the scientific conceptions related to chemical reactions and energy concepts than traditionally designed instruction. Moreover, after the instruction, learners in the experimental group demonstrated an attitude that was more positive towards chemistry than those in the control group. In this study, learners were given a pre- and post-test as a concept test, in which multiple choice and open-ended questions were administered to find out the misconceptions learners had about chemical change before instruction and to find out if misconceptions were changed or held after the instruction using conceptual change approach teaching strategy. Also demonstrations were used during the treatment in this study to decrease learners' misconceptions and to promote learners' positive attitude towards chemistry.

In their study, Karakuyu and Tuysuz (2011) have investigated the effectiveness of conceptual change texts, and touched upon the major role of concept maps in meaningful learning. In their study, they have found that conceptual change strategies affect learners' academic success in a positive way. In the current study, concept maps were used in order to consolidate chemical change concepts.

Kaya and Geban (2011) explored the effect of conceptual change based instruction on students' attitudes toward chemistry. This study aims to explore the effect of conceptual change based instruction accompanied with demonstrations (CCBIAD) on 11th grade students' attitudes toward chemistry. The sample consisted of sixty-nine 11th grade students in two classes in a high school. In the experimental group, CCBIAD was used, whereas in the control group, traditionally designed chemistry instruction was used. The students' attitudes were measured by Attitude Scale toward Chemistry. The results of ANOVA show that there was a significant mean difference between post-test scores of two groups in favour of the experimental group. As a conclusion, CCBIAD has a key role in forcing students' attitudes toward chemistry.

In their study, Kaya and Geban (2012), also investigated the effects of conceptual change-oriented instruction through demonstrations on 11th grade students' understanding of rate of reaction concepts when compared to traditionally designed chemistry instruction. Results showed that the group of learners in which conceptual change-oriented instruction was used (experimental group) had significantly better acquisition of scientific conceptions related to rate of reaction than the control group.

Kapartzianis (2012) explored the effectiveness that conceptual change model-based instructional activities had on changing learners' misconceptions about simple electric circuits towards scientifically accepted ideas. The findings showed that there was a significant improvement in learners' understanding of simple electric circuit concepts after they were taught using conceptual change model-based instructional activities.

McKenna (2014) conducted a research on using conceptual change texts to address misconceptions in the middle school science classroom. The aim of this study was to create conceptual change texts for use in the middle school Earth Science Curriculum. In the study, literature review demonstrated that student misconceptions are prevalent in most science classrooms and that the conceptual change model is the most effective model for addressing misconceptions. The research also found that conceptual change texts are an excellent application of the conceptual change model and can be used in any science classroom.

Meyer (2014) investigated the effectiveness of applying conceptual development teaching strategies to Newton's second law of motion. The study employed cognitive conflict teaching strategy and the development of ideas teaching strategy. The results indicated that there was an improvement in the learners' force conception from their initial alternative conceptions. In the current study, for example, learners were engaged in struggling with problems. They willingly committed themselves to the cognitive struggle of restructuring the new chemical change concepts.

School science education prepares learners to study science at a higher level, prepares them to follow a career in science and to become scientific literate citizens (Meyer, 2014). It is therefore the responsibility of the educator to ensure the learners' achievement in physical Sciences is developed to the extent that secures success at higher level studies. Chemical change is one of the most difficult topics in the science classroom (Bergquist & Heikkinen, 1990); it does not matter in which grade (Erdemir, Geban & Uzuntiryaki, 2000; Şendur, Toprak & Sahin Pekmez, 2010); and therefore this topic gives rise to more alternative ideas than other topics. It is therefore very important to eliminate these alternative ideas within this topic because it acts as a base for other topics in chemistry.

In summary, a review of the related literature indicates that misconceptions are one of the factors that lead to high failure rate in the learning of Physical Sciences. In order to teach Physical Sciences effectively, misconceptions must be spotted and overcome through the usage of the effective teaching approach. Literature also indicates that conceptual change approach impacts positively on the teaching and learning of Physical Sciences at all levels. Studies reviewed above suggest that epistemological, ontological and affective perspectives (multiple perspectives) of the conceptual change model should be employed in order for the conceptual change model to be more effective because the cognitive conflict in the classical conceptual change model could have limitations to provide appropriate conceptual anchors to bridge the gap between the learners' alternative conceptions and scientific conceptions. In addition, the learning of science is complex and idiosyncratic. These findings have a significant bearing on this study, which focuses on teaching for conceptual change at the secondary level. Moreover, the attitudes of learners toward

conceptual change texts were also examined in order to investigate whether they increase learners' interest and achievement.

2.5. Learning Theories

This study is based on the socio-cultural constructivist paradigm as envisaged by Piaget and Vygotsky. According to Piaget knowledge cannot be given to learners, it is the learners' responsibility to construct it from their mental and physical experiences within the environment (Mpofu, 2006). Knowledge is attained within a learner's mind through interaction with the environment (Joseph, 2011). Learning is a physical and psychological activity and for it to be meaningful, one has to understand and integrate knowledge into one's cognitive structure. A teacher has to arbitrate learning.

According to Jarvis (2006), learning must not only be meaningful to learners but is based on different theories. The most important learning theories, according to Louw and Edwards (1998), are classical conditioning, operant conditioning, social learning and cognitive learning. These four learning theories will be discussed briefly.

Classical conditioning is described by Baron (2001) as a basic form of learning in which one stimulus comes to serve as a signal for the occurrence of a second stimulus. Learners acquire information about the relations between various stimuli. Classical conditioning plays a role in the learner's emotion and attitude which are crucial catalysts for learning. Emotional learning can interfere with academic learning if the learner has a negative attitude to a teacher, the subject, school or even peers at the school. However, the opposite is also true where a favourable environment enhances a learner's academic performance (Woolfolk, 2010). Classical conditioning can be used in the classroom to strengthen favourable behaviour by rewarding it (Champion, 2013).

A learner's disorderly behaviour can be explained by and corrected through the **operant conditioning** theory developed by Thorndike and the American psychologist, B.F. Skinner (Berliner & Calfee, 2009; Champion, 2013). Operant conditioning theory is based on rewards that outline and preserve the behaviour of

learners. Operant conditioning is a form of learning in which behaviour is sustained or changed, through consequences (Baron, 2001).

Social-Learning Theory is a theory that was developed by Albert Bandura, a Canadian psychologist, that can be used to understand learner violence and destruction (Berliner & Calfee, 2009). The learners learn violence and destruction from their role models. Therefore, the learners think it is acceptable social behaviour for the peer group if the act goes unpunished. It is important to note that peer group is the one that in most cases causes social pressure. According to Woolfolk (2010) and Champion (2013), learner's behaviour can be directed by use of incentives. It is therefore important for educators to reward good behaviour by giving learners incentives. This theory underlines the conditions under which learners learn to emulate role models in the society (Baron, 2001).

The fourth theory, and also the focus theory for this study, is the **cognitive learning theory**. This theory is also known as the information-processing theory. It is used to understand how learners solve problems using the stored information as well as how learners retain information learned (Berliner & Calfee, 2009; Champion, 2013; Slavin, 2009). Cognitive science is an umbrella term for an interdisciplinary innovativeness concerned with information acquisition and processing. Cognitive science includes research into language, learning, perception, thinking, problem solving, and knowledge representation (Colman, 2009) and was popularised by Jean Piaget. The cognitive view of learning deals with the way in which knowledge is gained through information acquisition and how useful information is stored in the brain (Baron, 2001; Champion, 2013).

Piaget's theory of constructivism emphasises that children and adults use mental patterns to guide learning and interpret new experiences in relation to existing mental patterns (Piaget, 1978). Bodner (1986) analysed Piaget's theory of knowledge creation and furthered two key concepts, namely, accommodation and assimilation. According to McShane, (1991), assimilation and accommodation operate continuously to control the discovery of the information by the cognitive system. Therefore, assimilation and accommodation are necessary for cognitive growth and development (Yıldırım, Güneri, & Sümer, 2002; Wodsworth, 1996).

Assimilation is a process which uses existing concepts to deal with new information whereas accommodation is a process where new information cannot be explained with existing conceptions which may result in the refutation and replacement of older conceptions (Onder & Geban, 2006). When assimilating, learners compare the concepts with their old knowledge, and add more information to restructure it. Yet, sometimes, their old knowledge may be incomplete or downright wrong. That is why the existing concepts must be revised and redefined.

According to Wodsworth (1996) assimilation is the cognitive process by which a person integrates new perceptual, motor, or conceptual matter into existing patterns of behaviour. Joseph (2011) describes assimilation as the process whereby a new experience fit into the old experience. Assimilation is a process whereby learners use their existing concepts to deal with new experiences (Langford, 2014). That is, individual tries to clarify new information by means of his or her existing knowledge. Wodsworth (1996) presented an example to clarify the concept of assimilation as below:

“One might say that a child has experiences; sees new things (cows) or sees old things in new ways, and hears things. The child tries to fit these new events or stimuli into the schemata he or she has at the time. Suppose, a boy is walking down a country road with his father and the father points to a cow in the field and says, “What is that?” The child looks at the cow (stimulus) and says, “That’s dog”. What has happened? The boy seeing the object (cow) in the field, shifted through his collection of schemata until he found one that seemed appropriate and that could include the object. To the child the object (cow) had all the characteristics of a dog –it fits into his dog schemata- so the child concludes that the object was a dog. The stimulus (cow) was assimilated into dog schema” (p.6).

Therefore, assimilation can be understood as a way in which people transform incoming information so that it fits within their existing ways of thinking (Önder & Geban, 2006). Ausubel (1968) perceives that the basic principles of the assimilation theory are exhibited when a learner assimilates new concepts and positions them inside his/her recent conceptual framework.

Accommodation is the process where the current schema is changed, rearranged or reformulated in order to incorporate new information (Siegler, 1991; Bjorklund, 1995). According to Wodsworth (1996) accommodation is the creation of new schemata or the modification of old schemata which reflects the child's current level of understanding and knowledge of the world. Accommodation involves two main schools of thought which are discrepant events and conflict of ideas. When the learners develop a conflict between their existing concept and the new concept, the old concept is supposed to be replaced by the new, more acceptable concept (Duit & Treagust, 2003).

During the discrepant events strategy, the learners are first of all exposed to an event and their preconception is activated through their response to the situation. The learners' existing knowledge frameworks are sharpened with predictions or discussions by the learners trying to make sense of the situation. Cognitive conflict is established when the learners start to interpret the results. The educator should encourage and guide learners to cognitive accommodation and the formation of a more scientific concept or knowledge framework (Limón & Mason, 2010; Scott, Asoko & Driver, 1991).

When a learner encounters situations in which existing schemes cannot explain new information, existing schemes must be changed or new ones made to enable the translation of information. This process whereby the cognitive structure is adjusted in such a way that unknown and new objects and experiences are fitted into the cognitive structures so that the learner copes better with his environment is called accommodation (De Witt 2009, Shaffer & Kipp 2007).

Assimilation and accommodation operate continuously to control the detection of the information by the cognitive system (McShane, 1991). Therefore, assimilation and accommodation are necessary for cognitive growth and development (Yıldırım, Güneri, & Sümer, 2002; Wodsworth, 1996). When there is a balance between assimilation and accommodation, the situation is in a process where individual comfortably makes sense of new information based on his or her past experience (Yıldırım et. al., 2002). When this does not happen; that is, when there is an imbalance between assimilation and accommodation, the state of disequilibrium

occurs and when disequilibrium occurs, it activates the child to seek equilibrium. In other words, disequilibrium activates the process of equilibration and striving to return to equilibrium. Moreover, equilibrium is a necessary condition toward which the organism constantly strives.

The intellect according to Piaget is an internally organised structure that is continually being constructed and reorganized as the individual adapts to the environment (Smith, 2013). This construction process involves the interaction between the internal structure of knowledge and external stimuli that occurs when the individual acts on things he encounters in the world. Piaget relates the development at different stages of our lives to four factors (Wodsworth, 1996).

1. **Maturation:** is the term used for explaining “biological changes we go through from conception through death” (Yıldırım et. al., 2002). Heredity alone cannot account for intellectual development but it has an effect on cognitive development (Wodsworth, 1996).
2. **Active Experience:** is the term used for explaining that knowledge a child constructs that requires him or her to interact with the environment (Wodsworth, 1996). The interaction with the environment can be in the form of exploring, observing, organizing and interpreting the phenomena that exist in our environment (Yıldırım et. al., 2002).
3. **Social Interaction:** is the term used to explain the interchange of ideas among people (Wodsworth, 1996).
4. **Equilibration:** All the factors mentioned above cannot sufficiently explain cognitive development. Therefore, the concept of equilibration is used to explain the coordination of other factors and regulation of development in general (Wodsworth, 1996).

2.5.1. Constructivism

Constructivism is one of the pillars of the theoretical frameworks used in this study. It is important to use as it will help identify the learner’s existing concepts. Constructivism is a theory of learning in which every learner constructs his or her ideas (Önder & Geban, 2006). It stresses that each individual must construct meaning for himself or herself (Rasmussen, 1998). Thus, constructivism is a theory of learning in which every learner constructs his or her own ideas. In this study the

lessons were deliberately planned to allow for construction of new knowledge on the existing understanding of learners.

Bodner (1986) states that knowledge is constructed in the mind of the learner, therefore, the fundamental assumption of constructivism is that the student must recognize his or her own conceptions, analyse them and decide if they need reconstruction. If the learner decides his or her conceptions require reconstruction, then he or she will restructure these conceptions so that the new conceptions will be appropriate to scientific explanations. Therefore, it is necessary to connect new information with already existing knowledge, experiences or conceptualizations (Martin, 1997).

In constructivism, learning is defined as the active construction of meaning and it involves a change in the learner's conceptions (Kingir, 2011). Kingir further argued that learners are not viewed as passive recipients of knowledge; rather they are seen as responsible for their own learning. Constructivists have firm convictions in the process of learning and the context in which the learning takes place (Joseph, 2011). They believe that there is a real world that learners experience, but that meaning is imposed by the learners rather than existing in the world independently of them (Önder & Geban, 2006). They also believe that there are many ways to structure the world and there are many meanings or perspectives for any event or concept (Duffy & Jonassen, 1991). For conceptual understanding to take place such as in chemistry, learners need to experience different forms of representation of a concept (Joseph, 2011).

When learners want to understand new material, they must use the new knowledge and combine it with their existing knowledge (Bergquist & Heikkinen, 1990). The main function of constructivism is to organise knowledge by using previous experiences or understandings. Past experiences formed from observing certain processes in the world are important for learners (Saunders, 1992), because they supply the learner with the ability to make predictions and to supply reasons for these predictions. When a prediction is made and the learner's past experiences provide an incorrect prediction, the learner must be placed in a cognitive conflict, in a situation

where he or she is able to compare the cognitive universe with the natural universe. In other words, the learner must be placed in a cognitive conflict.

Cognitive conflict plays an important role in conceptual change, when providing an assimilation and accommodation framework (Treagust & Duit, 2008). Therefore, cognitive conflict plays an important role in learning science. Treagust and Duit (2008) concluded that conceptual change is positively influenced when cognitive conflict strategies are used. These strategies involve creating situations where learners' existing conceptions about particular topics are made explicit and then directly challenged in order to create a state of disequilibrium.

Kramer (2002) proposes a constructivism model that shows how the processes of assimilation, equilibrium/disequilibrium and accommodation are achieved during cognitive development. Figure 4 below shows Piaget's constructivism model of equilibrium.

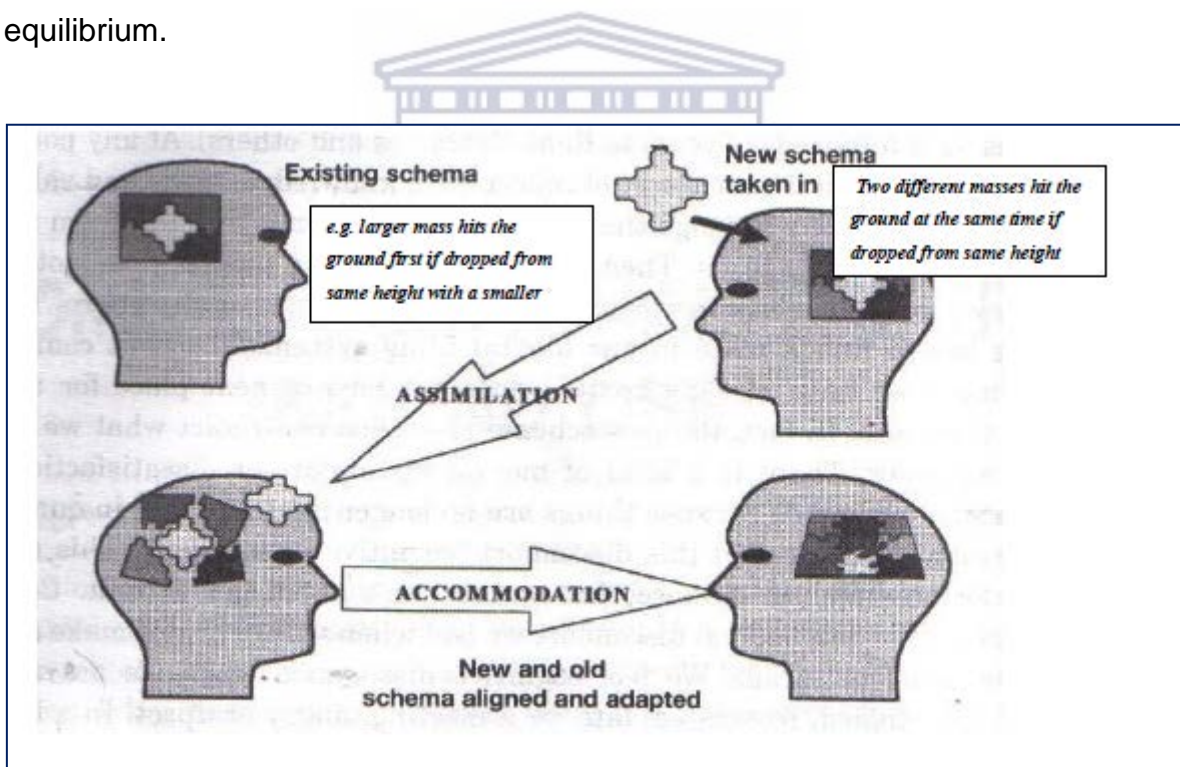


Figure4. Piaget's Constructivism model of Equilibrium: Source: Kramer (2002: 8).

There are three possible main points that educators should remember from Piaget's constructivism model of equilibrium as illustrated in fig 4 above:

- Learners construct new knowledge and skills based on what they already know.

- Learners adjust what they already know to fit the new knowledge and the old knowledge together in a balanced way.
- Teaching and learning experiences should be designed to give the processes of assimilation, disequilibrium and accommodation to function.

Cognitive conflict strategies are aligned with Posner et al.'s theory of conceptual change. That is, learners must become dissatisfied with their current conceptions and this is the first step for the conceptual change model. By recognizing the inadequacy of their conceptions, learners become more open to changing them.

Saunders (1992) also indicates a view of constructivism: "If the cognitive universe supports the natural universe, stronger bonds are formed on that specific mental construction, but as soon as the two universes don't comply with each other, a conflict is created". The learner then has three options: to discard the new knowledge, deny the existence of the knowledge, or rationalise the knowledge. When the newly obtained knowledge is trusted, it replaces the past (incorrect or unacceptable) experience, bringing a harmony between the cognitive universe and the natural observed universe. This is when meaningful learning occurs (Saunders, 1992).

Selley (1999) also stresses that construction is an internal, personal and often unconscious process and construction consist largely of reinterpreting piece of knowledge that one obtained from his or her experiences and interaction with other people, to build a satisfactory and coherent picture of the world. Moreover, constructivism is a meaning making theory where individuals create their own new understandings based on the interaction of what they already know (Richardson, 1997; von Glasersfeld, 1995).

Therefore, every individual constructs his or her own realities based on existing knowledge and then it is not meaningful to talk of the objective truth. For example, when teachers believe they have been understood by their students they should not put themselves into believing that they share the same opinions as their pupils. No one can ever be sure of this, because understanding is also a personal construction

of things that you understand in one way may be understood quite differently by someone else (Rasmussen, 1998).

Constructivist approach is learner centred. Learners should be active participants in the learning process since every student will construct his or her individual meaning. Therefore, the instructional activities must attract the learner and encourage active participation. Active participation in constructivist manner means that the student is actively testing the new concepts so that they can realize whether the new concepts can be explained by existing or prior knowledge so they can evaluate how well new concept is explained by existing schema and can choose whether to modify or change current schema. Therefore, constructivism is a theory of learning that rejects the idea that it is possible to transfer the content of teaching to pupils (Rasmussen, 1998). That is, constructivism states that knowledge is present every individual and that knowledge cannot be transposed completely without any change from the teachers' knowledge to that of learners.

Constructivist teaching requires teacher to act as a facilitator and create constructivist learning experiences. That is, teacher no longer teaches by obligation, but by negotiation. It involves more learner-centred, active learning experiences, more learner-learner and learner-teacher interaction, and more work with concrete materials and in solving realistic problems (Shuell, 1996).

Constructivist classroom support inquiry and learners can express their ideas and feelings freely. Constructivist approach on the other hand "...places emphasis on the meaning and significance of what the child learns, and the child's active participation in constructing this meaning" (Selley, 1999). Moreover, constructivist learning environments are designed to satisfy seven pedagogical goals (Honebein, 1996):

1. Provide experience with the knowledge construction process: learners take primary responsibility in selecting topics and methods of how to learn.
2. Provide experience in and appreciation for multiple perspectives: learners must engage in activities which enables them to think about several ways for solution since the real life problems rarely have one correct solution.

3. Embed learning in realistic and relevant context: learning activities are designed so that they reflect all the complexity that surrounds them outside the classroom.
4. Encourage ownership and voice in the learning process: illustrates the learner centeredness of constructivist learning.
5. Embed learning in social experience: learning should reflect collaboration between learner and teacher and learner and learner.
6. Encourage the use of multiple modes of representation: a variety of activities and instructional strategies coupled with variety of media provides richer experiences.
7. Encourage self-awareness of the knowledge construction process: it is important for learners to know how they know.

If teaching methods are based on constructivism, it is a helpful way to help learners' learning; it also helps teachers that use constructivism in their science classrooms to promote meaningful learning (Wing-Mui, 2002).

Though we need to limit the cognitive perspective when teaching from a constructivist's view, we must still keep in mind the following points when teaching concepts, as noted by Wing-Mui (2002:). We should:

- acknowledge the learner's existing knowledge;
- teach fewer concepts at a time;
- improve abilities within key areas of progression inside concept development, since learners are exposed to scientific concepts at a very young age; and
- acknowledge the diversity of learners.

2.5.1. A Comparison of Traditional and Constructivist Approaches

Constructivist teaching focuses on learners learning as opposed to a focus on completing the curriculum (Mintzes, Wandersee, & Novak, 1998). Traditional view sees learning as a process of transmitting the knowledge (Önder & Geban, 2006). However, in constructivism, learning is considered as a process where the learner is actively engaged in constructing knowledge while interacting with environment and society (Richardson, 1997). In traditional view the mind is considered as if it is a blank slate that is something that is waiting to be filled up. On the contrary, constructivism takes into account the prior ideas (Mintzes, Wandersee, & Novak, 1998).

Traditional teacher is responsible for effectiveness and extend of the learning (Önder & Geban, 2006). Moreover, information should be presented to the pupil in a clear, systematic and stimulating way (Selley, 1999). However, constructivist teachers must find ways to understand their students' viewpoints and their alternative conceptions develop classroom tasks which help knowledge construction and while performing all that task teachers play the role of facilitator (Selley, 1999).

In traditional perspective successful teaching leads to growth of learners' stock of knowledge and understanding which leads improvement in academic performance (Önder, 2006). On the other hand, from constructivist perspective successful teaching leads to growth of understanding, breadth of vision and maturation (Selley, 1999). Traditional view assumes that there exists a knowable reality outside of human perceptions. However, constructivist view acknowledges that there exists an external reality but realizes that cognizing beings can never know what that reality is actually like (Tobin & Tippins, 1993).

It is important to realize that although teacher supports all the items mentioned above and provides a rich learning environment one should not forget that each learner in the class will perceive the environment in a different way. Therefore, in order to understand learning in a constructivist classroom context, it is important to consider each learner's interactions with the environment and how those interactions affect the learning process. The traditional approach in the Eastern Cape has been to allow learners to learn from a theoretical basis whereby lessons are basically chalk and talk. In this study we tried to move away from this approach by bringing in constructivist-type lesson plans to allow learners to exhibit their own understanding and to challenge, build-on or change their conception on chemical change.

2.5.2. Types of constructivism

The literature identifies different types of constructivism, but for this study, the focus is on social constructivism. Steffe and Gale (1995) focus on two different types of constructivism, namely radical constructivism and social constructivism, while Ishii (2003) states that the term constructivism describes about fifteen different types of constructivism. This includes adding the following adjectives to the word constructivism – contextual, dialectical, empirical, humanistic, information-processing,

methodological, moderate, Piagetian, post-epistemological, pragmatic, radical, realist, social, and socio-historical.

Julie, Angelis and Davis. (1993) describe information-processing constructivism as knowledge which is not passively received but actively built up by the cognising subject; and the rejection of an epistemologically sceptical principle. Information-processing constructivism acknowledges that the learner is busy with active processes, both individual and personal, and that everything is based on the learner's previous knowledge. From the results of many thousands of studies reported in Duit (2009), research has shown that individuals are not simply passive learners but make sense of new information in terms of their previous ideas and experiences.

Julie *et al.* (1993) describe radical constructivism as constructivism that is based on both the principles mentioned in information-processing constructivism and they elaborate: "The function of cognition is adaption and serves the organization of the experimental world, not the discovery of ontological reality." Ishii (2003) further explains radical constructivism as the individual's knowledge being in a continuous state of re-evaluation. From this perspective we can say that the individual's knowledge is continuously being adapted and evolved. This constructivism, can be seen as the ability to use cognitive structure to adapt to the situation and ultimately to survive.

2.5.3. Social constructivism

Social constructivism, as one of the types of constructivism, is more suited to this study because of its focus on learning as a social process. In the Eastern Cape learners come with traditional understanding of science concepts that was learnt in their home environment. Learning and development in learners are shaped through social interaction, cultural tools and activities (Woolfolk, 2010). This is accomplished when learners interact with one another around an activity. Many scientists are of the view that higher mental processes develop through negotiation and interaction (Woolfolk, 2010). Kundi and Nawaz (2010), noted that social constructivism is a collective learning process that receives information from the community, peers and parents.

Caine and Caine (1994) mention that learners' brains are shaped by their environments. When a child is born it grows up in a family, shaping its brain through experiences and modelling of family members. As the child grows up its social circle expands to more than the immediate family and this leads to more experience and modelling (Rogers & Horrocks, 2010). The child's initial learning experience forms the basis of future learning. Educators need to be aware of social influences on the learners and manage the classroom environment so as to ensure maximum safety and participation.

Vygotsky is the pioneer of social constructivism. His theory of social constructivism focussed on the relationship between the individual and society and the influence of social interaction, language and culture in learning. He developed two theories namely, Zone of Proximal Development (ZPD) and the More Knowledgeable Other (MKO). According to Vygotsky (1978), learning is a continuous movement from the present intellectual level to the higher potential level. Every function in the child's learning appears first, on the social level and later on the individual level. This applies the same as voluntary attention, logical memory and the creation of concepts.

Zone of Proximal Development is the distance between the existing knowledge and the actual developmental level as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978). His view is that once a learner is within the ZPD for a particular task, provided with assistance will assist the learner to do a task and once the learner masters the task, assistance can be removed and the learner will be able to complete the task without assistance. The MKO is the more knowledgeable person than the learner on the relevant subject matter. Within the context of this study, the researcher is considered the MKO who will facilitate learning within the three levels of representing chemistry known as chemical symbols, formulae and reactions.

Kim (2001), Robottom (2004) and Treagust and Duit (2008) state that the focus of social constructivism is mainly on culture and context within society and that knowledge is constructed using the understanding gained through society. The underlying allegory here is perceived as conversation, where the individual uses language to form meaningful structures. Social constructivism is based on

knowledge, learning and reality and we need to understand these in order to apply a good instructional model (Kim, 2001). Here reality is constructed through social activity, but reality cannot be discovered. Knowledge is also constructed within the social context where individuals create a sense of meaning by interacting with one another. Learning is viewed as a social process and meaningful learning occurs when individuals are busy with social activities.

In constructivism, every learning process includes a search for similarities between what is already known and the new and unfamiliar one (Önder & Geban, 2006). That is, new concepts are tried to be explained by concepts that students already have and it is done by establishing relationship between them. Therefore, learning process often requires major restructuring of students' already existing conceptions. In social constructivism there are two aspects that affect learning (Kim, 2001). One of the aspects comprises the logic, language and mathematical systems that the learner obtains throughout his life; and the second aspect is the nature of interaction in society. Not everyone knows everything; therefore, we need to interact socially with other knowledgeable people. From them we acquire the knowledge to use efficiently in order to promote meaningful learning.

Learners arrive at the science class with their own ideas, beliefs and understanding of how things work (Robottom, 2004). Therefore, learning does not take place when the teacher fills the learner's heads with information and data, but when we change or work with their existing ideas and beliefs. Learning is seen by Robottom (2004) as conceptual change, constructing and reconstructing concepts; this includes existing concepts. Constructivism is therefore a major theory when working with conceptual change; and constructivism, for example, radical or/and social, influences the way research is conducted on conceptual change (Treagust & Duit, 2008). The following are the most important aspects, according to Julie *et al.* (1993) of a constructivist approach:

- assists learners when working with new methods in the learning process;
- helps learners to expand their knowledge of the subject or topic; and
- helps learners to develop instructional methods to promote meaningful learning and scientifically acceptable concepts – to create a sense of enthusiasm to learn and to be active within their own learning.

These aspects can also be applied to the role of the teacher. When we use constructivism in mathematical or scientific situations, we say that there are only true facts, principles, theorems and laws, as described by Ishii (2003). This is how knowledge is perceived in science. To clarify this statement, we can use Newton’s gravitational law as an example – “Every point mass in the universe attracts every other point mass with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them” – there is only one way this law is defined and that is the correct way.

Wing-Mui (2002) stated that when emphasis is placed on a constructivist instruction process, it increases certain areas in a science classroom. These areas include the learner’s conceptual knowledge, active engagement with scientific content, and applying knowledge gained to real-world situations (Wing-Mui, 2002). Figure 5 below shows constructivism learning model as adapted from Saunders (1992).

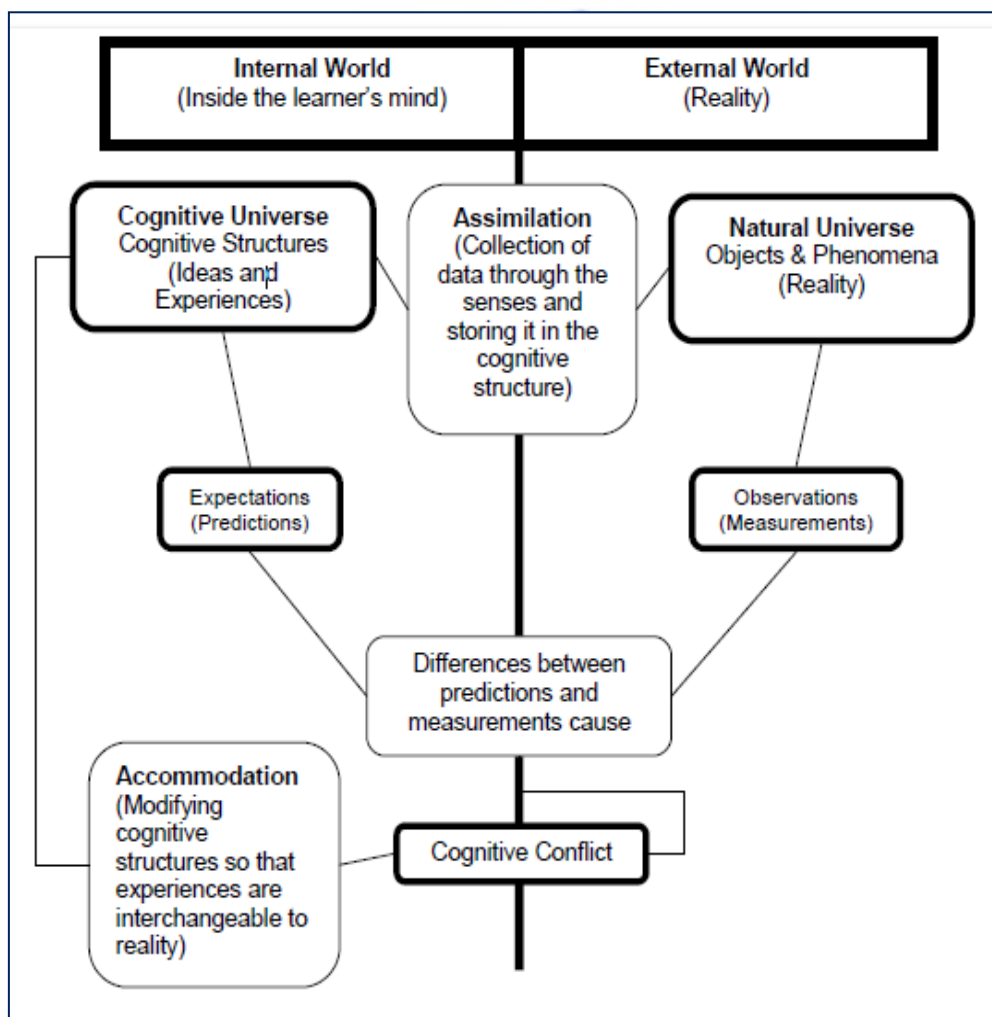


Figure5: Adapted constructivism learning model (Saunders, 1992)

Based on the scrutiny of the constructivist theories, the researcher agrees with Kesamang (2002) and Mpofu (2006) that the curriculum developer, the science teacher and science textbook writer should be aware of the fact that the learners' socio-cultural background may obstruct the easiness with which they learn school science. Therefore, efforts should be made to discover those elements of the learners' culture that are at inconsistency with the scientific culture and which could impact negatively on their achievement in school science.

2.6. Conclusion

Based on implications in the literature, the methodology of teaching is an important factor that influences understanding of science. In the present study, the researcher was concerned with learners' misconceptions and how conceptual change approach can be used to improve learners' understanding of chemical change in grade 11 curriculum.

In addition, research studies indicated that conceptual change approach enhanced learners' attitudes towards the subject. Therefore, in this study, the effect of conceptual change text oriented instruction on learners' attitudes towards chemistry was also evaluated. What this discussion highlights are that existing knowledge plays an important role when conceptual change is being used to change the learner's scientifically unacceptable concept to an acceptable one (Constructivism); thus changing the learners' conceptual framework and conceptual thinking (Cognitive thinking).

There are various instructional strategies such as demonstration, computer assisted instruction, cooperative teaching, concept mapping etc. used to provide conceptual change within chemical change, which is a building block of chemistry and harbours some of the most difficult concepts. The most challenging aspect of the Physical Sciences classroom is to help teachers and developing teachers to see science as a growing framework of concepts (spider's web of concepts) and to understand that there is a relationship between concepts (Novak, 1990). Teachers should also realise that there is a methodology for constructing new concepts (Langford, 2014). It is very important to not only correct the learners' alternative conceptions (Zoller, 1990), but

to make the new concepts stick. The learner therefore has to make sense of the new concepts and be able to re-use the information in another situation.



CHAPTER 3

METHODOLOGY

3.1. Introduction

The quality of a research depends on the consistency between the research questions, research methods, methods and processes of data collection, and data analysis (Mkonto, 2010). The purpose of this study is to present a suggestion of how conceptual change approach as a teaching strategy can improve learners' understanding of chemical change. Different data collection instruments were used to obtain the data necessary to describe and address the problem under investigation. This chapter discusses the methodologies and a series of procedures which were used to answer the research questions and to satisfy the aims of the study. This involves the discussion of the specific research design and strategies, research instruments, the population of the study, the selection of participants, the research ethical statements as well as reflection on myself as a researcher. The participants and sampling procedures are explained. Data collection and data analysis methods are explored. The trustworthiness of the research is also justified.

The following is the main research question that the study is addressing

How can a conceptual change approach be used as a teaching strategy to improve learners' understanding of chemical change?

Emanating from the main research question are the following sub-questions:

1. What were learners' initial understanding of chemical change?
2. How was the conceptual change approach implemented to address grade 11 learners understanding of chemical change?
3. What were learners' understanding of chemical change after the conceptual change lessons?
4. What were learners' perception of the conceptual change approach?

3.2. Research design

Research design refers to the approach that can be used to combine the different components of the research in a consistent and rational way (Babbie & Mouton, 2001). For the purpose of this study, both quantitative and qualitative research methods were used. Using such an approach gives the researcher an opportunity to apply what is best from both qualitative and quantitative approaches (Creswell, 2003). Tashakkori and Creswell (2007) described mixed methods research as a study in which the researcher collects and analyses data, incorporates the findings, and draws conclusions using both qualitative and quantitative approaches in a single study. Creswell and Clark (2007) further explained that the mixing of methods focuses on quantitative and qualitative data being collected, analysed and interpreted in a single study. The purpose is to have quantitative data, and to check the reliability of learners' answers to several questions.

The choice of this approach is relevant to the study as it aims to explore the concept problem among grade 11 Physical Sciences learners of the same school. Hesse-Biber (2010) lists three specific reasons that made the researcher decide to use a mixed methods research:

- The first reason for using mixed methods is *development*. Mixed methods aid in the development of a research project by creating a synergistic effect, whereby the results from one method aid development of the other method (Greene *et al.*, 1989). For example, statistical data collected from a quantitative method can often shape interview questions for the qualitative portion of the study. Results from one method shape subsequent steps in the research process. Here, interviews with the key informants and their recommendations provided insight as to how to develop the learning styles and assessment tools.
- The second reason is triangulation. *Triangulation* refers to the use of more than one method while addressing the same research question in order to examine the same aspect of a research problem. It examines the reliability of the findings acquired through different instruments (Green, Caracelli, Valerie & Graham, 1989). In this study the researcher used interviews, questionnaires in the form of pre-test and post-test as well as intervention in the form of a lesson plan. Triangulation strengthens the research as the strength of one form

counters the weaknesses of the opposite form. Similarly, by having multiple points of check for validity, the research is less likely to be inclined to error due to the weaknesses of one method (Patton, 1990). Triangulation ultimately strengthens and improves a study's conclusions, making them more acceptable to promote both qualitative and quantitative methods.

- The third reason is complementarity. It irradiates results from one method with the use of another. It allows the researcher to gain a full understanding of the research problem. This is accomplished by utilizing both quantitative and qualitative data and not just the narrative explanation alone to understand the problem in its entirety. Both complementarity and triangulation are useful for cross validation when multiple produce similar facts (Yauch & Steudel 2003). In this study, discussions during the intervention and responses from interviews qualified scores on the questionnaires.

Qualitative research was used in this study because it aims to better understand human behaviour and experience (Chokwe & Lephala, 2011). Qualitative research methodology is descriptive and inductive, concentrating on revealing meaning from the insight of the participants (Babbie & Mouton, 2001; Patton, 2002; Struwig & Stead, 2001; Willis, 2007). It is a methodology that involves accomplishing an understanding of a particular phenomenon. Furthermore, a qualitative method is of significance in this study because it pursues to understand misconceptions of grade 11 learners with regard to chemical change.

Qualitative research pursues to describe and make sense rather than to explain human behaviour. Creswell (1998) describes qualitative research as “an inquiry process of understanding based on distinct methodological practice of inquiry that explore a social human problem”. Mkonto (2010) further revealed that qualitative research methodology involves gaining an understanding of a particular phenomenon. It enables the researcher to explore the phenomenon in depth, emphasising on the procedure rather than on the outcomes, and allowing perceptions to change (Babbie & Mouton, 2001; Denzin & Lincoln, 2005).

The following are features of qualitative research as stated by Hancock (1998):

- Qualitative research is concerned with the beliefs and feelings of individuals producing individual outcomes.
- Qualitative research is deductive in that it tests theories, which have already been proposed.
- Understanding of a social situation is gained through a holistic perspective.
- The intensive and time-consuming nature of data collection requires the use of small samples.
- Qualitative research describes social phenomena as they occur naturally.
- Data are used to develop concepts and theories that help us to understand the social world.
- Data collection is time consuming.

This research was conducted in a classroom, the natural environment of learners and educators. This enabled the researcher to gain a holistic, insider's perspective of the context of discipline from the learner's point of view.

A common criticism against qualitative research is that the outcomes of the study may not be generalised as the sample size is too small (Johannes, 2005). This criticism is invalid in the sense that the objective of qualitative research is to designate and understand the social experience. Qualitative research can provide more awareness into a specific setting, generalization is not a prerequisite. The strength of qualitative research depends on the fact that the aim is to understand the meaning participants attribute to an event and not to generalise.

The quantitative data for this study were obtained through the use of questionnaires in the form of pre-test and post-test. Quantitative research focuses on the control of all the variables. In this study a set of questions was compiled by the researcher in the form of a pre- and post-tests in the evaluation phase. The purpose for using these tests was to obtain the opinions of the learners and the existing knowledge learners have with regard to chemical change. Quantitative research method involves counting, measuring of events and performing the statistical analysis of a body of numerical data" (Matveev, 2002). In this study, data are expressed in numbers. In quantitative research, data are generally collected through the use of a questionnaire (Mkonto, 2010), which was the case in this study. In particular, a single-group pre-test–post-test design as described by Creswell (2009) was used in this study. The

single group pre-test-post-test design is illustrated in Figure 6 (McMillan & Schumacher, 2010):

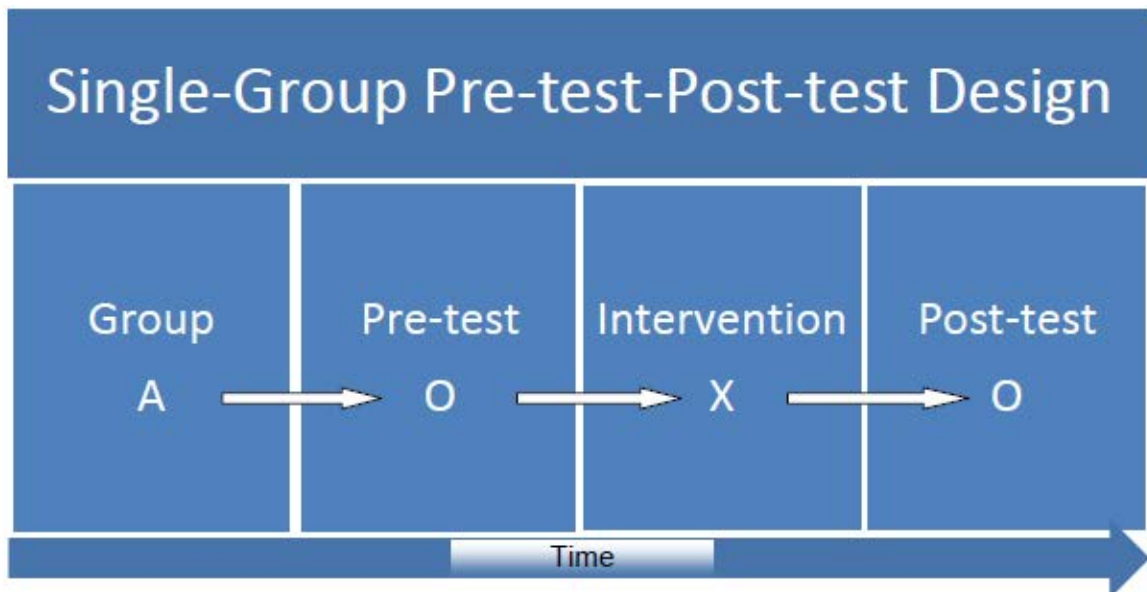


Figure 6: Single-Group Pre-Test-Post-Test Design (McMillan & Schumacher, 2010:278)

From figure 6 above, the group (A) of learners consisting of one grade 11 physical science class was given a pre-test (O), that was followed up with an intervention (X), and thereafter the respondents did the post-test (O). The results of the pre- and post-tests were used to calculate the learning gain. The results gave an indication on how effective the intervention was.

3.3. Case study

A Case study is defined as a qualitative research that can be used to study a phenomenon in a specific context (Chokwe & Lephalala, 2011). Wallace and Atkins (2012) further argued that a case study is the approach that has the ability to go beyond the 'how' and 'why' questions. It offers a way of investigating connections, patterns and context, and of reflecting on the details and the bigger picture under investigation. The researcher used learners of the same school in Sterkspruit district in the Province of the Eastern Cape. The study is therefore a case study.

3.4. Sampling

Sampling refers to a process of selecting a portion of the population to represent the whole population (Johnson & Christensen 2008). The research site was a secondary school in rural Sterkspruit District, Eastern Cape Province. The total number of Grade 11 Physical Sciences learners in the school is 34 and all of them took part in the study. For interviews, focus group interview was used in this study. Learners were divided into six groups, four groups consisted of six learners each and two groups consisted of five learners each. The purpose for the interview was to obtain relevant information to address the research question. According to Pika (2014), a sample is a subgroup of people, animals or objects selected to present the much larger population. The sample for this study is reflected in table 3 below.

Table 3. Sample for the study

PARTICIPANTS	SAMPLE SIZE	TECHNIQUE
Grade 11 learners doing Physical Sciences.	34	Whole population

3.5. Research instruments

This research was conducted in one school with only one grade 11 Physical Sciences class. This small sample compromised the validity of the study. In order not to compromise the reliability and validity of the findings, the researcher used a variety of data collection instruments. Triangulation between interviews and questionnaires provided the researcher with a more accurate picture of the behaviour of the learners.

3.5.1. Pilot Study

In order to gain a greater sense of confidence and maximum benefit from using pre-test and post- test, it was crucial that the instruments were piloted. Bryman (2008) advises that it is always desirable to conduct a pilot study before administering a self-completion questionnaire. The pilot study will ensure that the survey questions will be clear, eliminate ambiguities and target audience readability levels. The tests used in this study were first examined by the researchers' supervisor to check for the appropriateness of the questions on the tests. The revised tests were then piloted on

a small group of Grade 11 Physical Sciences teachers from neighbouring schools. The teachers provided feedback on the clarity of the questionnaire items, instructions and layout. The questionnaires were then revised. The advantages of using a questionnaire are that it has standardised answers from which respondents must choose, that it is inexpensive to administer and that it is easy to administer confidentially when some of the participants want to remain anonymous (Matveev, 2002). Altogether four different types of instruments were used in this study. They are:

3.5.2. Chemistry Achievement Test (CAT)

Chemistry Achievement Test (CAT) on chemical reactions, which was in the form of the pre-test and post-test (see Appendices 10.2.1. and 10.2.3) for determining the learners' conceptions on chemical reactions and energy changes during chemical reactions, one of the sections in chemical change that was used in this study. The test was developed by the researcher by examining related literature, and textbooks. Items in the test were related to energy and chemical change, chemical reactions in grade 11 as it appears in the Curriculum and Assessment Policy Statement (CAPS). The test consisted of 10 multiple choice questions, five questions where learners were to fill in blank spaces and four one-word questions for the description questions. The data collected through the CAT were analysed in terms of quantitative and qualitative descriptions.

In a pre-test, learners' alternative conceptions, difficulties on the target concept and pre-knowledge about chemical change were determined. The pre-test is attached as appendix 10.2.1. The Post-test given to learners was the same as the pre-test. Post-test is attached as appendix 10.2.2. Most of the questions in the test required learners to think qualitatively; that is, without doing any calculation and predict the correct answer where the alternatives are designed so that they reflect learners' misconceptions. The two tests were used to explore:

- (i) The learners' perceptions of the lesson on chemical change.
- (ii) The learners' perceptions of the experiment and the worksheet based on it.

3.5.2.1. The development of CAT

The CAT was developed to determine the learners' conceptions on chemical reactions as well as to measure learners' cognitive achievement. The CAT was administered by the researcher as a pre-test and as a post-test. It consisted of multiple-choice questions (MCQ) consisting of everyday life chemical reactions and content-based questions derived from the syllabus. These questions were designed to bring forth information about the learners' chemical change knowledge and reasoning. Most of questions in the test required learners to think qualitatively; that is, without doing any calculations and predict the correct answer where the alternatives were designed so that they reflect learners' misconceptions.

Multiple-choice questions are a diagnostic tool for identifying learners' conceptions about a given scientific subject (Soudani, Sivade, Cros & Medimangh, 2000). Treagust (1988) asserted that such a test could be used as a diagnostic tool and helps the teacher to begin to address existing misconceptions based on earlier teaching and learning, prior to commencing the topic or that have occurred following teaching the topic.

The learners were told that the test was not for continuous assessment (CASS) purposes. The purpose was to ensure that the learners were relaxed while answering the test. This also eliminated the learners' anxiety, which sometimes causes the learners to fail the test even though they know the content.

3.5.3. Intervention in the form of a lesson plan

In the intervention, inquiry teaching-learning activities and lessons were designed and presented to learners in order to enhance understanding and to address conceptual change conditions relating to grade 11 chemical change curriculum. The contextualized approach involved laboratory and everyday experiences. An intervention lesson plan is attached as appendix 10.2.3.

Conceptual change texts were constructed by use of Posner et al.'s (1982) conceptual change model as described in Section 2.4.2. In the conceptual change text, the topics were introduced with questions to activate misconceptions in the learners' minds, specify learners' misconceptions, clarify their reasons, and explain

why they are not good enough with solid examples. Conceptual change texts can be used in any science classroom from elementary school to college courses (Ozkan & Selcuk, 2013). The contextualised approach involved observations and everyday experiences. Some questions in the texts were: What is a chemical reaction? At this stage, prior knowledge of learners was taken into consideration thus emphasising theories proposed by Piaget, Bruner, Ausubel, Feuerstein and Vygotsky.

The lesson was video-recorded to allow thick description of the implementation. Practical work followed after the lesson presentation. The aim was to compliment the inquiry method that the researcher used during the lesson presentation with observation method. An observation schedule was used to collect the data. Observation schedule is attached as appendix 10.2.5. This was reinforced with the analysis of the video-tapes.

In doing the experiments, the learners had to work in groups. When the learners worked in groups they were offered the opportunity to verbally interact, thus sharing their understandings and the knowledge they had acquired. Group work can improve the quality of learners' responses to problems that require their ability to think. Letting the learners work in groups provides them the opportunity to combine their working memory space and previous knowledge. By using videos and experiments in the conceptual change texts, the researcher accomplished Posner et al.'s (1982) conditions of intelligibility and plausibility to help to stress on the learners' preconceptions and to make relationship between learners' conceptions and scientific knowledge.

Concept mapping was used as an alternative teaching method used to clarify to both the researcher and learners the key ideas they must focus on for any specific learning task (Novak & Gowin, 1984). The key concepts and their meanings were written on the chalkboard as chalkboard summary. From this summary, learners had to develop concept maps in groups. These they presented to the other learners who had to add or point out shortcomings of the map and eventually allocate the group marks. This later enabled learners to develop concept maps for revision and planning when writing essay type questions in other subjects.

The use of experiments in this study was inspired by the fact that the grade 10, 11 and 12 Physical Sciences Curriculum in South Africa places great emphasis on practical activities as tools of learning science. The worksheets developed were thought provoking and were meant to assess the learners' understanding of chemical reactions. A Predict-Observe-Explain (POE) technique adopted by Mthembu (2001) was used in all the experiments. In the POE method, learners are confronted with an experimental task and then asked to predict, observe and explain what happens when an experiment is carried out. The use of the POE method enables the teacher to have a clear understanding of the learners' prior knowledge, their level of understanding of the concepts already taught as well as identifying their misconceptions if there are any (Mthembu, 2001).

In the conceptual change texts, learners were asked explicitly to predict what would happen in a situation before being presented with information that demonstrates the inconsistency between common misconceptions and the scientific conceptions. This strategy was to activate learners' misconceptions, and then the researcher presented the explanation of the scientific conception, and provided common learners' misconceptions followed by evidence countering the misconceptions. As a result, learners became convinced that the scientifically acceptable new conception was more meaningful, thus the second condition of Posner et al (1982), intelligibility, was supported.

In the next step, the most commonly used misconceptions concerning chemical change were presented, and learners were convinced why they were wrong by giving them various evidences. During instruction learners generated their own meaning based on their backgrounds, attitudes, abilities and experience. According to the cognitive model, learners build sensible and clear understanding of the events and phenomena in their world from their own point of view (Osborne & Wittrock, 1985).

Here, the purpose was to enable learners to question those concepts, and see the inadequacy of what they know. When they were unable to do so, they were provided with a new set of information, examples so as to replace the misconception in their minds with the correct one (Pınarbaşı & Canpolat, 2002). New concepts were made

plausible. Learners received instruction on chemical change four times a week during a 50-minute class periods for two weeks.

While conducting the study, the researcher participated to several lessons and observed the learners. During the intervention, the researcher video-taped the activity and thereafter observed how learners were involved in the activity. The observation schedule is attached in the list of appendices (see Appendix 10.2.5.).

3.5.4. Interviews

An interview was one of the tools the researcher used in collecting data in this study. The interview is a flexible tool for data collection which allowed the researcher to use various receptive media to bring forth information, be they verbal, nonverbal, gestural or spoken (Cohen, Manion & Morrison, 2011). Dolo (2012) further explained that an interview is a suitable and effective method of which information can be gathered and has a direct bearing on research. An interview helps the researcher to access and gather the information that is inside an interviewee's head.

Questions asked in an interview can either be open-ended or closed. Open-ended or closed questions are known as fixed response questions. In an open-ended interview, the respondents are not limited by choice, but they express themselves in their own words (Dolo,2012). This is good because the interviewee gets to open up and express himself/herself freely on the subject.

Cohen and Crabtree (2006) argued that semi-structured interviews have the advantage that they consist of a list of interview questions and topics that need to be conveyed during the conversation, but can also accommodate the development of new questions that may be formed during the conversation. This is made possible because the interview guide consists of open ended questions. In relation to the above, the semi-structured interview in this study consisted of questions which were prepared beforehand while other questions emerged during the fieldwork. Use was made of rubrics such as probing questions and extra questions, as proposed by Berg (2001). Care was taken not to hinder the respondents' natural responses.

The researcher opted to conduct in-depth semi-structured focus group interview technique in which the sequence of usually open ended questions are determined in advance. The aim was to collect rich data from learners to better understand the phenomenon under investigation. A focus group interview was carried out to examine the learners' understanding of chemical change and their attitudes towards learning Physical Sciences. The aim was to draw responses from the participants with regard to a deeper understanding of whether the pre concepts that learners bring to school have changed or eliminated and whether the new concepts were understood by learners. The formulation of questions was guided by the conceptual framework discussed in chapter two.

The focus group interview occurs when a group of people is interviewed simultaneously to discuss a topic of interest (Johannes, 2005). The main advantage of focus group interview is the opportunity to witness a large amount of collaboration on a topic with the minimum of time required. It is also easy to assemble the focus group. The focus group consisted of five groups, three groups of the five had six learners each and two groups had seven learners each.

Respondents were asked the same basic questions in the same order, which provided consistency. An interview schedule is attached as appendix 10.2.4. After interview transcription, the data was sub-divided and assigned categories in the form of labels. This process, known as coding, was done to assign units of meaning for the descriptive data (Kvale & Brinkmann, 2009). Once coding was done, data was categorised into themes.

Advantages and disadvantages of interviews and focus group interviews

Advantages:

- Interviews help the researcher to have control over the topic as well as the format of the interview.
- They assist the researcher to record the data on why no responses were made.
- Prompting may be included regarding questions and if an inappropriate question asked.

Disadvantages:

- Respondents may hear and interpret questions in a different manner since there is a set of interview guide.
- Interviews adhering too closely to the interview guide and may be the cause of not probing for relevant information.

3.6. Data collection plan

One of the methods used to identify alternative conceptions is to develop multiple choice responses to questions based on learners' reasoning, including alternative conceptions. In this study, pre-test, intervention in terms of a lesson and post-test were administered to all the 34 participants. In a pre-test, learners' alternative conceptions, difficulties on the target concept and pre-knowledge about chemical change were determined. The pre-test is attached as appendix 10.2.1. Post-test which was the same as the pre-test, was also given. It is attached as appendix 10.2.2.

In an intervention, inquiry teaching-learning activities and lessons were designed and presented to learners in order to enhance understanding and to address conceptual change conditions relating to chemical change. The contextualized approach involved laboratory and everyday experiences. An intervention lesson plan is attached as appendix 10.2.3.

A focus group interview was administered in this study. Kvale (1996) regards qualitative research interview as a construction site for knowledge. Kvale further stated that an interview is an inter-change of views between two people discussing about a theme of mutual interest. Irrespective of the approach, interviews are used to collect information in a face-to-face contact (Mpofu, 2006). According to Ndagi (1984) it is used when a researcher wants to achieve reliable and valid information in the form of verbal responses from respondents in order to confirm or reject hypotheses. For interviews, learners were grouped into five groups according to the number of learners in a class that participated in the study. An interview schedule is attached as appendix 10.2.4.

Figure 7 illustrates the steps followed in collecting data for this research project. Phase 1 illustrate step 1 where learners were given a pre-test, phase 2 is the second step in the collection of data where intervention in the form of a lesson was presented and videotaped for the researcher to use when analysing the data. Phase 3 represent step three of the project where participants were given a post test and phase 4 indicates the last step the researcher used to collect the data, which is the step where learners were interviewed.

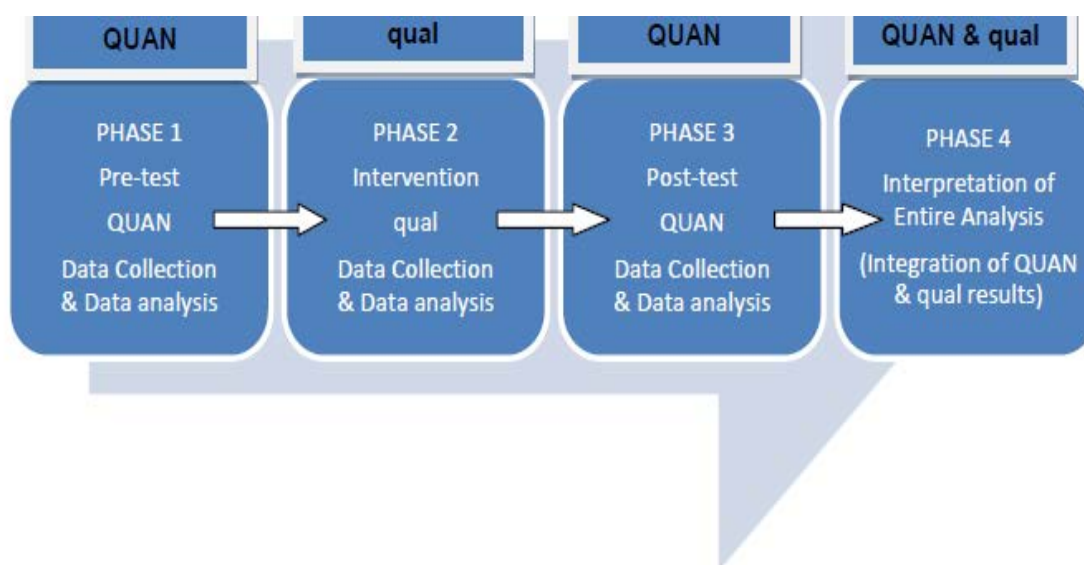


Figure 7: Steps followed during the collection of data.

3.7. Methodological framework

Methodological framework is summarised in table 4 below.

Table 4: Summary of the data collection methods

Research Question	METHOD	INSTRUMENT	RESPONDENTS	ANALYSIS
Main research question: How can conceptual change approach be used to improve learners' understanding of chemical change?				
Step 1: What were learners' initial understanding of chemical change?	Pre-test	Test	Learners	Marking memorandum
Step 2: How was the conceptual change approach implemented to address grade 11 learners understanding of chemical change?	Intervention and Observation of lesson Video-taping of lesson	Lesson plan designed to address conditions of conceptual change namely dissatisfaction, intelligibility, plausibility and fruitfulness Observation schedule	Learners	Questions and answers Thick description

Step 3: What were learners' understanding of chemical change after the conceptual change lessons?	Post- test	Test	Learners	Marking memorandum
Step 4: What were learners' perception of the conceptual change approach?	Interviews	Interview schedule	Learners	Coding

3.8. Analysis of data

Stake (1995) states that “there is no particular moment when data analysis begins. Analysis is a matter of giving meaning to first impressions as well as to final compilations”. Gardner (2009) further explained that data analysis refers to the process of inspecting, cleaning, transferring and modelling data with a goal of highlighting valuable information, suggesting conclusions and supporting decision making. Lebotse (2014) revealed that the purpose of data analysis is to explain concepts in a simplified manner and to indicate clearly the relationship between variables. Qualitative research generates a huge amount of data that needs to be summarised, described and analysed.

Data analysis for this study was divided into: (1). Pre-test and Post- test, (2). Intervention in terms of the activities in a lesson plan and observation of the lesson as well as (3) interviews obtained through focus group interviews. The marks for the pre-test and the post-test were recorded in an excel spread sheet, tabulated and categorised according to percentage and then displayed in the form of a graph.

Structured focus group interviews were used to examine learners' understanding in detail. Groups were coded as F₁ for focus group one, F₂ for focus group two et cetera and learners that were interviewed were coded as F₁L₁ for learner one from the first group, F₂L₁ for learner one from the second group et cetera. All of the interviews were coded manually for themes, audio-taped, transcribed in writing and translated to English in a case where another language was used. Descriptive tools such as tables and graphs were used in the analysis and interpretation of data. These are presented in chapter four.

3.9. Reliability and validity

Reliability is the degree to which an instrument yields stable and consistent results (Cozby, 2001). Reliability in quantitative research refers to the repeatability of the instrument and test administration in the study while in qualitative research reliability refers to the consistency of the researcher's role (insider, participant, and outsider), the data collection methods, data recording and interpretation of the participants' meanings from the data by the researcher (Johannes, 2005). To ensure reliability in this study, the researcher administered the same test twice to the same sample. The instruments were taken to the subject advisor for Physical Sciences in the district and two teachers who teach Physical Sciences in neighbouring schools for scrutiny purposes. They were given the instruments to specifically assess:

- i. the appropriateness of the level of the language used to target learners,
- ii. Clarity of questions,
- iii. Whether or not the content was at the level of the learners and
- iv. Whether the instruments measured what would be taught.

The scores from the two tests were correlated to evaluate the test for stability. The researcher ensured that the questions in the instrument did not make the respondents to feel inclined to favour her. The interview schedule was flexible to allow learners to express themselves in relative freedom and to enable the interviewer to ask thought-provoking questions. Before number check, interviews were audio-taped. After transcriptions, learners were given specific quotes to ensure that they were quoted correctly.

The strength of qualitative research is assigned in its validity. Fraenkel and Wallen (2001), states that validity refers to the appropriateness, meaningfulness and usefulness of the specific implications researchers make based on the data collected using an instrument. It therefore refers to how well a test measures what it is supposed to measure. The validity of an instrument is very important in a research. The validation of an instrument therefore ensures that the data collected in the study, using the instruments, can be used to draw valid interpretations and conclusions about the subject. To ensure validation, the researcher ensured that the title and the research question are clear, aligned, focused and link well with the instruments. The data for this study were collected over a two-week period. The two weeks provided

opportunities for continual data collection, observation of the participants in their classroom and allowing the learners to display their natural behaviour. At the beginning, the learners were mindful of the fact that they were participating in a research project.

To enhance the reliability and validity of qualitative research, researchers should make extensive use of triangulation. The underlying principle for triangulation is that it enables validation of results obtained from research (Modell, 2005). Triangulation is the use of multiple methods that emanate from a single study. The study adopted the triangulation method in order to ensure the trustworthiness of the research findings. In the study, the researcher used pre-test, post-test and interviews to triangulate the results. These instruments have undergone various processes of validation. The researcher is not teaching the learners that participated in the study and as such bias was eliminated.

According to Guba and Lincoln (1994), all research must provide assurance of trustworthiness of their analysis. According to Allen ((1996), a researcher should be aware that consistency is necessary but not sufficient for validity. He further argued that, for something to be valid, it must be reliable and must measure what it is intended to measure. In this study, all instruments were tested for validity and reliability to ensure that the study and the instruments measure what they are supposed to measure. One of the criticisms against qualitative research is that the findings cannot be generalised (Babbie & Mouton, 2001). However, the strength of qualitative research is embedded in the fact that the aim is to understand the meaning participants attribute to an event and not to generalise.

3.10. Ethical consideration

When conducting research, one needs to be guided by the ethics associated with it (Lebotse, 2014). According to Oppenheim (1996), the basic ethical principle is that no harm should come to the respondents as a result of their participation in the research.

Following this contention, the researcher made maximum efforts to ensure adherence to the necessary ethical standards. Before the research, permission was

requested from the University of the Western Cape (Appendix 10.1.1.), Eastern Cape Department of Education (see Appendix 10.1.2.), Sterkspruit district office (see Appendix 10.1.3.), the Principal of the school (Appendix 10.1.4) and the School Governing Body of the school concerned (Appendix 10.1.5). Permission was also requested from the parents of the learners who participated in the study as well as learners themselves (see Appendix 10.1.6.). The respondents together with their parents were presented with consent forms and a brief introduction to the study (see appendix 10.1.6). This enabled them to make informed decisions when consenting to the study. The process of data collection commenced immediately upon approval of the research proposal and instruments. All the names, surnames and identities used in the study were kept anonymous. Any information used in the study was kept confidential and the participants were made aware of the confidentiality. Also, the respondents were informed that if they feel like withdrawing from the research, they are free to do so.

Lastly, in the case of interviews, the researcher refrained from asking questions that could cause discomfort to the interviewees. In the study the researcher used electronic recording devices. The use of electronic recording devices was shown to the participants before the interviews. The interview transcripts along with the questionnaire data were securely stored in a password-protected computer file and will only be destroyed after a period of five years from the time the study is completed.

3.11. Conclusion

This chapter has given an overview of the methodological aspects of the study, which was underpinned by both quantitative and qualitative standards. It also explained the various data collection techniques and the different tools used to arrive at the findings. The following chapter provides the findings after the analysis of the data.

CHAPTER 4

RESULTS

4.1. Introduction

In the previous chapter, the methodology used in this study was outlined, the participants who formed the sample for the study, the sequence of the design were introduced, and the methodological types were discussed.

Stake (1995) states that “there is no particular moment when data analysis begins. Analysis is a matter of giving meaning to first impressions as well as to final compilations”. Gardner (2009) further explained that data analysis refers to the process of inspecting, cleaning, transferring and modelling data with a goal of highlighting useful information, suggesting conclusions and supporting decision making. Lebotse (2014) revealed that the purpose of data analysis is to explain concepts in a simplified manner and to indicate clearly the relationship between variables. Qualitative research generates a huge amount of data that needs to be summarised, described and analysed.

In this chapter, findings obtained after the analysis of the data are provided. Firstly, the quantitative results obtained through the pre- and post-tests are presented to establish the learning impact of the intervention. Thereafter the qualitative data that was collected during the intervention by means of video-recording are presented to enlighten the quantitative data in order to determine understanding in terms of the effectiveness of the teaching strategies and to answer the research questions:

How can the conceptual change approach be used as a teaching strategy to improve learners' understanding of chemical change?

- (i) What were learners' initial understanding of chemical change?
- (ii) How was the conceptual change approach implemented to address grade 11 learners understanding of chemical change?
- (iii) What were learners' understanding of chemical change after the conceptual change lesson?
- (iv) What were learners' perception of the conceptual change approach?

This chapter presents the results and interpretation in the following structure:

- Section 4.2 will present and interpret the results of the pre-test.
- Section 4.3 will present and interpret the results of the intervention.
- Section 4.4 will present and interpret the results of the post-test.
- Section 4.5 will present and interpret the results of the interview.
- Section 4.6 will be conclusion.

4.2. Learners' initial understanding of chemical change

The purpose of this part of the study was not only to evaluate learners' achievement in the field of chemical change, but mainly to assess learners' misconceptions in physical and chemical change, exothermic and endothermic reactions as well as energy changes during chemical reactions.

The first part of the study focused on identifying learners' misconceptions about chemical change. In order to identify misconceptions, the researcher designed the pre-test. The pre-test was out of 33 marks and the questions were based on physical and chemical change, exothermic and endothermic reactions and energy changes that are involved in chemical reactions. The test was categorised into three questions. Question one consisted of ten multiple choice questions, question two consisted of five questions where learners were asked to fill in the missing words and question three had four questions where learners were asked to give one word or term for the descriptions given. The pre-test is attached as appendix 10.2.1.

In order to minimize factors that could affect the reliability and validity of the data, the researcher chose to distribute the test to the learners before the September trial examinations, so that the learners would be relaxed and eager to participate in a survey. The test was printed on the date in which it was written. Learners did not know beforehand that they will be asked to write the test, this was done to ensure that their answers will reflect their knowledge during that specific time and would not be a result of preparation. It was made clear to the learners that the diagnostic test and interviews are anonymous, that their completion is made exclusively for research purposes and therefore will not influence in any way their performance in the course of Physical Sciences. During the completion of the test learners were not allowed to collaborate with each other, or ask explanations from the researcher about the test.

Due to the fact that the test would be used again at a later time, after learners had completed the test, both test and answer sheets were collected, and placed in a sealed envelope and the researcher kept them in her home, to ensure that learners won't keep copies of the test and become familiar with the questions, or pass them to other learners. Out of 34 learners, 32 wrote the test, 2 did not write the test thus constituting 6% total data. The two learners were absent the day the test was written.

In order to compare learner achievement, the number of learners who obtained the correct answers in the test for each question was counted and the data obtained was converted to percentages. The results obtained were summarised and represented in tables 5 and 6 and illustrated by means of a pie chart in figure 8 and a bar graph in figure 9. Table 6 indicates question by question analysis where responses of learners were counted and compared.

Table 5: Performance of learners in a pre- test

MARKS IN PERCENTAGE	NO. OF LEARNERS
$0 \leq X \leq 29$	19
$30 \leq X \leq 39$	9
$40 \leq X \leq 49$	4
$50 \leq X \leq 59$	-
$60 \leq X \leq 69$	-
$70 \leq X \leq 79$	-
$80 \leq X \leq 89$	1
$90 \leq X \leq 100$	-

The table above illustrates the overall performance of learners in a pre-test. From the table, 19 learners out of 32 obtained between 0 and 29 percent, 9 learners obtained 30 to 39 percent, 4 learners obtained between 40 and 49 percent. There were no learners who obtained between 50 and 79 percent. There was only one learner who obtained 88% percent.

Performance of learners in a pre-test

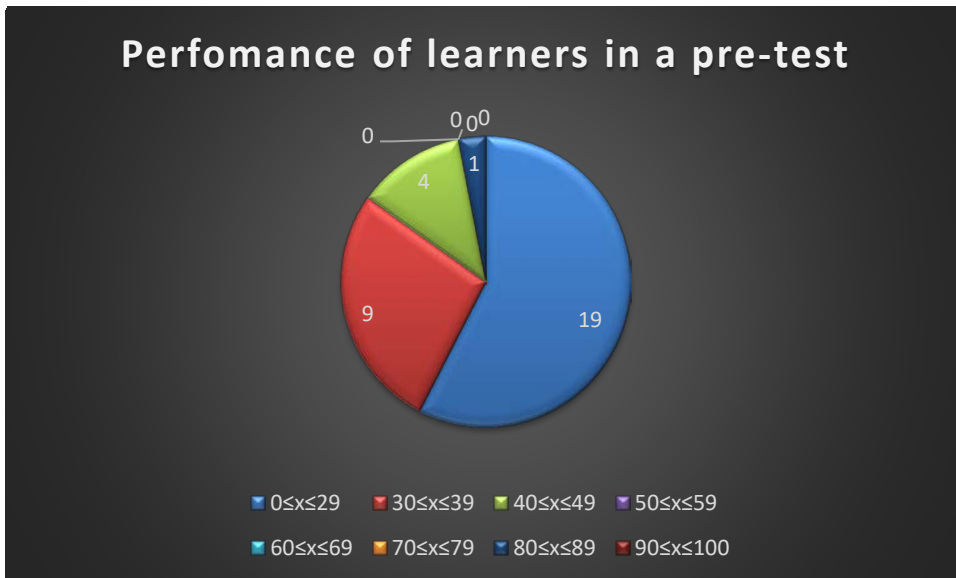


Figure 8: Performance of learners in a pre - test.

The pie chart above shows how learners performed in a pre-test. The graph indicates that in a pre-test 9 learners, which is 55,9% of the total participants, obtained between 0 and 29 percent, 9 learners, which is 26,5% of the sample obtained between 30 and 39 percent, 4 learners, which constitutes 11,8% of the total population, obtained 40 to 49 percent and only 1 learner, constituting 2,9% of the total sample, obtained 88%. There were no learners who obtained 50% to 79% and above 90%.

Table 6: Question by question analysis

QUESTIONS	CORRECT RESPONSES	INCORRECT RESPONSES
1.1.1.	14	18
1.1.2.	2	20
1.1.3.	5	27
1.1.4.	20	12
1.1.5.	6	26
1.1.6.	12	20
1.1.7.	14	18
1.1.8.	7	25
1.1.9.	7	25
1.1.10.	19	13
2.1.	12	22

2.2.	13	19
2.3.	15	17
2.4.	2	30
2.5.	10	22
3.1.	1	31
3.2.	4	28
3.3.	1	31
3.4.	1	31

The above table illustrates how many learners responded correctly in each item of the pre-test and how many learners responded incorrectly. From the table, it is indicative that items 1.1.2., 1.1.3., 1.1.5., 1.1.8, 2.4, 3.1 to 3.4., were not well answered by learners. These questions examined learners' understanding of physical change, chemical change and energy changes that take place during chemical reactions. This means that learners had misconceptions with regard to the items addressed by these questions. Figure 9 below summarises the responses of learners per question towards the pre-test.

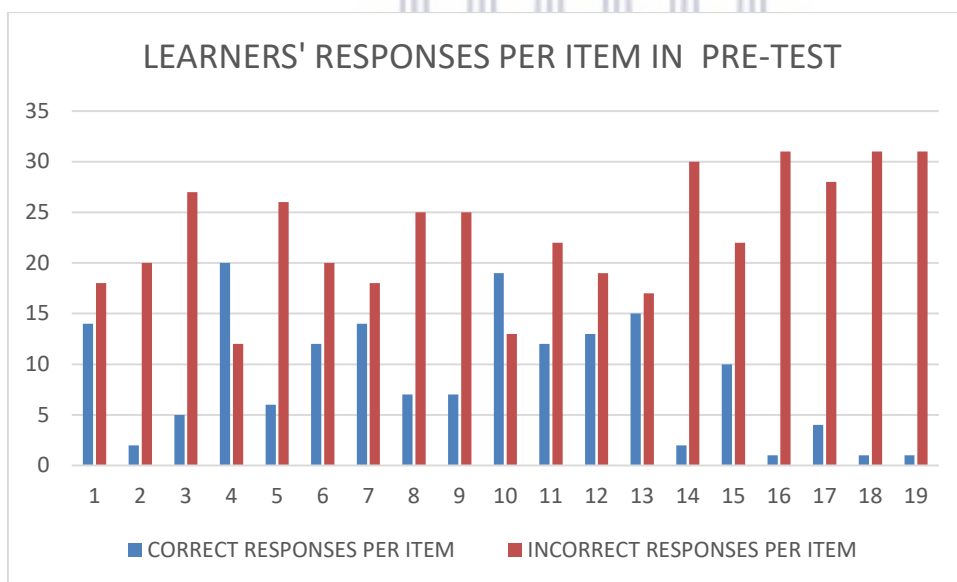


Figure 9: Learners' responses per item in a test.

The above graph illustrates the trend in which learners responded to each item of the pre-test. From the graph, it is evident that most learners had misconceptions with regard to chemical change.

4.3. The effectiveness of conceptual change approach as teaching strategy on the grade 11 learners understanding of chemical change.

The researcher prepared the conceptual change texts and were written for the following topics (appendix 10.2.3.): Chemical and Physical Changes, Chemical Reactions and Energy Changes during chemical reactions. Conceptual Change texts were prepared according to Posner et al (1982) conceptual change model. This instruction was designed to address learners' misconceptions related to chemical change concepts and to eliminate them by considering four conditions for conceptual change (Posner et. al, 1982), which are dissatisfaction, intelligibility, plausibility, and fruitfulness. Grade 11 Physical Science class was sampled for the study. The language of instruction was English. The classroom instruction was four 50-minute sessions per week.

4.3.1. Dissatisfaction

Prior the beginning of the intervention, the teacher introduced the lesson by telling the learners that the lesson will be on chemical change content, the context of which is chemical reactions. The context is in the chemistry section in the Physical Sciences subject and will be examined in paper two during the examinations.

Dissatisfaction is the first stage of Conceptual Change Theory. According to Posner et-al (1982), learners must become dissatisfied with their existing conceptions in order for the new information to be acquired. To accomplish the dissatisfaction stage, the teacher started the lesson with inquiry questions to activate learners' existing knowledge and misconceptions. When a new concept is introduced to learners their only experience is their environment, and the way they see and experience their world (Meyer,2014). Individually, learners were allowed to use their textbooks and the internet to write the definitions and to discuss with their partners the definitions and the answers to the questions they got and to compare similarities and differences they found.

The following are some of the questions asked and responses from learners. The questions were asked during the first stage of the lesson to activate learners' existing knowledge about physical and chemical change:

Teacher: What is a physical change?

L1: A physical change is a change in a state that results in no new substances being formed.

L2: Are changes that affect the form of a chemical substance but not its chemical composition.

Teacher: What is a chemical change?

L1: Any change that results in the formation of new chemical substances.

L2: Chemical change is a chemical reaction in which the original substance breaks apart to form a new substance.

Teacher: Differentiate between a chemical change and a physical change.

L5: Physical change cannot change its composition but chemical change can change itself into another form or another state.

L20: Physical change can be reversible when chemical change is not.

For the second concept of chemical reactions and energy changes involved in chemical reactions, the teacher checked learners' misconceptions by asking the questions and allowing learners to check the answers from their books and to discuss their answers as groups. The following are some of the questions asked and the responses from learners:

Teacher: What is a chemical reaction?

L 8: It is any change that results in the formation of new substances.

L 17: It's a change that cannot be reversible.

Teacher: What is an exothermic reaction?

L 22: Are reactions that releases more energy than they take in.

L 25: Reactions that produce heat.

Teacher: What is an endothermic reaction?

L 11: Are the ones that absorb energy in the form of light.

L 32: Are reactions that absorb more heat energy than it is released.

Then, learners were informed about probable misconceptions related to the phenomena asked in the questions and they were encouraged to discuss these questions. During discussions, learners recognised their initial perceptions as limited and were mostly dissatisfied with their existing concepts. This situation supported the first condition of Posner et al.'s (1982) model, dissatisfaction.

4.3.2. Intelligibility and plausibility

After learners' misconception were activated and learners became dissatisfied with their misconceptions, scientifically acceptable explanations that are more plausible and intelligible were described. The teacher provided opportunities for learners to be involved in discussion and question and answer sessions while studying conceptual change texts. The concepts were explained through the use of demonstrations, videos and experiments related to the concept. Since the learners observe sample events related to the concepts during their scientific explanation by the teacher, these concepts were aimed to be more intelligible to the learners (intelligibility). After that, new examples, especially daily life examples, related to this topic were given to students to enhance their understanding of chemical change and chemical reaction concepts deeply (plausibility).

Intelligibility

Intelligibility is the stage in Conceptual Change Theory where a new concept is made understandable to learners (Posner et.al. 1982). It is at this stage where the new concepts are explained. To accomplish intelligibility stage, the teacher introduced the lesson by giving learners some activities to complete and demonstrations. The following are some of the activities performed by learners and demonstrations by the teacher.

The teacher asked learners to conduct a scientific investigation by using a candle and a match to observe physical and chemical changes. Learners were requested to work in groups of six on that activity. Because there were 34 learners in a class, one of the six groups had 7 members. The objective of the investigation was to explore physical and chemical changes as well as the difference between the two. The following are examples of activities given to learners during the scientific investigation:

Activity 1: Take a candle and use a knife to cut off a small slice of candle wax. What change has this caused to the candle? Do you think this is a physical or a chemical change?

Activity 2: Now examine a match. Light the match and blow it out. What change do you observe in the match? Do you think this is a physical or a chemical change?

Activity 3: Light another match and use it to light your candle. Watch the candle burning and carefully observe any changes that take place. Allow some of the melted wax to fall on the saucer.

What do you observe?

Which of the changes that you see taking place are physical changes and which are chemical changes?

From your observations, how would you say a chemical change is different from physical change? Discuss your ideas with the whole group.

The teacher then did a demonstration and asked learners questions based on the demonstration. The teacher lit a candle and told learners that that was a chemical reaction. The teacher then put a jar over the candle and the flame went off.



Source: GoogleSearch.com

The following were some of the questions asked:

Teacher: What are the reactants in this chemical Reaction?

L₁: Jug and candle.

L₂: candle wax and oxygen.

What are the products in this chemical reaction?

L₅: water

L₁₄: carbon dioxide

Teacher: Why did the flame went out when the jar was put over the candle?

L₄: The flame went out because there is no supply of oxygen.

The teacher then reminded learners about physical change concept done in grade 10 before introducing the new concept of chemical change. The teacher wrote the definition of physical change on the chalkboard and gave an example of a physical change as follows:

Definition of a physical change:

Physical change is a change in which a substance changes its form or appearance but keeps its same chemical composition. In a physical change no new material is formed. Physical change can be reversed although the substance might not look the same as it was before.

An example of a physical change:

When liquid water changes to ice, liquid water is said to have undergone a physical change because ice is water in solid state and at this state the appearance is not the same as the previous appearance. Ice water can be changed to liquid again. The chemical composition of ice water is the same as the chemical composition of liquid water.

After the explanation, learners were asked to give examples of physical change they might thought of. The following are some examples given by learners:

L₁₁: Frying an egg.

L₂₁: pieces of candle

After activating learners' prior learning, the teacher then introduced the new concept of chemical change. Since observation and interpretation are identical and observation and interpretation depends on what one already knows, the teacher explained some phenomena and concepts related to chemical change, chemical reactions and energy changes in chemical reactions in an interactive way, in order to make learners aware of some fundamental concepts about chemical reactions before demonstrations thus enhancing intelligibility. Inquiry questions were asked. Learners were asked to give examples of chemical change and the following are some of the responses from learners:

Teacher: Give examples of chemical change.

L₁₆: When frying an egg.

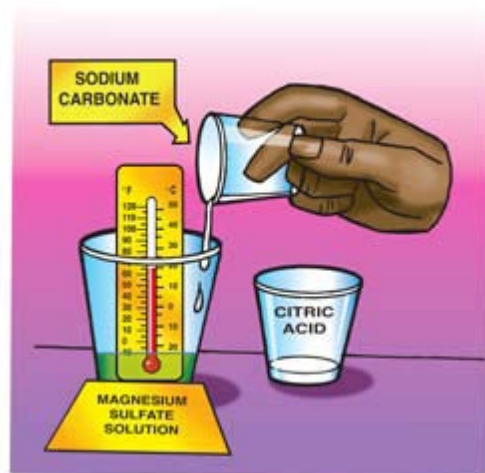
L₂₃: Food spoiler is a chemical change because food has changed from its natural form to a new form. For an example meat spoiling.

The concepts of exothermic and endothermic reactions were also introduced. A video showing exothermic and endothermic reaction was shown to learners. In the video, it was shown that exothermic reactions are chemical reactions that releases energy and endothermic reactions are reactions that absorb energy. An example of a chemical equation for exothermic reaction was given and the diagram showing energy changes during an exothermic reaction was projected. Learners were directed at explaining the concepts based on the activities they were exposed to. This allowed them to think and internalise their understanding of the concepts – which is an integral part of the Intelligibility phase.

Plausibility

This is the third stage on Conceptual Change Theory. According to Posner (1982), new concepts must make sense to the learner. At this stage, learners should be able to picture the new concepts learnt easily in the mind. It is at this stage where the new conception appears plausible.

To build background knowledge on exothermic and endothermic reactions and to accomplish plausibility, learners did the formal experiment. The objective of the experiment was for learners to explore energy changes during chemical reactions, heat of the reaction (ΔH) and the connection between energy changes and chemical changes. Learners were expected to observe whether energy is absorbed or released in two different chemical reactions and to categorise them as exothermic or endothermic. The experiments done were reactions between sodium bicarbonate and vinegar (scientifically known as citric acid) as well as baking soda and calcium chloride.



Experiment 1



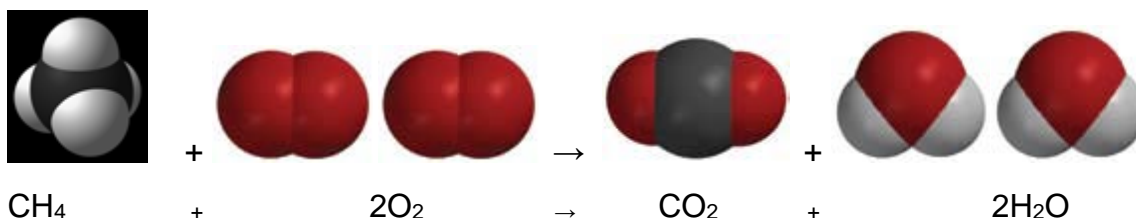
Experiment 2

Source: Google Search

The experiments were consolidated by projecting the video that showed the experiments on chemical reactions between acetic acid and sodium bicarbonate and the chemical reaction between magnesium and sulphuric acid. In the reaction of acetic acid and bicarbonate of soda, the temperature of the reactants was 21.4 degree Celsius and that of the products was 14.4 degrees Celsius indicating that the temperature dropped considerably. The drop in temperature shows that energy was released to the surroundings and this means that the reaction is an exothermic reaction.

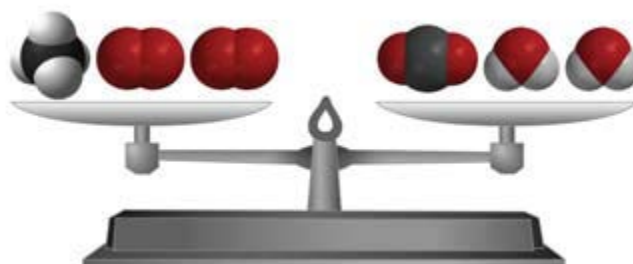
In the chemical reaction between magnesium and sulphuric acid, the temperature of the reactants was 22 degrees Celsius and the temperature of the products rose to 56.8 degrees Celsius. This means that the reaction took heat from the surroundings. The increase in temperature shows that the energy was used during the reaction. This type of the reaction is called an endothermic reaction.

The teacher then corrected the conceptions that learners had by explaining and writing the explanations on the chalkboard. Demonstration that was done by the teacher was explained. Learners were told that in that chemical reaction, oxygen and the candle wax are the reactants, carbon dioxide and water are the products. The balanced chemical equation for the reaction was written on the chalkboard as:



Source: Google Search

The chemical reaction equation was balanced to show that chemical reactions obey the principle of conservation of matter.



Source: Google Search

The teacher then explained to learners what a chemical reaction is. The following is the explanation given by the teacher to learners.

- A **chemical reaction** is a process that transforms one set of chemical substances to another. The substances that take part in chemical reactions are known as **reactants** and the substances produced by the reaction are known as **products**. The study of chemical reactions is part of the field of science called chemistry. When a chemical reaction occurs, bonds in the reactants *break*, while new bonds *form* in the product.

Learners were then asked to give types of chemical reactions they think they know and thereafter, the teacher gave some examples. The following are examples of some chemical reactions that were discussed in class: The common kinds of classical chemical reactions include:

- **Isomerisation**, in which a chemical compound undergoes a structural rearrangement without any change in its net atomic composition.
- **Direct combination or synthesis**, in which two or more chemical elements or compounds unite to form a more complex product:

For an example: $\text{N}_2 + 3\text{H}_2 \Rightarrow 2\text{NH}_3$

- **Chemical decomposition**, in which a compound is decomposed into elements or smaller compounds:

For an example: $2\text{H}_2\text{O} \Rightarrow 2\text{H}_2 + \text{O}_2$

Diagrams in terms of concept maps showing exothermic reaction and endothermic reaction were drawn and explained. Below is the example of an exothermic reaction between hydrogen gas and fluorine gas that was projected and explained to learners:

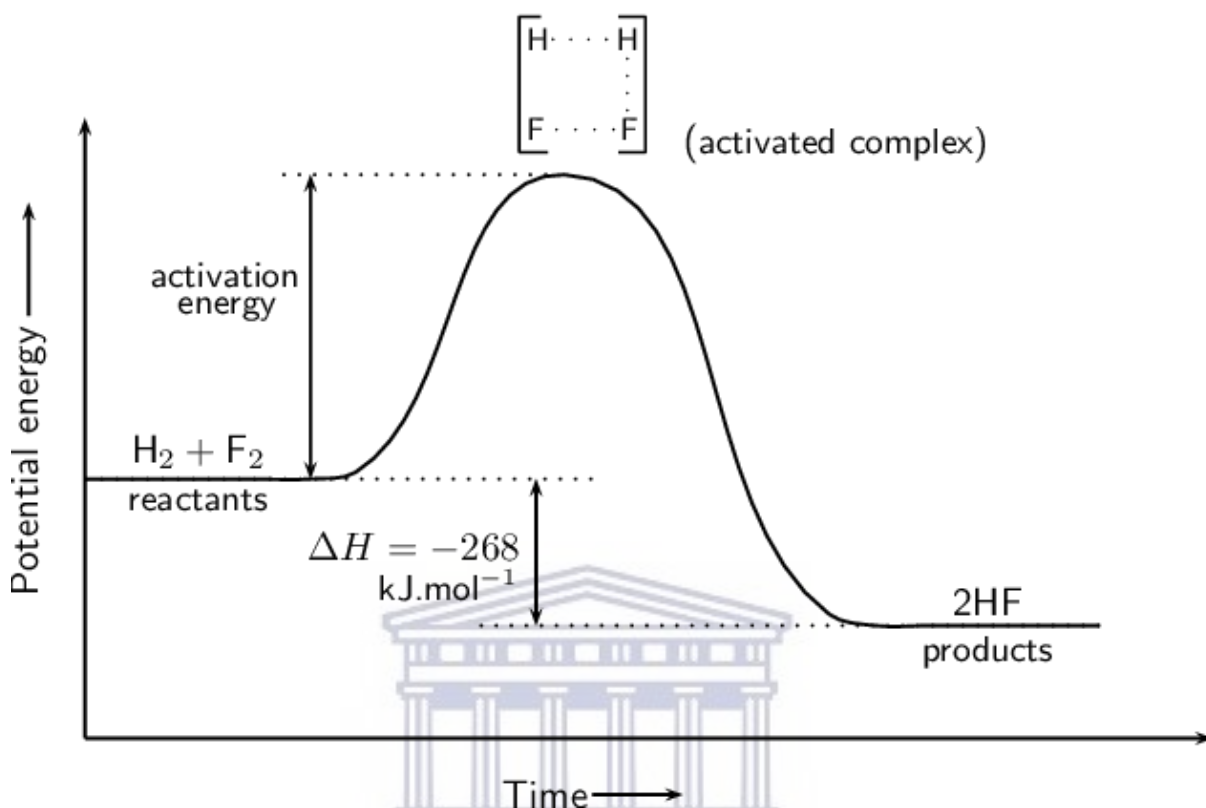


Figure 10: The energy changes that take place during an exothermic reaction

For this reaction to proceed, energy is needed and this energy is called an activation energy. To form the product, the bond between hydrogen and hydrogen, fluorine and fluorine must break. The new bond to form the product must also be formed. The reactants' bond break at the same time that of the products form and this is called the activated complex or transition state. In the given example, the product HF has a lower energy than the reactants. This is a characteristic that differentiates an exothermic reaction from an endothermic reaction. In an exothermic reaction, the heat of the reaction (ΔH) is negative.

Learners were also taught that the heat of the reaction may be determined mathematically by using the equation: $\Delta H = E_{\text{products}} - E_{\text{reactants}}$. The teacher did examples on the chalkboard to show learners how to calculate the heat of the

reaction using the formula. Then, the teacher gave learners individual activity to prove their understanding.

4.3.3. Fruitfulness

This is the last stage on Conceptual Change Theory. According to Posner et. al (1982) the new concept must be beneficial to learners. Learners must be able to solve real life problems with the new knowledge acquired in the future. After the demonstration, learners continued to discuss the events that are related to chemical reactions and energy concepts. In these discussions, the main purpose was to prove the usefulness of the learned conceptions. To provide this, learners tried to give some examples about the natural events and daily life experiences that are related to their new conceptions (fruitfulness of acquired concepts).

The teacher also gave learners examples of chemical changes that takes place in our daily lives and ask them to give some examples they think undergo chemical change. The following are some of the examples of chemical change that were projected for learners by the teacher:

Formation of Yogurt from Milk



Source: Google Search

Yogurt is formed as a result of bacterial action on milk. When certain bacteria, such as *Streptococcus thermophilus* and *Lactobacillus bulgaricus*, are added to warm milk and it is allowed to ferment, lactic acid is formed. The formation of lactic acid causes the milk to curdle. It is a chemical change because a new substance is formed, and the change from milk to yogurt is irreversible.

Changing Colour of Leaves



Source: Google Search

The green colour of the leaves is due to the presence of the green pigment chlorophyll. Chlorophyll absorbs sunlight and the light energy is converted to chemical energy in the chloroplasts, by the process of photosynthesis. Chlorophyll is highly unstable, and the leaves need to synthesize the pigment continuously. In addition to chlorophyll, there are other pigments present in the leaves, which are carotene and anthocyanin's. While carotene is yellow, anthocyanins are red. The change in temperature during winter causes the trees to cut off supply of water to the leaves, by a process called *abscission*. In the absence of water, photosynthesis stops, and so does the synthesis of chlorophyll. Thus, the leaf takes the colour of the other pigments, and we see a change in colour.

Learners were given some activities to complete and to reflect on their findings to the groups and also to give some examples of exothermic and endothermic reactions that occur in everyday lives. Some of the examples given by learners were:

L1: Photosynthesis and

L2: Cellular respiration.

In addition to what learners have given as examples of chemical reactions, the teacher also gave other types of chemical reactions that occurs in everyday lives.

The teacher categorised them according to exothermic reactions and endothermic reactions. The following are some examples given by the teacher:

- Endothermic reaction: Thermal decomposition of lime stone. This is the process used in industry to break down limestone into quicklime and carbon dioxide. Quicklime can be used to make steel from iron and to neutralise soil that is too acidic.
- Exothermic reactions: Hot and cold packs that are often used by athletes to treat minor injuries such as inflammation and sprains. A hot and cold pack has two compartments. One contains water and the other contains salt. When the seal between the compartments is broken and the packs are shaken vigorously, the salt dissolves in the water. Depending on the salt, the reaction can be exothermic or endothermic.
- Airbags in modern cars. Chemical reaction in airbags generates high temperatures and causes the formation of a gas that expands rapidly. This inflates the airbag.

4.4. Learners' understanding of chemical change after the intervention

The purposes of this part of the study were:

- a. to find out if the misconceptions of learners that have been uncovered and classified in the first part of the study have been changed towards scientifically accepted ideas after the implementation of instructional unit taught using Conceptual Change Texts and
- b. to measure the effectiveness of Conceptual Change Approach instructional activities on learners' misconceptions about chemical change.

So the quantitative and qualitative data that were collected during this part of the study were analysed having the aforementioned purposes in mind. Not all learners participated in this activity, three learners did not write the post-test, thus 8.8% of data. Post-test was the same as the pre-test. The results show that there was a great improvement in the performance of learners in a post-test as compared to the pre-test. The results are analysed and interpreted in the form of a table and graph (table 7 and figure 11).

Table 7: Performance of learners in a post- test

PERCENTAGE	NUMBER OF LEARNERS
$0 < X \leq 29$	0
$30 \leq X \leq 39$	4
$40 \leq X \leq 49$	4
$50 \leq X \leq 59$	2
$60 \leq X \leq 69$	6
$70 \leq X \leq 79$	9
80 and above	6

The table above shows that in a post-test, there were no learners who obtained between 0 and 29%, 4 learners obtained between 30% and 39%, 4 learners received between 40% and 49%, 2 learners received between 50% and 59%, 6 learners obtained between 60% and 69%, 9 learners obtained between 70% and 79% and 6 learners obtained 80% and above.

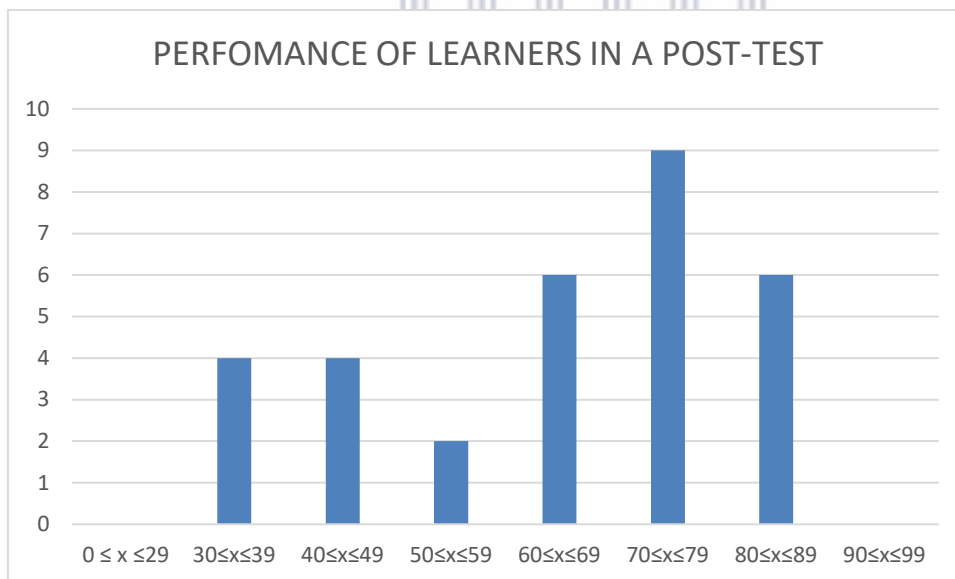


Figure 11: Performance of Learners in a post-test

The graph above shows a trend on how learners performed in a post test. From the figure above, it is indicated that no learners obtained marks between 0 and 29%, 4 learners obtained marks between 30% and 39%, 4 learners obtained marks between 40% and 49%, 2 learners received between 50% and 59%, 6 learners obtained

between 60% and 69%, 9 learners obtained marks between 70% and 79% and 6 learners obtained marks between 80% and 89%.

4.5. Analyses of learners' perceptions to the interview questions

In this study, focus group interviews were conducted with 34 grade 11 Physical Sciences learners. Learners were divided into five groups. Three groups had 6 learners each and two groups had seven learners each. The purpose of the interviews was to obtain detailed information about learners' reasoning of physical change, chemical change and chemical reactions as well as to find the experience gained by learners during the intervention. The learners were a mixture of high-, medium-, and low-achievers in all the groups.

The interviews helped to clarify learners' misconceptions observed in chemical change and chemical reactions chemistry achievement test. Interview results indicated that learners, after the intervention, had more scientific understanding of chemistry concepts compared to the results obtained by learners in a pre-test. Learners' responses to the interview questions were coded and the codes were categorized into the following themes: definition of the concepts, examples of the concepts, relationship among the concepts, learners' feeling towards taking physical science as a subject and learners' perception towards the lesson presentation. The distribution of the number of the learners, in terms of percentages across codes were given in Table 8, and each category was explained:

Table 8: The distribution of the number (percentages) of learners in groups across the codes identified from interviews (NA: No answer, M: Misconception, PC: Partially correct, C: Correct)

	NA	M	PC	C
DEFINITION OF THE CONCEPTS:				
Definition of:				
• Physical change and Chemical change	0	0	2 (6%)	32 (94%)
• Chemical reaction	3 (9%)	0	10(29%)	21(62%)
• Exothermic reaction	0	0	0	31(100%)
• Endothermic reaction	3 (9%)	0	8(23%)	23(68%)
• Activation Energy	0	6(18%)	0	28(82%)
• Bond Energy	3 (9%)	2(6%)	0	29(85%)
EXAMPLES OF THE CONCEPTS:				
• Examples of physical change	0	2(6%)	0	32(94%)
• Examples of chemical change	5(15%)	0	0	34(100%)
• Examples of chemical reactions	9(26%)	0	0	29(85%)
• Examples of exothermic reactions	9(26%)	0	0	25(74%)
• Examples of endothermic reactions	8(24%)	0	0	26(76%)
RELATIONSHIP AMONG THE CONCEPTS:				
• Physical change and Chemical change	0	0	0	34(100%)
• Chemical Reactions	0	0	0	34(100%)
• Exothermic and Endothermic reactions	0	0	0	34(100%)
• Bond energy	11(33%)			23(67%)
LEARNERS' ATTITUDES TOWARDS PHYSICAL SCIENCE AS A SCHOOL SUBJECT:				
• Physical science difficult subject	0	0	0	34(100%)
• Advise to other learners with regard to taking physical science	0	0	0	34(100%)

4.5.1. Definition of the concepts

Learners were asked the definitions of physical and chemical changes, chemical reactions, exothermic and endothermic reactions and bond energy. Related to the definition of physical change and chemical change, 32 learners which is 94% of the total learners, defined the two concepts correctly, only two learners defined the concepts partially correct. For example, a learner in one of the groups, defined physical change correctly as F₁L₂ "A change in the physical properties of matter without a change in its chemical properties". Another learner defined physical change partially correct as: F₃L₂ "A change in matter without a change in its chemical properties". The second one is partially correct because in a physical change, the matter's physical properties changes but chemical properties do not. Another learner defined chemical change correctly as: F₁L₁:" A chemical change is a change where new substances are formed and is irreversible".

With regard to chemical reactions, there was no learner with a difficulty in defining the concept. One of the learners defined the concept as: F₆L₃: "Chemical reaction is a change that results in the formation of new chemical substances. Another learner defined the concept as: F₂L₄: "A chemical reaction is an example of a chemical change where the change cannot be reversed".

With regard to exothermic and endothermic reactions, all the 34 learners were able to define the concepts correctly. For an example one of the learners defined exothermic reaction as: F₂ L₅: "Exothermic reaction is a chemical reaction that releases more energy than the energy it absorbs", the other learner defined the term endothermic reaction correctly as: F₃ L₁:" Endothermic reaction is a chemical reaction that absorbs energy in the form of heat".

Regarding the definition of bond energy, 3 learners could not define the concept, 8 learners defined the concept partially correct and 23 learners could define the concept correctly. For an example one of the learners defined the concept of bond energy incorrectly as: F₅L₁: "Bond energy is the system that is used to break the system. This definition is incorrect because bond energy is not used to break the system but is used to break the bonds of the reactants during chemical reaction. Another learner defined the concept partially correct as F₆L₇: "Bond energy is the

measure of bond strength in a chemical bond”. One of the learners defined the concept correctly as: F₅L₂: “Bond energy is the amount of energy needed to break the bonds between the atoms of reactants in a chemical reaction”.

4.5.2. Examples of the concepts

Learners in all the groups were asked to give examples of physical change, chemical change, chemical reactions, exothermic reactions and endothermic reactions. Related to the physical change, learners in some of the groups gave similar examples, like cutting paper into pieces, cutting the candle into pieces, and stated changes as melting of an ice and burning of a candle incorrectly as physical change. There were 3 learners in the whole sample who could not give examples of physical change. In the whole population, two learners gave ‘spoiling of yoghurt’ and ‘burning of candle’ as examples to the physical change incorrectly. In addition, most of the learners, 29 of them, could give examples of chemical change. For an example, one of them gave burning of wood as an example, the other one gave meat spoiling as an example and the other gave rusting process as examples of chemical changes. Only one learner stated that ‘obtaining yoghurt from milk’ is an example of chemical change different from the peers.

When learners were asked to give examples of chemical reactions, most learners gave burning of a candle, baking of cake, cellular respiration and photosynthesis as examples of chemical reactions. In as far as exothermic and endothermic reactions, most learners could give examples of these reactions. There were 9 learners who could not give examples of exothermic reactions and 8 learners who could not give examples of endothermic reactions. 25 learners could give examples of exothermic reactions and 28 could give examples of endothermic reactions. For an example, some learners gave combustion of fuels as example of exothermic reaction and photosynthesis as an example of endothermic reaction.

4.5.3. Relationship between the concepts

Learners were asked to give a difference between a chemical change and a physical change, an exothermic reaction and an endothermic reaction in the interviews. In order to support the findings obtained from the post-test, these questions were also asked in the interviews. Related to difference between physical change and chemical

change, all the 34 learners could differentiate between physical change and chemical change.

The following are some of the responses from learners:

Researcher: Differentiate between a physical change and a chemical change.

F₁L₁: Physical change is reversible and chemical change is irreversible.

F₄L₃: Chemical change is when two or more substances combine to form a new substance.

Interview results revealed that all learners changed the conception they had about physical and chemical change.

With regard to chemical reaction, learners were asked to give evidence as to how they can conclude that chemical reaction has occurred, all of them could tell that if there is a change of colour or in the form of bubbles, that indicates that chemical reaction has occurred. Learners were also asked to give examples of exothermic and endothermic reactions, not all of them could, 9 learners could not give examples of exothermic reactions and 8 were unable to give examples of endothermic reactions.

Regarding bond energy, 11 learners could not answer that question, they just could not give any relationship in as far as bond energy is concerned. They still maintained the misconception they had before the intervention. For an example, one learner stated that bond energy is the study of the strength in chemical bonding. The other learner maintained that bond energy is the amount of energy that is released during chemical reactions. 23 learners were able to relate bond energy with chemical reactions. For example, one of the learners stated that bond energy is the energy that is required to break the bonds between the atoms of the reactants.

4.5.4. Attitude of learners towards taking Physical Sciences as a subject of specialisation at school

With regard to attitudes of learners towards taking Physical Sciences as a subject of specialisation, learners showed a positive attitude. During interviews, learners were asked whether Physical Sciences is a difficult subject or not, most responded

positively stating that the subject is not difficult, it just needs focus and time. They indicated that, after the presentation of the lesson, they find out that Physical Sciences is not a difficult subject, it is just the way they are usually taught. The researcher asked them to explain how they are usually thought and they stated that they have never done the experiments before because their school does not have a science laboratory. They justified their view by stating that:

F_{4L3}: After you have taught us, I realised that physical science is not a difficult subject.

F_{2L6}: The way you taught us, I grasped everything, because you did the demonstrations, the experiment and you also showed us the video. I am not going to forget the topic.

There was one learner who stated that the subject is difficult for her. She stated that she feels the subject challenging. One learner stated that the subject is not difficult but for them, because their school does not have resources and they are leaving in rural areas, the subject appears more challenging. For example, he said “For us leaving in rural areas, our schools do not have resources like science laboratory where we could do the practical and also there are no enough textbooks, the subject becomes difficult because we cannot do the practical part and also we are sharing the textbooks”.

When they were asked whether they can advise other learners to take physical science as one of their school subject, they stated that they can do that. For instance, one of the learners stated “I will advise other learners to take Physical Sciences madam because when you have Physical sciences, there are lot of opportunities like engineering and biomedical science”.

4.5.5. Learners’ perception towards lesson presentation

At the end of the intervention, all learners participated in focused group interviews. The purpose was to bring about their ideas about the implementation of the lesson. During interviews, learners were asked how they performed in the pre-test compared to post-test and to motivate their answers. The responses were that all of them obtained higher marks in the post test because of the way the lesson was presented. They compared the presentation of the lesson with the way they are usually taught.

Based on the learners' responses, the following codes were obtained: activities, experiments, learner participation, group activities, writing activities and preference of approach.

Table 9: The distribution of the number (percentages) of learners across the codes identified from interviews

CODES	NUMBER OF LEARNERS (PERCENTAGE)
Activities and Experiments	34(100%)
Learner Participation and group Activities	34(100%
Writing Activities and Preference Approach	34(100%

4.5.5.1. Activities and Experiments

According to all learners, the experiments and demonstrations done in class were the main difference. Some learners stated that they have never done science experiments because the schools they attended in the area do not have laboratories. For example, one of the learners stated "The way you presented the lesson made me to grasp all the information. The demonstrations and experiments we did in class improved my understanding. The other learner stated that: "It was for the first time doing experiments in class, usually the teacher talks, we just listen and take notes, but in this lesson, we participated in class and were allowed to exchange ideas. We talked, discussed and did experiments". All learners stated that they usually take notes, but this time they wrote laboratory reports which increased their knowledge retention.

4.5.5.2. Learner participation and group activities

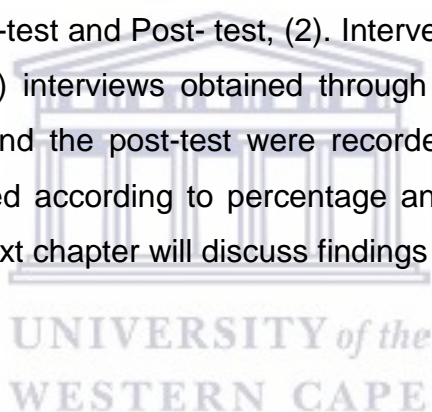
Regarding learner participation and group activities, learners indicated that they usually listen to the teacher when teaching and take notes, but in this lesson, the whole class participated. They further stated that, in this lesson, all of them talked, discussed and did experiments. For an example, one learner stated: "We exchanged our ideas during discussions". Some learners stated that group activities increase their friendship, participation in class and social skills.

4.5.5.3. Writing activities and preference approach

Learners compared writing activities during their learning. They stated that they usually write notes when their teacher taught them but in this lesson they have learnt to write science report. For an example one learner stated “When the teacher is teaching, we usually take notes and I was not learning, but in this lesson I wrote by myself, I learnt more”. Another learner expressed that “I enjoyed writing by myself”. After learners compared the presentation of the lesson with their traditional way of teaching, all of them preferred the way the researcher presented the lesson. They supported their views by giving reasons like learning better, motivated, enjoying the lesson, participation and involvement in the lesson and retention of new knowledge.

4.6. Conclusion

This chapter presented analysis of results and interpretation. Both quantitative and qualitative data was presented using tables and graphs. Data analysis for this study was divided into: (1). Pre-test and Post- test, (2). Intervention in terms of the activities in a lesson plan and (3) interviews obtained through focus group interviews. The marks for the pre-test and the post-test were recorded in an excel spread sheet, tabulated and categorised according to percentage and then displayed in the form tables and graph. The next chapter will discuss findings of the data analysis.



CHAPTER 5

DISCUSSION

5.1. Introduction

In this chapter the findings of the data analysis are discussed and reported upon. The main purpose of this study was to investigate the effectiveness of using conceptual change approach in improving learners understanding of chemical change on grade11 learners' understanding of chemistry concepts and chemistry achievement in chemistry units on chemical change.

Chemistry is a science whose primary purpose is the description and explanation of chemical change (Hesse & Anderson, 1992). A number of chemistry textbooks consist of chemical equations that represents various types of chemical reactions and explanation of how and why those reactions occur. Since the concept of chemical reactions is considered to be an important objective of chemistry teaching, teachers should be made aware of learners' difficulties in this area.

Before coming to school learners have many preconceptions. Some of these preconceptions are inconsistent with scientific views and are called misconception. Misconceptions deter learning since learners construct knowledge by the help of already existing conceptions. If some of these prevailing conceptions are wrong, then learners cannot learn science meaningfully. Therefore, identification of misconceptions which are very resistant to change and difficult to extinguish, and finding ways for remediation of misconceptions are very significant. Therefore, the main purpose of this study was to determine misconceptions learners held about chemical change and to investigate the effectiveness of conceptual change text instruction on understanding chemical change. In addition, learners' attitudes towards chemistry before and after the conceptual change text instruction, learners' attitudes towards conceptual change texts, learners' science process skills and understanding of chemical change were also investigated.

Constructivism is one of the pillars of the theoretical frameworks used in this study. It is important to use as it will help identify the learner's existing concepts. Constructivism is a theory of learning in which every learner constructs his or her

ideas (Önder & Geban, 2006). It stresses that each individual must construct meaning for himself or herself (Rasmussen, 1998). Thus, constructivism is a theory of learning in which every learner constructs his or her own ideas.

In this study, the researcher tried to find misconceptions learners have about chemical change concept through pre-test and by reviewing the previous studies. It has been observed that like all chemistry concepts, learners have several misconceptions related to chemical change. Furthermore, literature review indicated that most high school learners have misconceptions in various chemistry concepts including chemical change. However, there are not many studies related to chemical change concept. Therefore, the classification of misconceptions presented in this study gains importance

Learners have misconceptions related to chemical change which deters understanding and learning chemical change concept and chemistry in a meaningful way and as such learners consider chemistry as a difficult subject. Therefore, finding ways to enhance meaningful learning which requires remediation of misconceptions is of vital importance. Remediation of misconceptions requires understanding of how individuals construct knowledge. Piaget's cognitive stage theory is a good source for understanding how cognitive development occurs from infants through adolescents. In this theory individuals learn through assimilation, accommodation and equilibration processes. In terms of this theory, learners construct new concepts through assimilation and accommodation of new information while they are exploring the world and store these concepts into correct mental classifications in their minds.

Prior knowledge learners have affects their further learning. These prior conceptions can hinder construction of new knowledge. According to information processing theories, individuals construct knowledge by forming connections between newly organized knowledge and existing relevant knowledge and therefore, if prior knowledge is dissonant with the new information, meaningful learning cannot occur. Prior knowledge is the most influential predictor of science achievement (Gooding, Swift, Schell, Swift & McCroskery, 1990; Lawson, 1983) and the degree to which prior knowledge is consistent with the new subject matter is an indicator of the

improved science learning. Therefore, teaching for understanding requires identification of misconceptions.

There are several causes of misconceptions such as prior experiences, textbooks, teachers' explanations, instruction, terminology, social interaction and everyday language. The new knowledge is constructed by the help of prior knowledge according to information processing theories. Therefore, if the prior knowledge is incompatible with the new information, the construction of the knowledge will be inappropriate. The everyday language can also lead misconceptions. Teachers also have misconceptions related to several subjects and content areas, they can also be a source of misconceptions.

5.2. Pre-test and post-test results

The Alternative Conceptions about Chemical Change Test (Chemistry Achievement Test) was administered to learners before the intervention as a pre-test and after the intervention as a post-test. The average percent of correct responses of the pre-test was 26.7% and that of the post-test was 65,1%. When the post-test scores were compared with the pre-test scores, it has been found that a statistically significant difference between the mean scores of the pre-test and the post-test existed in favour of the post-test. The results show that there was a significant difference between the post-test mean scores of the learners compared with the pre-test mean scores, after they have been taught by Conceptual Change Instruction. These findings showed that learners unveiled significantly higher performance levels in the post-test than in the pre-test. The participants made substantial gains in their understanding of the nature of chemical change. The results of the pre-test and the post-test were analysed and illustrated by the following table and graph:

Learners' responses to both tests were examined in detail by conducting item by item analyses. For post-test, the proportions of learners' correct responses were examined and it was found that there were differences in the proportions of correct responses between the pre-test and the post-test, in favour of the post-test. For the post-test, learners' correct responses and misconceptions were investigated. It has been found that learners held some misconceptions related to chemical change even after the intervention. In the unit of chemical changes, some learners could not

differentiate between physical and chemical changes. For example, some learners thought that chemical changes were irreversible, while physical changes were reversible whereas most of the chemical changes are irreversible.

Table10: Comparison of pre-test and post-test results.

PERCENTAGE	LEVELS	PRE-TEST	POST-TEST
$0 < x \leq 29$	1	22	-
$29 < x \leq 39$	2	6	4
$39 < x \leq 49$	3	3	3
$49 < x \leq 59$	4	-	3
$59 < X \leq 69$	5	-	8
$69 < X \leq 79$	6	-	6
$79 < X \leq 100$	7	1	8

The results in table 10 above show that before the intervention, 22 learners obtained level 1, which in terms of percentage, is less than 30%, 6 learners obtained level 2, less than 40% but greater than 29% and 3 learners obtained level 3, which in terms of the percentage, is more than 39% but less than 50%. From the table, it is evident that there were no learners who obtained levels 4, 5 and 6 except one learner who obtained level 7. This is evident that 97% of the learners came to class with misconceptions with regard to chemical change.

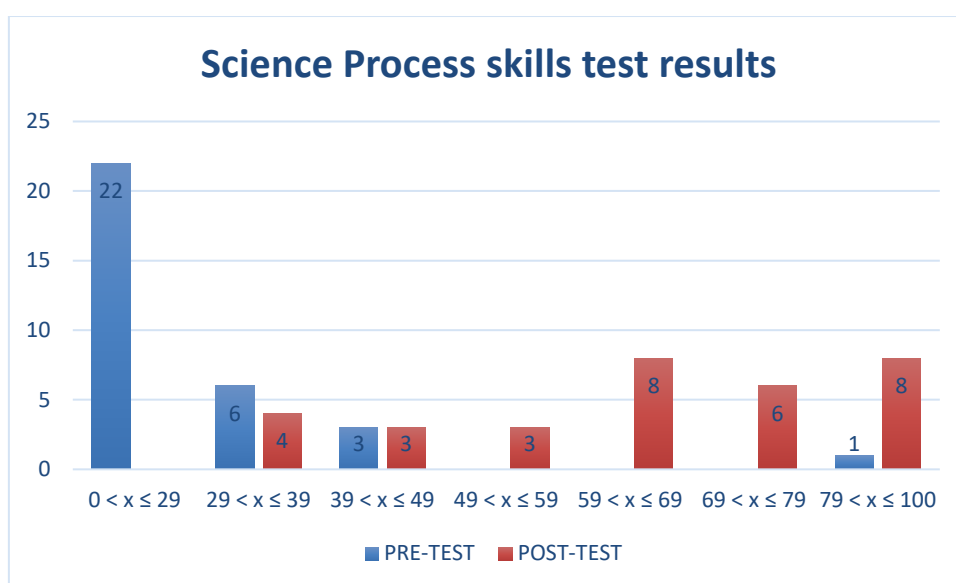
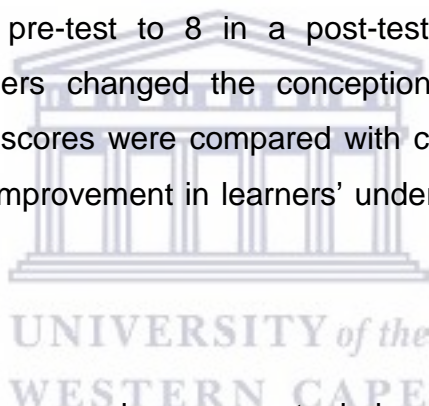


Figure 12: Performance of Learners in terms of levels in a pre-test and a post-test

Figure 12 above indicates number of learners who obtained different levels in a pre-test and a post-test. From the graph, it is indicated that from a pre-test, as the percentage increased, the number of learners who obtained higher percentage decreased. There were 22 learners who obtained level 1 in a pre-test as compared to zero learners who obtained level 1 in the post test, 6 learners obtained level 2 in a pre-test whereas only 4 learners obtained level 2 in a post test. That means, the level of learners' previous knowledge in chemical change was generally low prior to the intervention. When comparing pre-test and the post-test, there were 3 learners who obtained level 3 in both the tests, this indicates that the three learners did not change their conceptions even after the intervention. As the levels are increasing, from level 4 to level 6, the graph shows that there were no learners who obtained those levels in a pre-test, 3, 8 and 6 learners obtained levels 4, 5 and 6 respectively in a post-test. This indicates that some learners, after the intervention, changed the conceptions they had about chemical change. The number of learners who obtained level 7 increased from 1 in a pre-test to 8 in a post-test. This shows that after the intervention, most learners changed the conceptions they had about chemical change. When post-test scores were compared with corresponding pre-test scores, there was a substantial improvement in learners' understanding and achievement of the chemical change.



5.3. Intervention

In this study respondents were given conceptual change texts instruction, designed to remediate learners' alternative conceptions about chemical change. In the course of this process, the researcher primarily had two aims: (i) to remediate current alternative conceptions and (ii) to prevent the development of new ones. Learners have their own beliefs about the nature of matter. These beliefs may lead them to understand and explain chemical change in quite different ways. Learning about chemical change is not just the learning of facts and rules. As mentioned in Chapter four, the intervention was made in a class of grade 11 physical science learners of the same school. Learners were taught by considering conceptual change texts accompanied with demonstrations and experiments. The texts were prepared according to Posner et.al (1982) conceptual change theory.

Prior learning is very important in construction of new knowledge, and it may affect learners' further learning positively or negatively. In the literature, prior knowledge was stated as the most influential predictor of science achievement (Gooding et al., 1990; Lawson, 1983) and the degree to which prior knowledge is consistent with the new concepts is an indicator of the improved science learning. Teaching for conceptual change requires identification of prior learning, resolution of the conflict between prior understandings and new information, and the application of new concepts into new situations. These steps were embedded in the implementation of Conceptual Change Approach. In this study learners' prior conceptions were taken into account, and their misconceptions were activated through discussions in the argument based inquiry activities. Several conflicting situations based on these misconceptions were prepared. In cognitive conflict, learners are provided with evidence that contests with their existing concepts, as such, necessary in order to achieve conceptual change. By the help of these conflicting situations learners will realize that something is wrong. According to Posner et.al. (1982), in order to achieve conceptual change learners must be dissatisfied with existing conception. Learners were dissatisfied with their existing conceptions through the laboratory investigations.

Cognitive conflicts used helped learners to realize that something is wrong with their prior conceptions. Moreover, when learners are faced with conflicting situations they try to understand these confusing situations. They would ask several questions to themselves to resolve these conflicts in their minds. In other words, they try to explain and find answers to their own questions. These questions help them to monitor their level of understanding. For example, when the activity where the relationship between temperature and exothermic reaction was given to learners, some of them asked themselves "How can a chemical reaction release energy?" and they focused their thinking into finding the relationship between temperature and chemical reactions. During this process, learners scrutinized and self-evaluated their understanding which would probably enable them to notice errors they have made and self-correct them. These processes were considered to be metacognitive because they provided learners to check how well they comprehend what they were learning. Then, learners' misconceptions related to chemical change followed by evidence that they are wrong are presented. In addition, why learners construct such alternative conceptions were also explained with correct scientific explanations.

According to Posner et.al. (1982), in order to achieve Conceptual Change, the new conception must be intelligible. The learner must know what the new conception means and easily understand the conception. Therefore, Conceptual Change Texts were prepared so that every learner can easily understand and comprehend what was written. In addition, in order to make content concrete and enhance remediation of misconceptions, demonstrations, experiments, videos, examples and detailed diagrams were used. In other words, activities that involved presenting and developing ideas helped learners to practice and strengthen the conceptual understanding. This also satisfies plausibility stage, the third condition mentioned by Posner et al. (1982) where the new conception must appear plausible in order for conceptual change to take place. The learner must believe that it is reasonable and it is consistent with their world view.

Some daily life examples were given to show that the chemical change concept is very important for understanding the nature. Learners can then find some value for learning the new concept, thus satisfying fruitfulness, which is the last condition presented by Posner et. al. (1982) for obtaining conceptual change. Therefore, it is evident that identification of misconceptions and cognitive conflict were very important in conceptual change approach.

Then, scientific conceptions were negotiated in small groups and whole-class discussions. These discussions helped learners to assess and express their ideas about the chemical change concept. The important part of this approach was the social interaction because the scientific concepts were discussed through learner-learner and learner-teacher interaction. These discussions facilitated learners' understanding of chemical change, and encouraged the involvement of the learners in the learning process.

When the characteristics of the Conceptual Change Approach are considered, these findings can be considered as expected outcomes, because inquiry-based activities, writing activities, and small-group and whole-class negotiations were used and all of them contributed to the attainment of learning by learners. Learners were engaged in demonstrations and laboratory investigations through which they sought answer for

their own questions. Looking for an answer for their own questions was meaningful for the learners, which naturally stimulated them to learn.

Learners are actively involved in the learning process if they construct their own knowledge (Krajcik & Sutherland, 2010). In this study, learners were engaged in small groups discussions and whole-class negotiations. Discussion of the concepts in a social context facilitated learners' understanding of the concepts. They became convinced that the scientifically acceptable new conception was more meaningful. Sharing ideas through the interactions between learner-learner and teacher-learner interactions influenced learners' construction of scientific knowledge (Fellows, 1994b, Burke, Hand, Poock & Greenbowe, 2005). Learners were engaged in writing activities through the laboratory report writing. They were involved in writing activities before, during, and after the intervention.

During the instruction, learners wrote data and observations based on their experimentation, and wrote claims and evidences based on their data and observations. At the end of the instruction, they read from other sources and compared their interpretations with that of other sources and their peers, and then wrote them on the report. They also wrote their reflections throughout the learning process. The reflection part on the laboratory report format helped learners compare their beginning ideas with the ideas that they learnt through the classroom activities. These writing activities facilitated construction of new concepts in a scientific way (Driver, 1988; Fellows, 1994b). Solsona, Izquierdo and de Jong (2003) argued that integration of content of the laboratory work is essential for the learners' meaningful construction of scientific knowledge.

The knowledge about particulate nature of matter has a constructive role in the development of the concepts of the chemical change. Learners must understand the interaction between the particles of matter and the arrangement of the atoms in a chemical reaction. Some of the misconception learners held was that when the candle is burning, there is a physical change and when a nail rusts, that is a chemical change.

A practical way of fostering conceptual change in science is to provide learners with opportunities to experience scientific phenomena through laboratory investigations and to relate scientific conceptions with everyday life (Kingir, 2011). Park, Khan and Petrina (2009) further argued that when students operate and manipulate experimental equipment, observe changes, take measurements, negotiate and discuss with peers during laboratory activities, they are actively participating in learning process. The current study revealed that there were still some misconceptions held by some few learners even after the intervention. This indicates that the conceptions that are not scientific can be converted into anticipated conceptions only to some extent with the intervention because they are very resistant to change (Bilgin & Geban, 2006; Duit, 2007; Pınarbaşı et al., 2006). In the literature, many studies have investigated students' understanding of chemistry concepts such as chemical bonding (Taber, 2002), acids and bases (Ross & Munby, 1991), the particulate nature of matter (De Vos & Verdonk, 1996), atoms and molecules (Griffiths & Preston, 1992), and chemical equilibrium (Hackling & Garnett, 1985). These studies show that some learners retain many alternative conceptions and learners face several cognitive conflicts when dealing with chemistry concepts.

5.4. Interview Results

After the post-test, focus group interviews were used to examine learners' understanding in detail. Interviews were conducted to examine learners' ideas about chemical change. The interviews helped to clarify learners' misconceptions in a comprehensive manner. It was found that the misconceptions observed in the interviews were consistent with those detected as a result of the concept test. Interview results also revealed that some learners could not support their ideas scientifically. For example, when learners were asked the type of change when a candle burns, they answered in such a way that all burning processes were a type of chemical change. When they were asked for further explanation, they could not, they asserted that according to their understanding, they think that all burning processes are chemical change.

Personal interviews could be an indicator of student attitude (Koballa & Glynn, 2004). Using the semi-structured interview protocol, learners were questioned about their attitudes toward chemistry and the approach used in the implementation. All the

learners indicated that they enjoyed the activities done in the classroom and claimed that they understood the chemistry concepts better than they usually do in their traditional classes. Learners were very passionate about being given control over the design of the experiment and planning their own investigations. They preferred to have chemistry classes in this format. One of the learners stated that ‘I would love to have chemistry classes like this, because I could see what you were talking about happening during the experiments’. The other learner said “I understood all what you taught us in this lesson”. Learners expressed the way the lesson was interesting. They said they enjoyed the lesson, concepts were more understandable, and they are not going to forget them easily. One of the learners stated” Before the lesson, I did not know that when the candle is burning there is chemical reaction that is taking place”. They stated experiments, group work, and writing style as the main differences between the Conceptual Change Approach and the way they are used to when being taught.

Conceptual Change Approach affected learners’ attitudes towards chemistry positively. One of the learners mentioned, “The way you taught us is different from the usual way we are used to, you made me understand better because I could see what you were talking about in the experiments and the demonstrations we did in class. That motivated me a lot and made me to realise that Physical Sciences is not difficult”. Improvement in learners’ attitudes towards chemistry were supported by the previous studies (Günel, Kabataş-Memiş, & Büyükkasap, 2010; Erkol, Günel, Kışoğlu, Büyükkasap & Hand, 2008; Kabatas, Günel, Büyükkasap, Uzoğlu, & Hand, 2008). Learners’ attitudes towards science can be improved by using effective instruction, including hands-on activities, laboratory activities, inquiry-based activities (Kyle, Bonnstetter, & Gadsden, 1988), and relevance of science to daily life. Science activities that are fun and personally fulfilling have the potential of leading positive attitudes toward science and conceptual understanding (Koballa & Glynn, 2004). An improvement in learners’ achievement in science significantly influences their attitudes toward science (Park, Khan & Petrina, 2009).

Interview results revealed that some learners have still some misconceptions after the intervention. The researcher coded the answers separately, and then the results were compared. Table 11 show some of the interview results.

Table 11: Codes for learners' responses to interview question-3

Code	What can you say about the amount of energy required to break bonds in the reactants compared to the amount of energy that is released when bonds are formed in the products in an exothermic reaction?	Respondents
Misconception	There is no energy involved.	1
Partial understanding	In an exothermic reaction, more energy is released when the new bonds in the products are formed.	1

From Table 11, it is indicated that in interview question 3, one learner had a misconception that there is no energy involved when bonds are broken and when new bonds are formed during chemical reaction. One learner had partially understood and said "In an exothermic reaction, more energy is released when the new bonds in the products are formed". There were two learners who could give scientific explanation and said "In an exothermic reaction, more energy is released when the new bonds in the products are formed than is used to break the bonds in the reactants".



5.5. Conclusion

The results obtained in Chapter 4 showed that instruction based on conceptual change approach caused significantly better attainment of concepts related to chemical change. Moreover, when the proportion of correct responses given to each item by learners in pre-test and post-test was compared, it became apparent that Conceptual Change Approach was a better designed instruction in elimination and remediation of misconceptions. The findings obtained from this study are consistent with the findings of other national and international studies in terms of supporting the idea that Conceptual Change Approach leads to greater conceptual understanding of science concepts. The results of this study support the results obtained in previous studies (Hewson & Hewson, 1983, Suits, 2000, Sungur, Tekkaya & Geban, 2001, Ceylan, 2004, Özmen, 2007, Ceylan & Geban, 2010, Karakuyu & Tuysuz, 2011,

Kaya & Geban, 2011, Kaya & Geban, 2012, Kapartzianis, 2012, Mckenna, 2014, & Meyer, 2014).

As a summary of the findings from the study, one can say that conceptual change approach as a teaching strategy is very efficient in diagnosing and overcoming learners' misconception problem. Conceptual change strategies have a direct and positive influence on learners' academic success and creativity. Hence, they should be applied to classes more often.



CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1. Introduction

This chapter presents an overview of the scope of the study and a summary of the results and findings discussed from chapters 4 and 5. In addition, implications of the findings and limitations pertaining to the study are discussed, conclusions are drawn and recommendations for further studies are presented.

The aim of this study was to determine how conceptual change framework as a teaching strategy can be used to improve learners' understanding of chemical change in a grade 11 Physical Sciences class using conceptual change texts as a teaching tool.

6.2. Overview of the scope of the study

6.2.1. Rational for the study

This is presented in chapter 1 of the study. This chapter serves as the introduction to the research. It highlighted the background of the study, the state of Science Education in South Africa, interventions made by the National Department of Education in the country as well as the Province of the Eastern Cape in order to improve performance of learners in Physical Sciences, the research problem, the research question, the significance of the study as well as the limitations to the study. It is in this chapter where the context of the study was explained.

Physical Sciences as a subject should prepare learners to study further at a higher level and also to follow a career in a Physical Sciences-related field. In South Africa there is a huge demand for people following a career in science as well as a demand for scientific literate citizens. Conversely, Physical Sciences has been a problem nationally and internationally with poor learner performance. However, statistics related to the pass rate of grade 12 South African learners with regard to Physical Sciences showed a deterioration in learner performance. It was therefore, vital that research be conducted in Physical Sciences to address the afore-mentioned problems. To address these problems, it is imperative to improve the teaching of Physical Sciences as well as the education of Physical Sciences educators.

Therefore, it becomes imperative to pay more attention to the teaching of Physical Sciences due to technological advancement and to supply in the labour market needs (Redish, 2006).

Many publications emphasise the importance of science in maintaining the economic wealth of modern societies, thereby justifying both the learning of science as essential for sustainable development in the future and for active participation in society and societal issues (Roth & Lee, 2004). In view of this problem, the study explored new strategies and ways to enable learners to achieve the desired outcomes at a higher level in Physical Sciences. The aim of this study was therefore to investigate how the conceptual change approach as a teaching strategy can be used to improve learners' understanding of chemical change in an attempt to improve performance in Physical Sciences as a subject

6.2.2. Literature Review

This is discussed in chapter 2. In this chapter theoretical framework and literature related to the study were reviewed. International, national and local studies addressing this study were also discussed.

The various forms of literature were reviewed to establish the objectives of the research and in order to understand the nature of the discrepancy between learners' understanding and what they needed to know about chemical change or any other subject matter in chemistry. Literature revealed that in the teaching of any topic in any subject, one has to consider what the learner knows and how the existing concepts may affect learning. This study therefore used conceptual change theory by Posner et al. (1982) and socio-cultural constructivist paradigm as envisaged by Piaget and Vygotsky (see chapter 2). Here, learners change and/or reconstruct their existing knowledge and concepts within the topic, in this case chemical change.

Literature also indicated that learners bring prior knowledge, experience, cognitive resources and interests into the classroom. It is therefore vital that educators be aware of these conceptions that learners bring into the classroom. In order to develop scientific enlightened learners, this prior knowledge should be integrated with the scientific knowledge of learners. Constructivism is therefore helpful in

identifying the learner's existing concepts, while conceptual change theory assists the learner in changing his/her concepts. Through constructivism and conceptual change, a high level of critical and cognitive thinking is expected of the learners.

In order to achieve the overall objective of the study, the literature from the fields of chemistry education, misconceptions about chemical change, conceptual change theory and conceptual change teaching and learning were reviewed and the outcomes of this review helped the researcher to formulate the design of the study.

6.2.3. Methodology

This section of the study was discussed in chapter 3. In this chapter, research design and methodology, including the quantitative and qualitative research methods were discussed. The procedures, design, population, sample and instrumentation that were used to measure the effectiveness of the conceptual development teaching strategies, validity and reliability of the study were also explained. It is also in this chapter where the ethical aspects of the study were also explained.

The sample of learners who participated in the study were grade 11 learners taking Physical Sciences in a school in one of the districts in the Eastern Cape Province. In the study different data collection instruments were used to obtain the data necessary to describe and address the problem under investigation. For the purpose of this study, both quantitative and qualitative research methods were used to afford the researcher an opportunity to utilize what is best from both qualitative and quantitative approaches. Mixed methods were also used to ensure triangulation and clarification of the results. Triangulation was used in order to strengthen the findings and to prove their trustworthiness. Maximum efforts have been made to ensure adherence to the necessary ethical standards.

6.2.4. Findings

The findings for this study were discussed in chapter 4. This is the section where thick description of the study was done. The researcher here gave the picture of what processes and strategies followed and implemented during the research. In this chapter analysis, interpretation and synthesis of quantitative and qualitative data were discussed. The quantitative part of the study was visually illustrated by tables

and graphs. The qualitative data that was used to explain and support the quantitative data was also discussed. The qualitative data was collected by means of video-recordings, focus group interviews and observations. Based on the learning gained, the effectiveness of the conceptual change approach as teaching strategies were evaluated.

6.2.5. Discussion

Discussions based on the findings are detailed in chapter 5 of this study. The results of the quantitative and qualitative data analysis have been presented and analysed separately in this chapter. Data collected through pre- and post-test as well as focus group interviews were used to calculate the learning gain of the interventions. The data was discussed in accordance with the Conceptual Change strategy. During discussion, specific quotes were cited and the findings were summarised. Finally, the quantitative and qualitative data were integrated and the combined results were discussed.

6.2.6. Conclusion and recommendations

Conclusion and recommendations are outlined in chapter 6 of this study. In this chapter, an overview of the study was provided, conclusions and recommendations drawn regarding the effectiveness of the applied conceptual change approach teaching strategies on Chemical Change.

6.3. Major findings of the study

In order to answer the research questions, the researcher conducted a four-part research project. The following is the main research question for the study:

How can a conceptual change approach be used as a teaching strategy to improve learners' understanding of chemical change?

Emanated from the overall objective of the study were the research sub-questions outlined below:

1. What were learners' initial understanding of chemical change?
2. How was the conceptual change approach implemented to address grade 11 learners understanding of chemical change?
3. What were learners understanding of chemical change after the conceptual change lesson?

4. What were learners' perception of the conceptual change approach?

6.3.1. What were learners' initial understanding of chemical change?

To answer this research question, learners were first given a pre-test. Data analysis from the first part uncovered a pattern of misconceptions that learners had with respect to chemical change. The most prevalent misconceptions among learners were:

1. A physical change is a change in matter that produces new substances.
2. Ability to burn is an example of a physical property.
3. Water freezing is an example of a chemical change.
4. Energy is released when bonds are broken in a chemical reaction.
5. When two solutions react, the container feels hot, thus the energy in the universe is increased.
6. A chemical change occurs when a change of state occurs.
7. A chemical reaction occurs when two or more ionic compounds are mixed.

The results showed that learners come to class not empty headed but they come with knowledge that is not scientifically acceptable. Based on the pre-test, the findings were that learners did not perform well in the pre-test. Most (22 of the 32) learners obtained 29% and below constituting 68.75% of the sample, see figure 9.

6.3.2. How was the conceptual change approach implemented to address grade 11 learners understanding of chemical change?

This research question was answered through the implementation of the intervention. The findings from the first part of the study and synthesis of the theoretical framework guided the researcher in the creation and planning of Conceptual Change instructional activities. These activities were developed according to Posner et. Al. (1982) Conceptual Change Model. These texts were used to determine the effectiveness of Conceptual Change Framework strategies. The results showed that, after the treatment, learners had better acquisition of scientific conceptions with respect to chemical change. Learners were given an opportunity to revise their prior knowledge and struggle with their preconceptions. To remedy these alternative conceptions cognitive conflict was created between alternative conceptions held by learners and scientific ones. This dissatisfaction allowed learners to accept better scientific explanations of concepts.

In the study, Conceptual Change Texts based on demonstrations highlighted the intelligibility and plausibility of the target scientific explanations and promoted Conceptual Change by challenging learners' alternative conceptions producing dissatisfaction, followed by correct explanation and demonstration which is both understandable and plausible to learners. The teacher-learner interaction that occurred during the discussion part of the lesson helped learners to share their ideas and ponder these ideas in depth. Demonstrations also made learners more enthusiastic to participate in discussions. In addition, these discussions facilitated and encouraged learners' understanding and restructuring of concepts. Because learners are participating in this type of instruction, their self-efficacy and intrinsic interest was improved. It was found that the Conceptual Change oriented instruction through demonstrations, and experiments caused a significantly better acquisition of scientific conceptions in relation to chemical reactions and energy concepts in chemical change.

There is a consistency between the findings in this study and the previous studies that Conceptual Change Approach can facilitate learning of scientific concepts (Chambers & Andre, 1997; Hewson & Hewson, 1983; Ozmen, 2007; Ceylan & Geban, 2009; Cetin et.al. 2009; Ceylan & Geban, 2010; Igwebuike, 2012; Kapartzianis, 2012; Meyer, 2014; Küçük, 2015; Kaboro et.al. 2015). In these studies, Conceptual Change Strategies were used to remedy learners' misconceptions and better acquisition of scientific conceptions.

Data obtained from observation notes confirmed the validity of the data from the tests and interviews. It showed that the Conceptual Change Framework used in the texts aroused learners interest and willingness during implementation. It further indicated that learners performed the assigned tasks voluntarily and gradually developed a sense of responsibility.

6.3.3. What were learners' understanding of chemical change after the conceptual change lesson?

This question was answered by giving learners a post-test after the intervention. In this study, it had been found that there was a statistically significant difference between learners' pre-test (26.7%) and post-test (65.1%) scores. From this evidence,

it was significant that after the implementation, learners became more successful in the instructional objectives that were taught using conceptual change texts. The results of the frequency analysis of learners' misconceptions in both pre-test and post-test showed a significant percentage drop in the number of learners having the misconceptions targeted by the conceptual change texts and to non-existent difference in the rest of the misconceptions. Results from the analysis of the post-test showed a significant increase on learners' understanding of scientific conceptions instructed using Conceptual Change Framework.

6.3.4. What were learners' perception of the conceptual change approach?

To answer this research question, learners were interviewed. During interviews, more than 85% of the learners answered correctly in the interview questions and were able to justify their responses scientifically. From the analysis of the test results as well as interviews, it seems clear that the methods used during intervention (i.e. demonstrations, concept maps, experiments and videos) in this study have had a positive impact on learners' understanding of chemical reactions.

6.4. Implications of the study.

Learners' prior knowledge plays a key role in further teaching and learning in that misconceptions are inconsistent with scientific views. Therefore, learners cannot form suitable and correct relations between concepts and as such meaningful learning cannot occur. Therefore, teachers should be aware of learners' misconceptions and their harm to learning while developing their instruction materials and planning.

The literature reviewed in chapter 2 firmly established that conceptual change texts, developed using Posner et.al. Conceptual Change Model, are an effective method for remediating learners' misconceptions about scientific concepts. It also reveals several characteristics that these conceptual change texts must have to be effective. These characteristics include: multiple modalities, explicit directions/scaffolding, multiple opportunities for reflection/analysis, social constructivism as well as research on specific misconceptions. Based on the findings of the literature review, the conceptual change texts produced by this study include all of these characteristics. The conceptual change texts include multiple modalities of learning by including discussion, text, videos, hands-on experiments, and inventive creativity. The texts

include section-by-section scaffolding through the conceptual change process with specific instructions that intentionally assist learners towards better understanding of the science concepts. Social constructivism is utilized through partner reading activities, discussions, and group experiments. Finally, all the conceptual change texts produced by this study are supported by academic research on misconceptions.

Teachers also might have the same misconceptions learners have. Therefore, they should obtain courses that can help them identify and remediate their misconceptions. This study provided evidence that Conceptual Change Framework used in the present study was effective in changing learners' misconceptions and facilitated greater conceptual understanding. Thus, curricula should be developed and implemented to ensure that all learners can have the opportunity to learn and understand concepts difficult to understand such as chemical reactions.

There is not much study about the implementation of Conceptual Change approach in chemistry education in South Africa. The findings from this study can serve as a guide to teachers, textbook writers and curriculum developers in South Africa and other countries when designing an effective chemistry instruction in the topic of chemical change. Chemistry textbooks, as a main source of knowledge in schools, might be revised and planned by considering the active participation of the learners and following the Conceptual Change approach. The teaching of chemistry should give learners the opportunity to construct the chemical change concept, as a phenomenon in which one or two substances are transformed into new substances that are completely different from the initial ones. Learners should develop scientific criteria rather than personal criteria for the identification of chemical changes. Learners should understand whether there is maintenance or change of substance's distinctiveness during a matter transformation.

Development of learners' understanding of chemical change is an important issue in chemistry education because most of the phenomena in chemistry occur at the atomic or molecular level, and they are difficult for learners to understand them due to its abstract character (Gabel, 1999; Garnett, Garnett & Hackling, 1995). In order to enhance learners' conceptual understanding of chemical change in chemistry, the teachers need to design instruction considering multiple representations

(macroscopic, symbolic and microscopic) of the chemistry concepts. This study may be a guide to Further Education and Training (FET) educators in terms of the implementation of a learner-centred approach.

Understanding of chemical change concepts at grade 11 enhances learners' understanding of chemical reactions and chemical equilibrium concepts, which are the topics of grade 12 chemistry curriculum in South Africa. Because learners' prior knowledge affects their further learning, teachers should be aware of what learners know and they should deal with these misconceptions by embedding them within the instruction based on constructivism, like Conceptual Change Approach. The more the teachers are aware of learners' misconceptions, the more they could design classroom activities that will remediate the specified misconceptions. When designing the new curriculum of chemistry courses for secondary schools, constructivism approach has to be adopted. To become more effective in nurturing conceptual change, teachers should seek to understand learners' naive conceptions so they can be addressed directly by instruction.

This study can be a guide for the chemistry teachers about the ways of provoking learners' prior learning. In this study, multiple-choice items, open-ended items, and class discussions were used in the determination of learners' previous knowledge. Teachers should take into account learners' prior knowledge and alternative conceptions, because they account for a significant proportion of learner achievement in science (Pınarbaşı et al., 2006). Teachers should receive in-service training on conceptual change strategies. In addition to this, prospective teachers in faculties of education should practise these strategies in methodology classes.

The literature review has shown that in order to prepare conceptual change texts, the primary thing to do is to reveal what learners already know besides their misconceptions. Niaz et al., (2002) have also concluded that if learners are given the opportunity to argue and discuss their ideas, their "understanding can go beyond the simple regurgitation of experimental detail". This is a very effective strategy not only for getting rid of learners' misconceptions, but also diagnosing them. These suggestions imply that teacher preparation courses and professional development opportunities for experienced teachers should include attention to both the theoretical

background of conceptual change, and instructional methods that nurture conceptual change

This study can also be a guide in assessing the learners' chemistry conceptions because it showed that multiple-choice test items, open ended test items and interviews were used for assessing learners' conception. Normally, the aim of the education is to make all learners scientifically literate, and achieve the basic science concepts and principles. Conceptual Change Approach can be implemented at schools in closing the achievement gap among the learners at high school.

Well designed Conceptual Change Texts instruction can lead a significantly better acquisition of scientific concepts. Therefore, four conditions necessary for conceptual change mentioned by Posner et al. (1982) can be used while designing Conceptual Change Texts. School managers should encourage teachers to use Conceptual Change Texts in their instructions. Curriculum designs based on constructivist approach could be used. Curriculum developers and teachers should be aware that Conceptual Change Texts could be used in large sized classrooms.

However, conceptual change is a complex process, and promoting it requires the proper environment and equipment. Thus for the effective teaching of Physical Sciences, the researcher's opinion is that the classrooms or the laboratories must be equipped with the necessary materials and computer equipment. When teaching any concept in the subject, the teacher should not only consider learners' prior knowledge of the concept in question but should also integrate what is taught in class to their everyday lives. This will enable the learners to know that science is not only what is taught in class but a part of their everyday experiences. If learners are made aware of this, their attitude towards science as a subject might improve and consequently, their performance might also improve. The inclusion of relevant provocative issues, like baking of cake, formation of yoghurt and the like that are affecting the learners' lives could also be used to arouse their interest in the chemical reactions lesson.

Demonstrations not only make learners to be aware of their misconceptions (Chi & Roscoe, 2002) but also increase their motivation and interest to learn chemical concepts. Using demonstrations in chemistry classroom make a contribution to

learners' conceptual understanding since learners have a chance to observe the chemical events regarding the subject. Demonstrations are also effective for taking learners' attention to lesson and motivating them to participate in the lesson. Therefore, teachers should use appropriate demonstrations during their chemistry instruction.

Teachers should also be aware of several sources that may cause misconceptions and that one of these sources of misconception are teachers themselves. Therefore, they should be careful in planning their lessons and their instructions in order not to let learners form any misconceptions. They should not forget that anything that was not explained enough can be a source of misconception therefore they should be very careful in their instructions. Teachers must also be aware that instruction itself can be a source of misconception. Examples and generalizations without clear explanations can also lead to misconceptions. For example, analogies can cause misconception if the points that differentiate base domain from target domain were not explained clearly. Therefore, teachers should be careful while they are using analogies.

It is difficult to distinguish and remediate misconceptions. Therefore, finding ways to remediate misconceptions is very important. Many previous studies and this study indicated that instruction based on CCA where CCTs are used, help learners in remediation of their misconceptions. Therefore, teachers should be aware of the effectiveness of CCA. A teacher who is both familiar with common misconceptions, and who is able to anticipate where and when learning is likely to distort teaching, is well equipped to avoid some of the common learning difficulties in the subject.

6.5. Limitations of the study

The study is done in one school that has only one physical science class, therefore a case study. It will not provide results on a broader scale. In the study, only grade 11 learners were participants in the study. Grade 12 learners could not take part because they are writing an external paper and therefore they could not be disturbed. Another challenge that was faced by the researcher was the learners' lack of enthusiasm and interest in their work as well as their negative attitudes towards physical sciences and education in general. As a teacher, the researcher had to

make lessons as interesting as possible. The researcher had to accommodate the learners' weaknesses without compromising the standard of the lesson

The study was limited to 34 learners doing Physical Sciences in one high school only indicating a small proportion of the population. The school where the study was performed is rural, learners seldom speak English. The study was also limited to chemical change topic in chemistry grade 11 curriculum only. Not all the topics under chemical change were done, only chemical reactions and energy changes involved in chemical reactions were performed. Multiple-choice tests were used to evaluate learners' chemistry achievement.

The school had insufficient Physical Sciences textbooks. Learners had to share textbooks which caused some learners not be able to study at home. Availability of teaching resources is vital in the implementation of any teaching approach in schools. In a situation where these are lacking or insufficient, it slows down the pace of teaching and learning processes. The researcher observed that the lack of textbooks is one of the hindrances to implementing a Conceptual Change Approach. This lack is contributory to a lot of other challenges in the teaching and learning processes.

The school does not have a science laboratory. Demonstrations and experiments were done inside the classroom which could result in danger if dangerous apparatus were used. Learners were not used to practical experiments and demonstrations because of the absence of a science laboratory. In addition, conceptual change texts require learners to both read passages and respond in written format which can be quite challenging for learners who can read below grade level or have writing challenges. To address this issue, it is advised that teachers guide learners through the individual sections of the conceptual change texts and stop to paraphrase and discuss the readings with the entire class. This practice is beneficial for all learners in the classroom as it allows for discussion and clarification. It is also suggested that conceptual change texts include pictures that help to engage learners and help to explain the reading.

Discussions that take place at specific points of the conceptual change texts are supposed to provide clarification and social constructivism but sometimes lead to learners changing their answers to adapt to that of higher achieving learners within the class for distress of being wrong (Cepni & Cil, 2010). This conquest the purpose of the conceptual change texts as they depend on honest reflection.

6.6. Recommendations for future studies

Based on the results of the study, the following is recommended:

1. In this study the researcher due to unexpected reasons did not teach the whole chemical change unit using conceptual Change Approach instruction. It would be advisable to investigate the effects of teaching the curriculum project in its entirety.
2. Similar research studies can be conducted with a larger sample size and in different high schools for the comprehensive view of the findings to a larger population. The results of this research would strengthen the validity of the findings of this study.
3. The Conceptual Change Approach can be implemented for different grades and different subjects. The sample size should be increased so that the findings can be generalised.
4. The effects of Conceptual Change Approach instruction should be investigated in different physics and chemistry topics apart from chemical change.
5. This study was a short-term study. Long-term studies of the Conceptual Change Approach could be tested at different grades and at different chemistry topics.
6. Different teaching strategies based on CCA can be employed to remediate learners' misconceptions.
7. Further research in determining unexpected misconceptions and effective techniques for changing these concepts could be done.
8. The topic chemical reactions needs additional attention from the curriculum designers, textbook authors and teachers (Hesse & Anderson, 1992). These specialists need to take into consideration the echoing issue of misconceptions that affect learners' thinking and learning about chemical reactions and related topics. Hesse & Anderson (1992) have further asserted that these misconceptions form the basis for explanations which focus analogies to everyday events. It is therefore important that they be highlighted in textbooks for the teachers to be aware of them. Teachers should integrate these misconceptions into the lessons in such a way that

the learners are able to identify them and link valid prior concepts with the newly taught scientifically correct concepts. This will enable them to build a more scientifically interconnected conceptual framework (Soudani, Sivade, Cros & Medimangh, 2000).

9. For further study, learners' interviews may be combined with conceptual change texts to determine learners' interest to the method.

10. The textbooks should be revised and designed according to the Conceptual Change approach.

6.7. Conclusion

This chapter outlined an overview of the scope of the study, summary of the results and findings discussed in chapters 4 and 5, implications of the findings and limitations pertaining to the study, conclusions drawn as well as recommendations for future studies.

This study viewed the conceptual change approach as a teaching strategy. The results indicate that in this case study learners' understanding could be improved through the four stages of conceptual change. It was certainly found that the stages involved all of the learners in the lesson and facilitated their understanding through a series of activities guided by the conceptual change framework. This process could have the necessary effect to improve the achievement of learners so needed in Physical sciences in this province and in South Africa as a whole.

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10. APPENDICES

10.1. Ethics Clearance

PERMISSION LETTERS


10.1.1. UWC

P.O. BOX 192
LADY GREY
9755
07 APRIL 2015

The Chairperson
Ethics Committee
University of the Western cape
Bellville
Cape Town
7493

Dear Sir/Madam

Re: Permission to conduct a research



I, Mrs Mantua Mavis Bidi, an MEd student at the University of the Western Cape, hereby request permission to conduct a research project at Mehlomakulu Senior Secondary School, on the investigation of how conceptual change approach can be used to improve learners understanding of chemical equilibrium at secondary schools.

The identities of the participating learners and the school will remain private while the findings of the study will be disseminated to the management of the school and the Western Cape Education Department in a hard and soft copy format. In no way will the University of the Western Cape be prejudiced or slandered.

Hoping that my application will receive your favourable consideration.

Yours Faithfully

M.M. Bidi

10.1.2. **EASTERN CAPE EDUCATION DEPARTMENT**

P.O. BOX 192

LADY GREY

9755

07 APRIL 2015

The Head of Department
Eastern Cape Education Department
Bisho

Dear Sir/Madam

Ref: Permission to carry out a research at your school

As the above matter refers, I do hereby seek your permission to carry out a research at Mehlomakhulu Senior Secondary School situated in Sterkspruit District.

I am a student at the University of Western Cape studying Masters Degree in Science Education. The research I intend to carry out is one of the crucial requirements to fulfil the degree. The study seeks to investigate how conceptual change approach can be used to improve learners understanding of chemical equilibrium at secondary schools.

I do hereby guarantee that discreet of names and confidentiality will be adhered to. In the event that you approve my application, I will also apply to the principal of the school, the School Governing Body, parents of learners concerned as well as learners concerned.

I hope that my request will receive your favourable consideration.

Yours faithfully

M.M. Bidi

MEd Student, University of the Western Cape (UWC) mahadibidi@gmail.com

10.1. 3.. **DISTRICT DIRECTOR**

P.O. BOX 192
LADY GREY
9755
07 APRIL 2015

The District Manager
Department of Education
Sterkspruit District
Sterkspruit
9762

Dear Sir

Re: Permission to conduct a research

I, Mrs Mantua Mavis Bidi, an MEd student at the University of the Western Cape, hereby request permission to conduct a research project at A. Senior Secondary School, using grade 11A physical science class, on the investigation of how conceptual change approach can be used to improve learners understanding of chemical equilibrium at secondary schools.

The identities of the participating learners and the school will remain private while the findings of the study will be disseminated to the management of the school and the Western Cape Education Department in a hard and soft copy format.

I hope that my request will receive your favourable consideration and I will receive the necessary approval to conduct my research.

Yours Faithfully

M.M. Bidi

MEd Student, University of the Western Cape (UWC) mahadibidi@gmail.com

10.1. 4.. **SCHOOL PRINCIPAL**

P.O. BOX 192
LADY GREY
9755
07 APRIL 2015

The Principal
Mehlomakulu S.S. School
Private Bag x 1009
Herschel
9762

Dear Sir

Re: Permission to conduct a research

I, Mrs Mantua Mavis Bidi, a post graduate student at the University of the Western Cape, hereby request permission to conduct a research project at Mehlomakulu Senior Secondary School, using grade 11A physical science class, on the investigation of how conceptual change approach can be used to improve learners understanding of chemical equilibrium at secondary schools.

The identities of the participating learners and the school will remain private while the findings of the study will be disseminated to the management of the school and the Western Cape Education Department in a hard and soft copy format.

I hope that my request will receive your favourable consideration and I will receive the necessary approval to conduct my research.

Yours Faithfully

M.M. Bidi

MEd Student, University of the Western Cape (UWC) mahadibidi@gmail.com

10.1.5. **SCHOOL SGB**

P.O. BOX 192
LADY GREY
9755
07 APRIL 2015

The Chairperson
School Governing Body
Mehlomakulu S.S. School
Private Bag x 1009
Herschel
9762

Dear Sir

Re: Permission to conduct a research

I, Mrs Mantua Mavis Bidi, a post graduate student at the University of the Western Cape, hereby request permission to conduct a research project at Mehlomakulu Senior Secondary School, using grade 11A physical science class, on the investigation of how conceptual change approach can be used to improve learners understanding of chemical equilibrium at secondary schools.

The identities of the participating learners and the school will remain private while the findings of the study will be disseminated to the management of the school and the Western Cape Education Department in a hard and soft copy format.

I hope that my request will receive your favourable consideration and I will receive the necessary approval to conduct my research.

Yours Faithfully

M.M. Bidi

MEd Student, University of the Western Cape (UWC) mahadibidi@gmail.com

10.1. 6.. CONSENT FORMS

Parent consent form:

UNIVERSITY OF THE WESTERN CAPE

FACULTY OF EDUCATION

Using conceptual change approach as a framework for improving learners' understanding of chemical equilibrium: A case study of a secondary school in Sterkspruit, Eastern Cape Province.

NOTE: This consent form is to be retained by the teacher and school principal and kept in a secure place. The student may be required to represent the original copy to the University of the Western Cape Ethics Committee as evidence that consent has been granted to conduct research at your school.

I, -----(Full name of parent/guardian in print) hereby, give permission for Mantua Mavis Bidi (MEd student) who is a student at the University of the Western Cape to interview my son/daughter-----. The purpose of this data to be collected by means of an interview is to be used in research study of grade 11 learners. All the information shall be treated as highly confidential and I am aware that I may refuse to have this interview.

I further understand that participation is a personal decision and entirely voluntary, that my son/daughter may refrain from answering any or all questions which s/he might feel uncomfortable, and that I may withdraw my child from the study at any time and that the content obtained through the interview and questionnaire will only be used for the purpose of this research project.

I understand that the above research project has been explained and specified and those involved intend to share the research in the form of publications and that pseudonyms will be used to protect my child's identity

I consent to my child's voluntary participation in the research by completing this form.

Signed ----- at(place) ----- on this day -----

Learner consent form:

I, -----, a learner at Mehloamakulu S.S. School in grade 11 herewith grant permission to be a participant in the research study of Mrs. M.M. Bidi, an MEd degree student at the University of the Western Cape. I am aware that my participation in this study will not influence my results at school.

Signed:

Learner -----Date: -



10.2. Research Instruments

Appendix 10.2.1. Chemical Equilibrium Concepts Achievement Test:

Grade 11

Marks: 33

1.1. Write a letter corresponding to the correct answer

1.1.1. A change in matter that produces new substances is called

- A. Chemical reaction
- B. Physical change
- C. Mixture
- D. Solution

1.1.2. Which of the following is an example of a physical property?

- A. Chemical composition
- B. Ability to burn
- B. Freezing point
- D. Ability to react with metals

1.1.3. Which of the following is an example of a chemical change?

- A. Meat spoiling
- B. Water freezing
- C. Mercury rising
- D. Butter softening

1.1.4. Chemical equations must be balanced because they describe how chemical equations obey the principle of

- A. Activation
- B. Conservation of matter
- C. Decomposition
- D. Mass coefficients.

1.1.5. What energy changes that takes place when bonds are broken?

- A. Exothermic
- B. Energy is absorbed
- C. Energy is released
- D. Endothermic

1.1.6. When two solutions react, the container “feels hot”. Thus

- A. the reaction is endothermic
- B. the reaction is exothermic
- C. the energy of the universe is increased.
- D. the energy of both the system and the surroundings is decreased.

1.1.7. A chemical reaction in which energy is absorbed in the form of heat is called

- A. Synthetic
- B. Exothermic
- C. Combustion
- D. Endothermic

1.1.8. When two or more substances combine to form a more complex substance, the process is called

- A. Decomposition Reaction
- B. Replacement Reaction
- C. Synthesis Reaction
- D. Physical Reaction

1.1.9. A chemical change occurs when this evidence is present:

- A. A solution is formed B. A change of state occurs
C. Energy is needed or released D. The reaction is reversible
- 1.10. A chemical reaction takes place when two or more:
A. molecular compound are mixed B. ionic compounds are mixed
C. substances are mixed D. substances combine to form new substances

{2 x 10 = 20}

- 2.1. In a chemical reaction..... are created or broken.
2.2. Chemical reactions that absorb heat are called
- 2.3. Water vapour changes into a liquid to form rain. This is an example of a ... change.
2.4. The force that holds atoms together is called
2.5. A chemical reaction that releases energy in the form of heat is called ...

{1x5=5}

3. For each of the following, give one word or term for the description.

- 3.1. The minimum amount of energy that is needed for a reaction to proceed.
3.2. A measure of the bond strength in a chemical bond.
3.3. A type of reaction where ΔH is less than zero.
3.4. A type of reaction that requires heat or light to proceed.

{2 x 4 = 8}

Appendix 10.2.2. Post Test

Grade 11

Marks: 48

1.1. Write a letter corresponding to the correct answer

1.1.1. A change in matter that produces new substances is called

- | | |
|----------------------|--------------------|
| B. Chemical reaction | B. Physical change |
| C. Mixture | D. Solution |

1.1.2. Which of the following is an example of a physical property?

- | | |
|-------------------------|---------------------------------|
| A. Chemical composition | B. Ability to burn |
| C. Freezing point | D. Ability to react with metals |

1.1.3. Which of the following is an example of a chemical change?

- | | |
|-------------------|---------------------|
| A. Meat spoiling | B. Water freezing |
| C. Mercury rising | D. Butter softening |

1.1.4. Chemical equations must be balanced because they describe how chemical equations obey the principle of

- | | |
|------------------|---------------------------|
| A. Activation | B. Conservation of matter |
| C. Decomposition | D. Mass coefficients. |

1.1.5. What energy changes that takes place when bonds are broken?

- | | |
|-----------------------|-----------------------|
| A. Exothermic | B. Energy is absorbed |
| C. Energy is released | D. Endothermic |

1.1.6. When two solutions react, the container "feels hot". Thus

- | | |
|---|---|
| A. the reaction is endothermic | B. the reaction is exothermic |
| C. the energy of the universe is increased. | D. the energy of both the system and the surroundings is decreased. |

1.1.7. A chemical reaction in which energy is absorbed in the form of heat is called

- | | |
|---------------|----------------|
| A. Synthetic | B. Exothermic |
| C. Combustion | D. Endothermic |

1.1.8. When two or more substances combine to form a more complex substance, the process is called

- | | |
|---------------------------|-------------------------|
| A. Decomposition Reaction | B. Replacement Reaction |
| C. Synthesis Reaction | D. Physical Reaction |

1.1.9. A chemical change occurs when this evidence is present:

- | | |
|---------------------------------|-------------------------------|
| A. A solution is formed | B. A change of state occurs |
| C. Energy is needed or released | D. The reaction is reversible |

1.10. A chemical reaction takes place when two or more:

- A. molecular compounds are mixed B. ionic compounds are mixed
C. substances are mixed D. substances combine to form new substances

{2 x 10 = 20}

2.1. In a chemical reaction are created or broken.

2.2. Chemical reactions that absorb heat are called

2.3. Water vapour changes into a liquid to form rain. This is an example of a ... change.

2.4. The force that holds atoms together is called

2.5. A chemical reaction that releases energy in the form of heat is called ...

{1x5=5}

3. For each of the following, give one word or term for the description.

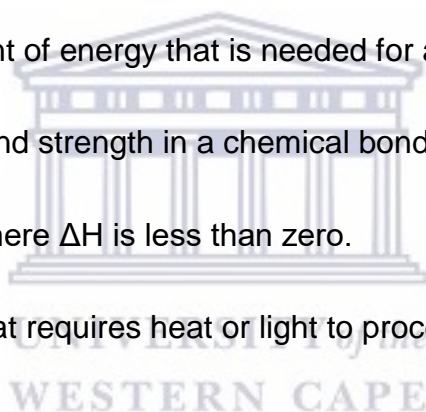
3.1. The minimum amount of energy that is needed for a reaction to proceed.

3.2. A measure of the bond strength in a chemical bond.

3.3. A type of reaction where ΔH is less than zero.

3.4. A type of reaction that requires heat or light to proceed.

{2 x 4 = 8}



Appendix 10.2.3. Lesson Plan

LESSON PLAN: PHYSICAL SCIENCE

Grade: 11

Content: Chemical Change

Context: Chemical reactions

Lesson plan 1

Teaching method and approach: Inquiry, Cooperative learning, Direct instruction, Demonstrations.

Activity1. Check Your Misconceptions: Dissatisfaction

What is a chemical change?

1. Teacher ask learners:

- What is a physical change?
- what is a chemical change?
- Differentiate between a chemical change and a physical change.

In groups: Learners use their textbooks and internet to write the definition of chemical change

Discuss with your partner the similarities and differences you found.

Activity 2: Common Mistakes corrected: Intelligibility and Plausibility

The teacher then reminded learners about physical change concept done in grade 10 and wrote the definition on the chalkboard. The teacher defined physical change as:

Physical change is a change in which a substance changes its form or appearance but keeps its same chemical composition. In a physical change no new material is formed. Physical change can be reversed although the substance might not look the same as it was before.

The teacher gave an example:

When liquid water changes to ice, liquid water is said to have undergone a physical change because ice is water in solid state and at this state the appearance is not the same as the previous appearance. Ice water can be changed to liquid again. The chemical composition of ice water is the same as the chemical composition of liquid water.

The teacher asked learners to conduct a scientific investigation by using a candle and a match to observe physical and chemical changes. Learners were requested to work in groups of six on that activity. Because there were 32 learners in a class, two of the six groups had 7 members.

Activity 1: Take a candle and use a knife to cut off a small slice of candle wax. What change has this caused to the candle? Do you think this is a physical or a chemical change?

Activity 2: Now examine a match. Light the match and blow it out. What change do you observe in the match? Do you think this is a physical or a chemical change?

Activity 3: Light another match and use it to light your candle. Watch the candle burning and carefully observe any changes that take place. Allow some of the melted wax to fall on the saucer.

What do you observe?

Which of the changes that you see taking place are physical changes and which are chemical changes?

From your observations, how would you say a chemical change is different from physical change? Discuss your ideas with the whole group.

The teacher explained to learners that a chemical reaction is a chemical change. In a chemical reaction, the substances that undergo a change are known as reactants and the new formed substances are known as products.

During a chemical reaction you will observe some of the following taking place:

- The reaction produces gas bubbles.
- There is a change in colour.
- There is a change in smell or odour.
- The reaction of two liquids results in a solid or a precipitate.
- The reaction causes a change in temperature.
- The temperature can go up (get hotter) or down (get colder).

Demonstration:

Teacher project few examples of chemical change that takes place in our daily lives and ask them to give some examples they think undergo chemical change.

Formation of Yogurt from Milk



What do you think?

Baking a Cupcake



What do you think?

Changing Colour of Falling Leaves



What do you think?

Compare your ideas about what you think a chemical change is.

Reading Tip: Preview the Vocabulary

Yogurt is formed as a result of bacterial action on milk. When certain bacteria, such as *Streptococcus thermophilus* and *Lactobacillus bulgaricus*, are added to warm milk and it is allowed to ferment, lactic acid is formed. The formation of lactic acid causes the milk to curdle. It is a chemical change because a new substance is formed, and the change from milk to yogurt is irreversible.

When you mix the different ingredients and put it in the oven, a series of chemical reactions take place. To begin with, the baking soda or sodium bicarbonate (NaHCO_3) breaks down to form sodium carbonate (Na_2CO_3) and bubbles of carbon dioxide. The carbon dioxide makes the cake fluffy and soft. In addition to this, the heat causes the protein molecules in the egg yolk to form new bonds. Baking a cake is an irreversible process because once you have the cake ready, you can't bring the ingredients back to their original form. Also, it leads to the formation of a new substance, and hence, is a chemical change.

The green colour of the leaves is due to the presence of the green pigment chlorophyll. Chlorophyll absorbs sunlight and the light energy is converted to chemical energy in the chloroplasts, by the process of photosynthesis. Chlorophyll is highly unstable, and the leaves need to synthesize the pigment continuously. In

addition to chlorophyll, there are other pigments present in the leaves, which are carotene and anthocyanins. While carotene is yellow, anthocyanins are red. The change in temperature during winter causes the trees to cut off supply of water to the leaves, by a process called *abscission*. In the absence of water, photosynthesis stops, and so does the synthesis of chlorophyll. Thus, the leaf takes the colour of the other pigments, and we see a change in colour.

Compare your ideas about what you think chemical change is to your incorrect ideas. What are some similarities and/or differences between the misconceptions and your thoughts about what a chemical change is?

Discuss with your partner the similarities and differences you found.

SECTION 3: The Correct Answer: Plausibility

Activity1:

Learners were asked to do the following activity:

Test your understanding of physical or chemical change:

1. If you put a slice of bread into a hot toaster, will you observe a physical or a chemical change? Explain your answer.
2. If you dissolve an ionic compound lead nitrate in water, is this a chemical or a physical change? Explain your answer.
3. If an iron nail is left in the rain for a few days and starts to rust, is this a chemical or a physical change? Explain your answer.

SECTION 4: A little more explanation. Fruitfulness

Learners are asked to give some examples of chemical change and physical change they might think about in their real lives and to explain how can they tell what kind of changes they are. They are asked to tell what kind of changes they are.

In addition to the ones mentioned above, the teacher then gave some other examples of chemical change involving organic compounds viz.

- Burning a log of wood

- Frying or boiling an egg
- Photosynthesis - a process in which carbon dioxide and water are changed into sugars by plants
- Rotting of fruits
- Digestion of food
- Souring of milk
- Burning of paper
- Different metabolic reactions in the cells
- Decomposition of waste in a compost pit

Lesson summary:

- Process of dissolving is a physical change when the molecules are not changed in the process. E.g. Solution of sugar water.
- Process of dissolving is a chemical change when ionic molecules are broken down into their separate ions in a solution. E.g. Solution of salt water.
- When a substance changes phase, this is a physical change because the chemical composition of the substance has not changed, even though its form has changed. The process is reversible.



Lesson Plan 2

Content: Chemical change

Context: Chemical Reactions and Energy Changes in Chemical Reactions.

Grade 11

Teaching method and approach: Inquiry, Cooperative learning, Direct instruction, Demonstrations.

Key Concepts:

- If two substances react and the temperature of the mixture decreases, the reaction is **endothermic**.
- If two substances react and the temperature of the mixture increases, the reaction is **exothermic**.
- A chemical reaction involves the breaking of bonds in the reactants and the forming of bonds in the products.

- It takes energy to break bonds.
- Energy is released when bonds are formed.
- If a reaction is endothermic, it takes more energy to break the bonds of the reactants than is released when the bonds of the products are formed.
- If a reaction is exothermic, more energy is released when the bonds of the products are formed than it takes to break the bonds of the reactants.

Check Your Misconceptions: Dissatisfaction

- What is a Chemical Reaction?
- What is an exothermic reaction?
- What is an endothermic reaction?
- What is bond energy?
- What is enthalpy of the reaction?
- Are there any changes in energy during chemical reaction?

Learners are allowed to discuss their answers to the questions.

The teacher lit a candle and tells learners that this was a chemical reaction.

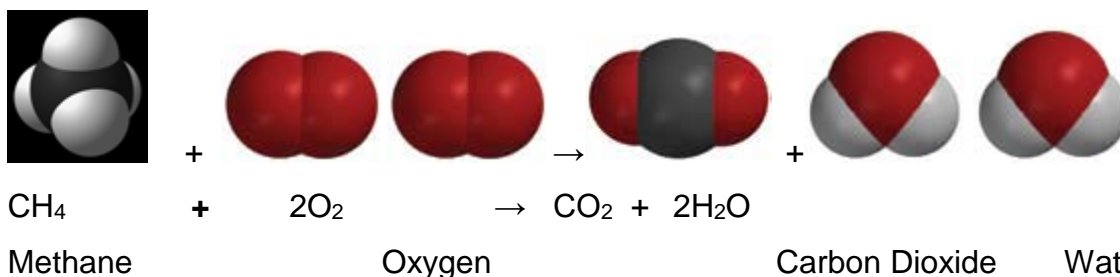


The teacher then asks learners the following questions:

- What are the *reactants* in this chemical reaction?
- What are the *products* in this chemical reaction?
- Why did the flame go out when the teacher put a jar over the candle?

- Where do the atoms come from that make the carbon dioxide and the water on the right side of the equation?

Common Mistakes corrected: Intelligibility



Candle wax combusts to form carbon dioxide and oxygen. The teacher writes the above chemical equation on the chalkboard.

Count up the number of atoms on each side of the equation below and fill in the spaces in the columns.

$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$		
Atom	Reactant side	Product side
Carbon		
Hydrogen		
Oxygen		

The teacher explains to learners what a chemical reaction is.

- A **chemical reaction** is a process that transforms one set of chemical substances to another. The substances that take part in chemical reactions are known as **reactants** and the substances produced by the reaction are known as **products**. The study of chemical reactions is part of the field of science called chemistry.
- Chemical reactions can result in molecules attaching to each other to form larger molecules, molecules breaking apart to form two or smaller molecules, or rearrangement of atoms within or across molecules.

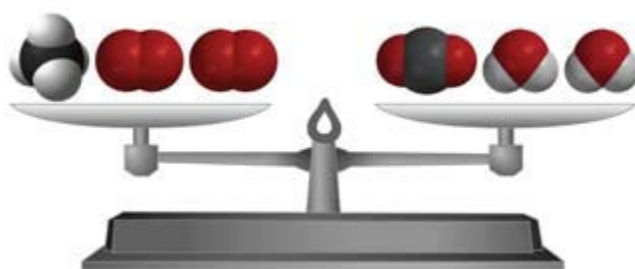
Chemical reactions usually involve the making or breaking of chemical bonds, and in some types of reaction may involve production of electrically charged end products. Reactions can occur in various environments: solids, liquids, gases, or combinations of same.

- When a chemical reaction occurs, bonds in the reactants *break*, while new bonds *form* in the product. The following example explains this. Hydrogen reacts with oxygen to form water, according to the following equation:
 - $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

In a chemical equation, like the one above, you will notice that there are regularized numbers in front of some of the molecules and small numbers after certain atoms within a molecule. The little number is called the subscript and tells how many of a certain type of atom are in a molecule. The bigger number is called the coefficient and tells how many of a particular type of molecule there are. If there is a coefficient in front of the molecule and a subscript after an atom, multiply the coefficient and the subscript to get the number of atoms. For example, in the products of the chemical reaction there are two water molecules, or $2\text{H}_2\text{O}$. The coefficient means that there are two molecules of water. The subscript means that each water molecule has two hydrogen atoms. Since each water molecule has 2 hydrogen atoms and there are two water molecules, there must be 4 (2×2) hydrogen atoms.

Are atoms created or destroyed in a chemical reaction?

How do you know?



- A chemical reaction involves the breaking of bonds in the reactants and the forming of bonds in the products.

Types of Chemical Reactions

The common kinds of classical chemical reactions include:

- **Isomerisation**, in which a chemical compound undergoes a structural rearrangement without any change in its net atomic composition.
- **Direct combination or synthesis**, in which two or more chemical elements or compounds unite to form a more complex product:
 - $\text{N}_2 + 3 \text{H}_2 \Rightarrow 2 \text{NH}_3$
- **Chemical decomposition**, in which a compound is decomposed into elements or smaller compounds:
 - $2 \text{H}_2\text{O} \Rightarrow 2 \text{H}_2 + \text{O}_2$
- **Single displacement or substitution**, characterized by an element being displaced out of a compound by a more reactive element:
 - $2 \text{Na(s)} + 2 \text{HCl(aq)} \Rightarrow 2 \text{NaCl(aq)} + \text{H}_2(\text{g})$
- **Metathesis or double displacement**, in which two compounds exchange ions or bonds to form different compounds:
 - $\text{NaCl(aq)} + \text{AgNO}_3(\text{aq}) \Rightarrow \text{NaNO}_3(\text{aq}) + \text{AgCl(s)}$
- **Acid-base reactions**, broadly characterized as reactions between an acid and a base, can have different definitions depending on the acid-base concept employed. Some of the most common are:
 - **Arrhenius** definition: Acids dissociate in water releasing H_3O^+ ions; bases dissociate in water releasing OH^- ions.
 - **Brønsted-Lowry** definition: Acids are proton (H^+) donors; bases are proton acceptors. Includes the Arrhenius definition.
 - **Lewis** definition: Acids are electron-pair acceptors; bases are electron-pair donors. Includes the Brønsted-Lowry definition.
- **Redox reactions**, in which changes in the oxidation numbers of atoms in the involved species occur. Those reactions can often be interpreted as transfers of electrons between different molecular sites or species. An example of a redox reaction is:
 - $2 \text{S}_2\text{O}_3^{2-}(\text{aq}) + \text{I}_2(\text{aq}) \Rightarrow \text{S}_4\text{O}_6^{2-}(\text{aq}) + 2 \text{I}^-(\text{aq})$
 - In which iodine (I_2) is reduced to the iodine anion (I^-) and the thiosulfate anion ($\text{S}_2\text{O}_3^{2-}$) is oxidized to the tetrathionate anion ($\text{S}_4\text{O}_6^{2-}$).
- **Combustion**, a kind of redox reaction in which any combustible substance combines with an oxidizing element, usually oxygen, to generate heat and form oxidized products as exemplified in the combustion of methane:

- $\text{CH}_4 + 2 \text{O}_2 \Rightarrow \text{CO}_2 + 2 \text{H}_2\text{O}$
- **Disproportionate** with one reactant forming two distinct products varying in oxidation state as per this example:
- $2 \text{Sn}^{2+} \Rightarrow \text{Sn} + \text{Sn}^{4+}$
- **Organic reactions** encompass a very wide assortment of reactions involving organic compounds which are chemical compounds having carbon as the main element in their molecular structure. The reactions in which an organic compound may take part are largely defined by its functional groups.

We will start by looking at **EXOTHERMIC REACTIONS**. We will use:



Project a diagram showing energy changes that take place during an exothermic reaction.

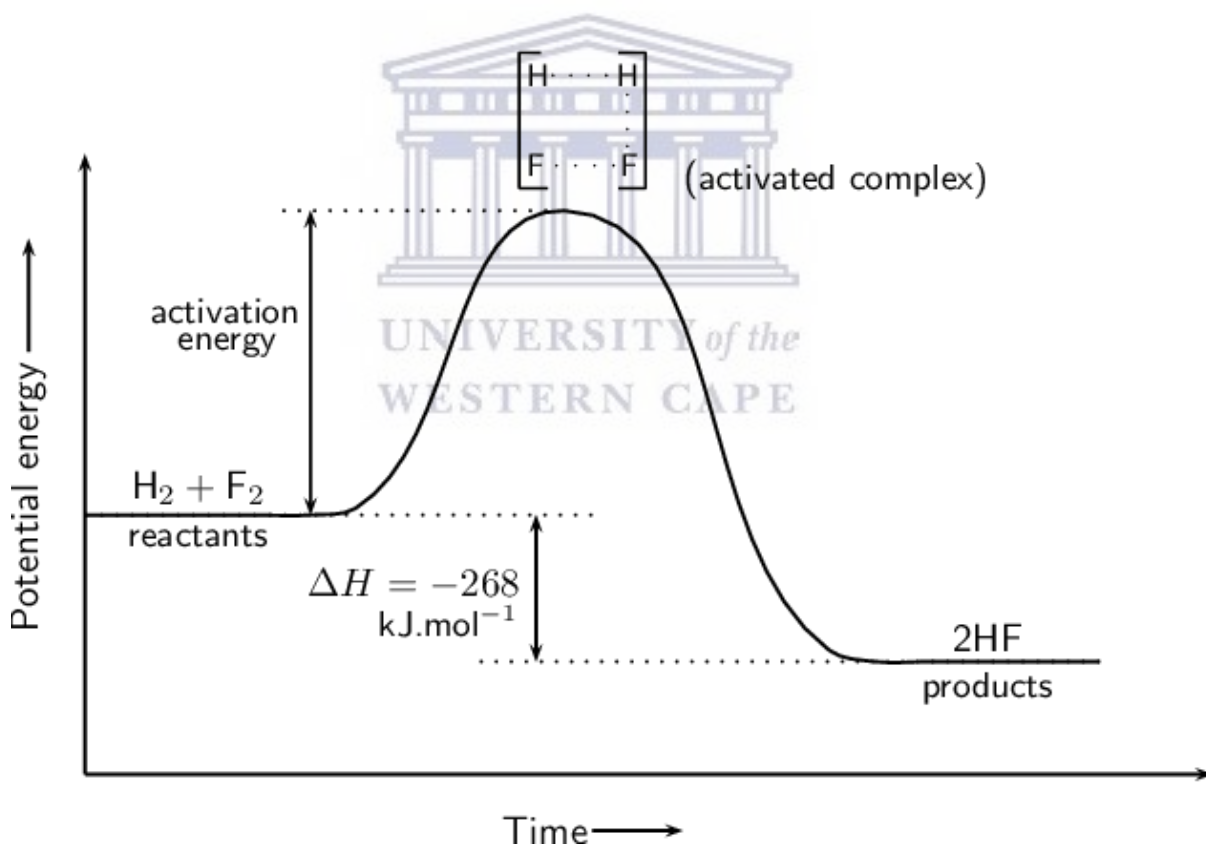
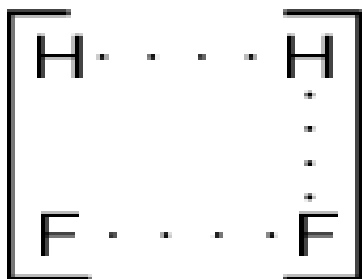


Figure 1: The energy changes that take place during an exothermic reaction

The reaction between $\text{H}_2(\text{g})$ and $\text{F}_2(\text{g})$ (Figure 1) needs energy in order to proceed, and this is the activation energy. To form the product, the bond between H and H in

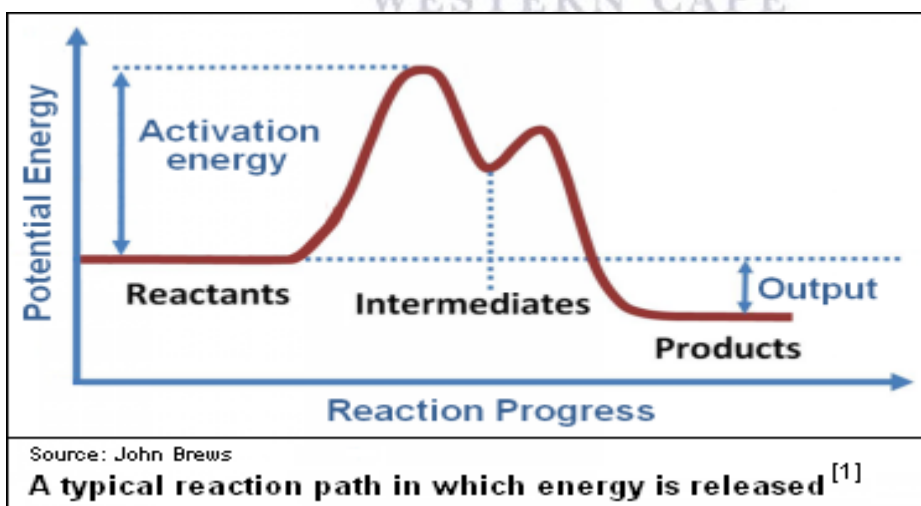
H₂ must break. The bond between F and F in F₂ must also break. A new bond between H and F must also form to make HF. The reactant bonds break at the same time that the product bonds form.

We can show this as:



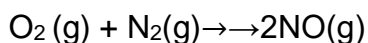
This is called the **activated complex** or **transition state**. The activated complex lasts for only a very short time. After this short time one of two things will happen: the original bonds will reform, or the bonds are broken and a new product forms. In this example, the final product is HF and it has a lower energy than the reactants. The reaction is **exothermic and ΔH is negative**.

The activated complex is the complex that exists as the bonds in the products are forming and the bonds in the reactants are breaking. This complex exists for a very short period of time and is found when the energy of the system is at its maximum.



Let us look at an endothermic reaction

In endothermic reactions, the final products have a higher energy than the reactants. An energy diagram is shown below(Figure 2) for the endothermic reaction:



Notice that the activation energy for the endothermic reaction is much greater than that of the exothermic reaction.

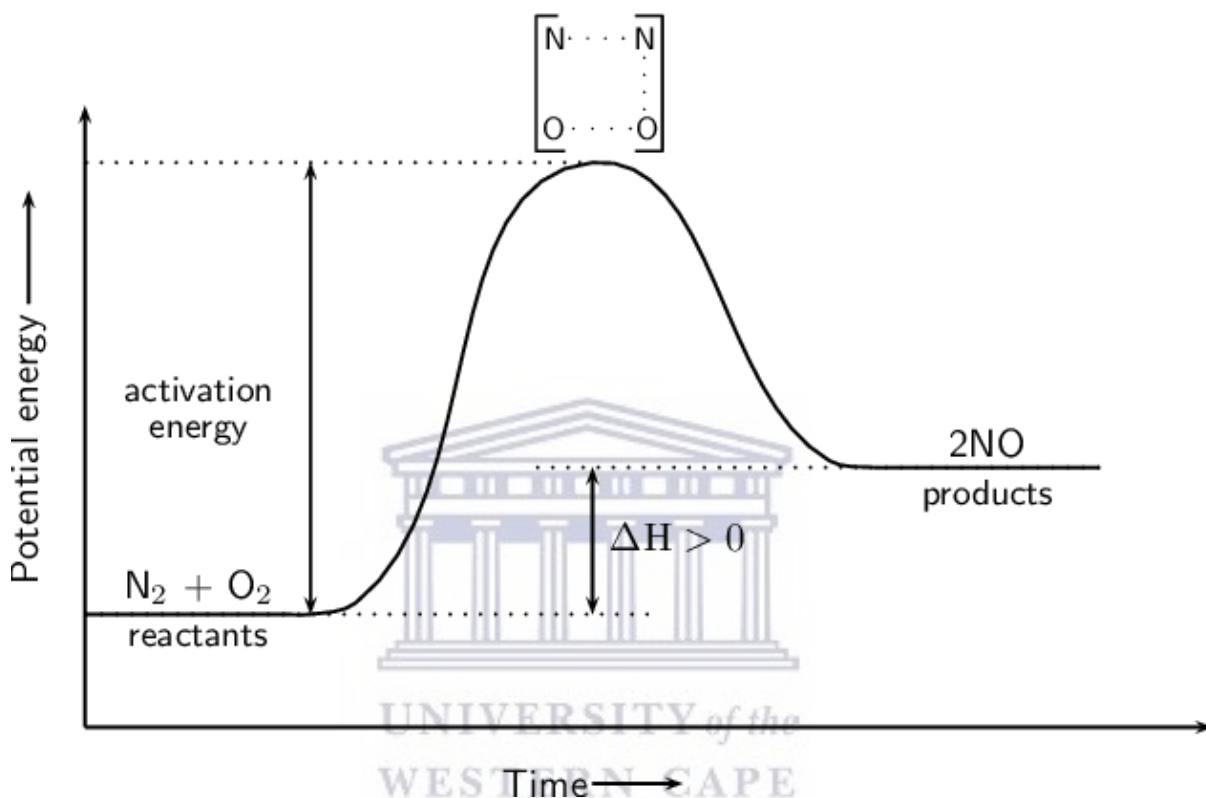


Figure 2: The energy changes that take place during an endothermic reaction.

It is because of this activation energy that we first need to show an increase in energy from the reactant to the activated complex and then a decrease in energy from the activated complex to the product. We show this on the energy graphs by drawing a curve from the energy of the reactants to the energy of the products.

Let us look at the heat of the reaction

The heat of the reaction is represented by the symbol ΔH , where

$$\Delta H = E_{\text{products}} - E_{\text{Reactants}}$$

SECTION 3: The Correct Answer: Plausibility

Build your background knowledge on chemical change before the reading by watching the following video. The teacher projects a video showing what an exothermic reaction and endothermic reaction is.

To consolidate learning, learners do the following formal experiment:

Formal experiment 1: Endothermic and exothermic reactions

In this investigation, students classify chemical reactions as exothermic or endothermic. Next, students explore the relationship between an observed change in temperature and the classification of a change as chemical or physical.

Objective

Students will explore energy changes during chemical reactions, heat of reaction (ΔH), and the connection between energy changes and chemical changes.

Safety

- The teacher and learners wear properly fitting goggles.
- Acetic acid (vinegar) vapors can be irritating. The investigation was done in a well-ventilated area. In the event of eye contact, the teacher was aware that they must flush with water. The concentration of acetic acid in this experiment does not present any significant hazards.
- Calcium chloride can be an irritant to body tissues. In the event of contact, affected areas shall be washed with water. Calcium chloride solutions shall be disposed according to local regulations.

Materials for Each Group

- Vinegar
- Baking soda
- Calcium chloride
- Water
- Thermometer
- 4 small clear plastic cups

- 1 cup measuring cup
- Measuring spoons (1 tablespoon, ½ teaspoon)

Time Required

One class period, approximately 45–50 minutes.

Lab Tips

After learners explore one example of an endothermic change and one example of an exothermic change, they are then asked to explore the connection between energy changes and chemical reactions. To do this, learners may need some guidance to arrive at the idea that temperature changes may also accompany dissolving.

Learners will have an easier time devising a fair test if they are well versed in the definitions of physical changes and chemical changes. Learners should propose an experiment to the teacher before they test their hypothesis. To observe a temperature change during a physical change, learners should devise the following procedure:

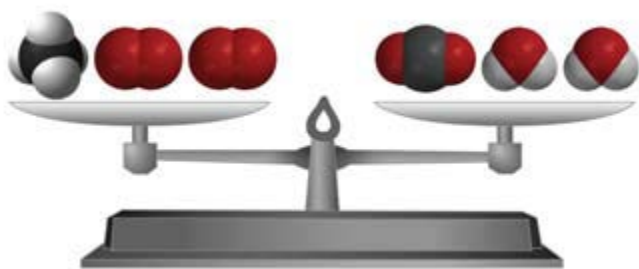
- Add 10 ml of water to a small plastic cup and place a thermometer in the water. Record the initial temperature (T_i).
- Add ½ teaspoon of calcium chloride to the water and swirl the cup. After it has stopped changing, record the final temperature (T_f).

Pre-Lab Discussion

This investigation introduces the concepts of enthalpy (heat) change or ΔH in the context of exothermic and endothermic reactions. To give learners a deeper grounding in the basics and reinforce basic concepts covered previously, the teacher reviews the mechanics of chemical changes, how to write balanced chemical equations, and the law of conservation of energy.

Are atoms created or destroyed in a chemical reaction?

How do you know?



Incorporating into the Curriculum

This investigation is incorporated into a unit on chemical changes or thermochemistry.

Student Investigation

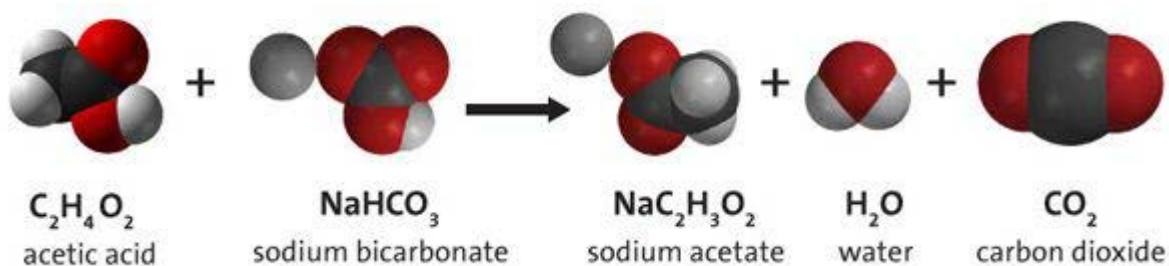
Preparing to Investigate

Energy Changes in Chemical Reactions

In this activity, learners will explore the energy changes that accompany chemical reactions. To understand the energy implications of chemical reactions, it is important to keep in mind two key ideas:

1. It takes energy to break bonds.
2. Energy is released when bonds are formed.

To understand this, consider the chemical reaction between vinegar (also known as acetic acid to chemists) and baking soda (known as sodium bicarbonate). Before the atoms of acetic acid and sodium bicarbonate can be rearranged to form the products, the bonds between the atoms in those molecules must be broken, and because the atoms are attracted to one another, it takes energy to pull them apart.



Then, when the products are formed (sodium acetate, water, and carbon dioxide) energy is released because atoms that have an attraction for one another are brought back together. Not every bond between atoms in the reactants is necessarily broken during a chemical reaction, but some bonds are.

By comparing the energy used when bonds in the reactants are broken with the energy released when bonds in the products are formed, you can determine whether a chemical reaction releases energy or absorbs energy.

Chemical reactions that release energy are called exothermic. In exothermic reactions, more energy is released when the bonds are formed in the products than is used to break the bonds in the reactants. Chemical reactions that absorb (or use) energy are called endothermic. In endothermic reactions, more energy is absorbed when the bonds in the reactants are broken than is released when new bonds are formed in the products. If a chemical reaction absorbs as much energy as it releases, it is called **isothermic**—there is no net energy change.

But because we can't observe bonds breaking or being formed, how can we distinguish between exothermic and endothermic chemical reactions?

Identifying Exothermic and Endothermic Reactions

There are two methods for distinguishing between exothermic and endothermic reactions.

Monitor temperature change

When energy is released in an exothermic reaction, the temperature of the reaction mixture increases. When energy is absorbed in an endothermic reaction, the temperature decreases. You can monitor changes in temperature by placing a thermometer in the reaction mixture.

Calculate the enthalpy of reaction (ΔH)

To classify the net energy output or input of chemical reactions, you can calculate something called the enthalpy change (ΔH) or heat of reaction, which compares the energy of the reactants with the energy of the products.

Enthalpy is a measure of internal energy. So, when you calculate the difference between the enthalpy of the products and the enthalpy of the reactants, you find the enthalpy change (ΔH), which can be represented mathematically as:

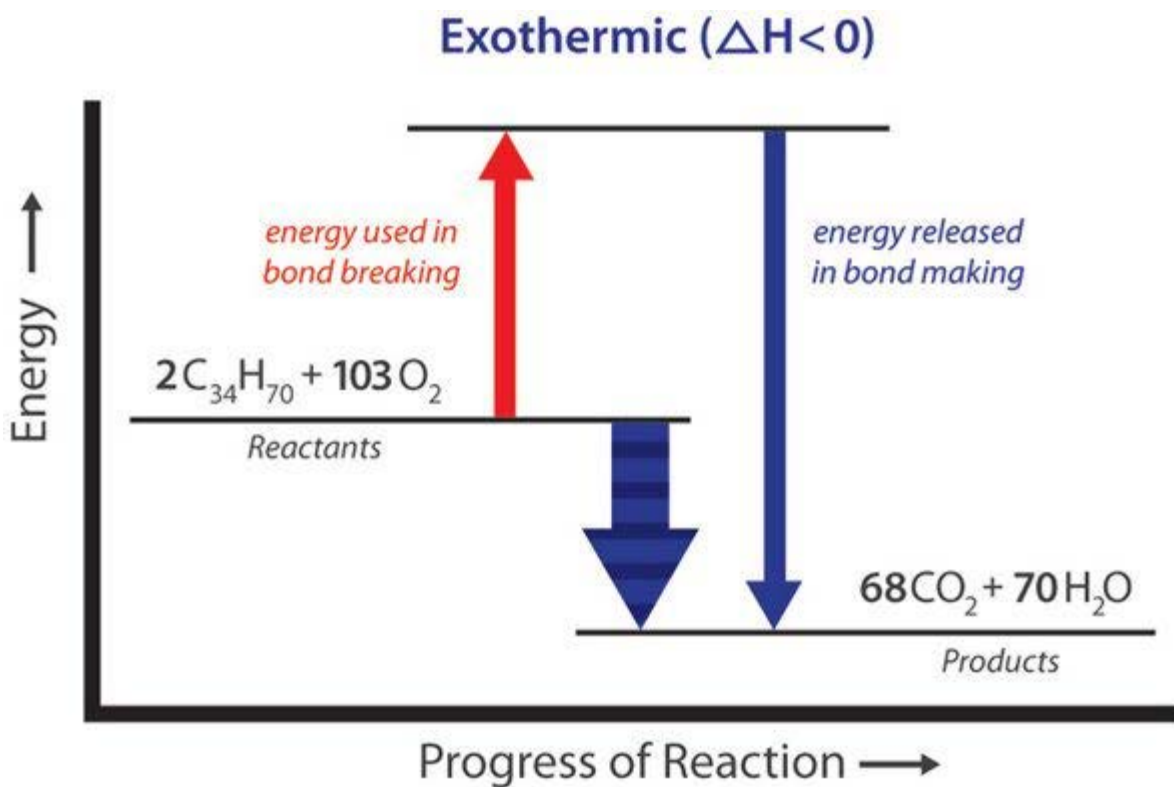
$$\Delta H = \text{energy used in reactant bond breaking} + \text{energy released in product bond making}$$

Wait, how can you find a difference by adding? The enthalpy values are added in the equation above because, by definition, energy used in reactant bond breaking is always positive (+) and energy released in product bond making is always negative (-).

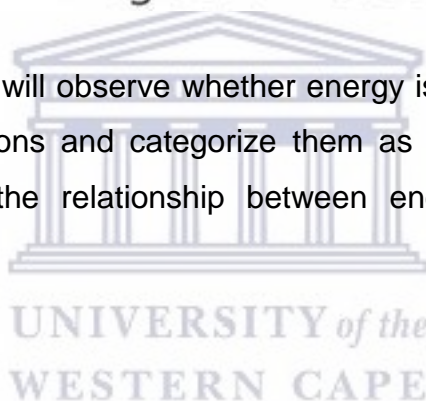
If ΔH is negative (-) then the chemical reaction is exothermic, because more energy is released when the products are formed than energy is used to break up the reactants. If ΔH is positive (+) then the chemical reaction is endothermic, because less energy is released when the products are formed than the energy is used to break up the reactants.

You can also use energy level diagrams to visualize the energy change during a chemical reaction as a result of the energies used and released according to the above equation for ΔH . To understand these diagrams, compare the energy level of the reactants on the left-hand side with that of the products on the right-hand side.

The graph below shows the energy change when a candle burns. The wax ($C_{34}H_{70}$) combusts in the presence of oxygen (O_2) to yield carbon dioxide (CO_2) and water (H_2O). Because more energy is released when the products are formed than is used to break up the reactants, this reaction is exothermic, and ΔH for the reaction is negative.

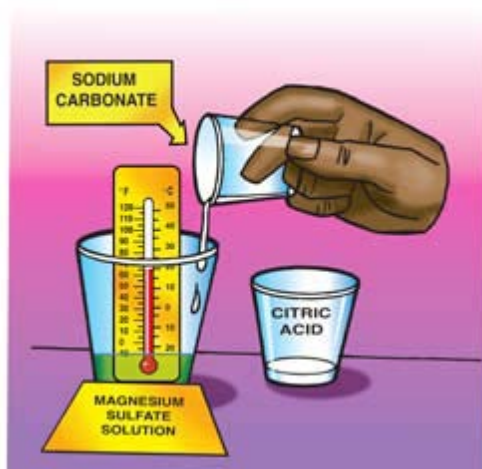


In this investigation, you will observe whether energy is absorbed or released in two different chemical reactions and categorize them as exothermic and endothermic. You will also explore the relationship between energy changes and chemical reactions.



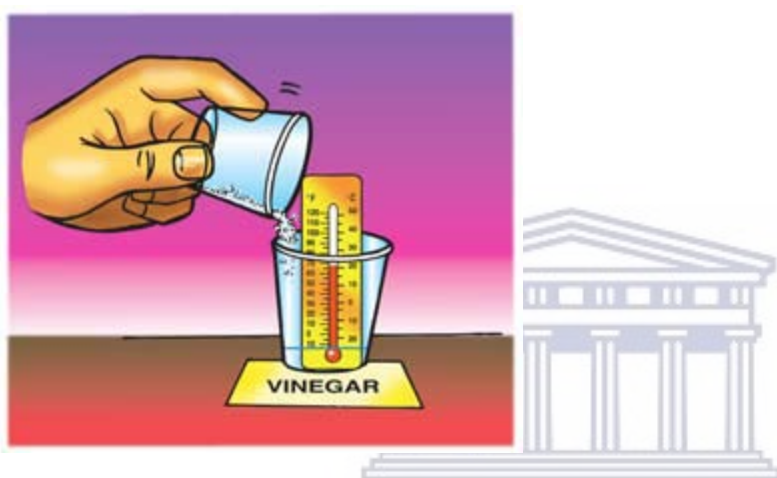
Gathering Evidence

Baking Soda and Vinegar



1. Pour about 10 ml of vinegar into a small plastic cup. Then, place a thermometer into the vinegar. Record the initial temperature (T_i) in the table below.
2. While the thermometer is in the cup, add about $\frac{1}{2}$ teaspoon of baking soda to the cup.
3. Watch the thermometer for any change in temperature. After it has stopped changing, record the final temperature (T_f) and any other observations you made in the table below.

Baking Soda and Calcium Chloride



1. Make a baking soda solution by dissolving about 2 tablespoons of baking soda in 1 cup of water. Stir until no more baking soda will dissolve.
2. Place about 10 ml of baking soda solution in a small plastic cup. Then, place a thermometer into the baking soda solution. Record the initial temperature (T_i) in the table below.
3. While the thermometer is in the cup, add $\frac{1}{2}$ teaspoon of calcium chloride to the cup. Watch the thermometer for any change in temperature. After it has stopped changing, record the final temperature (T_f) and any other observations you made in the table below.

PROCESS	T _{initial}	T _{final}	Exothermic or Endothermic	Other Observations	ΔH (+/-)
Baking Soda + vinegar					
Baking soda solution + calcium chloride					

Analyzing Evidence

1. Calculate the temperature change for both chemical reactions. To do this, subtract the initial temperature (T_i) from the final temperature (T_f), and record the difference in the column labeled ΔT . You may see this calculation expressed elsewhere as $\Delta T = T_f - T_i$.
2. Based on your observations of the baking soda and vinegar reaction, is the reaction exothermic or endothermic? Apply your knowledge of energy changes in chemical reactions to complete the table above.
3. Based on your observations of the baking soda solution and calcium chloride reaction, is this chemical reaction exothermic or endothermic? Apply your knowledge of energy changes in chemical reactions to complete the table above.



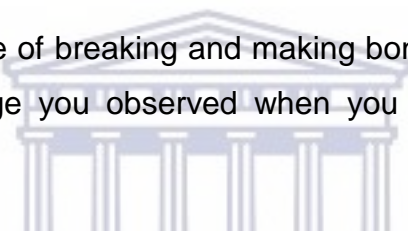
Interpreting Evidence

1. In the chemical reaction between baking soda and vinegar, what did you observe other than a temperature change? What might this tell you about one of the products of this chemical change?
2. In the chemical reaction between baking soda solution and calcium chloride, what did you observe other than a temperature change? What might this tell you about one of the products of this chemical change?
3. Use your answers from questions 1 and 2 to help you write the chemical equation for:
 1. the chemical reaction between baking soda and vinegar
 2. the chemical reaction between baking soda and calcium chloride

4. Using the language of breaking and making bonds, explain the net energy change for the chemical reaction between baking soda and calcium chloride.
5. Draw energy profiles for both chemical reactions. Refer to the exothermic energy profile shown previously as an example. Are they the same or different?
6. What is the sign of the heat of reaction (ΔH) for an exothermic reaction? Why?

Reflecting on the Investigation

1. Based on your investigation so far, do you think that energy changes only accompany chemical reactions? Using only the materials from the first two reactions, design an experiment that would test this idea. Propose a procedure and have it approved by your teacher before you continue experimenting.
2. Is dissolving calcium chloride in water a chemical change? Explain your reasoning.
3. Using the language of breaking and making bonds, how can you describe the temperature change you observed when you dissolved calcium chloride in water?



SECTION 4: A little more explanation. Fruitfulness

The teacher gives learners the following activity. Learners are expected to complete the activity in groups and report their findings:

How might you use exothermic or endothermic processes to solve a real-world problem? Are there any instances when it would be useful to quickly make something hot or cold? Explain how it is useful to know which processes absorb or release energy.

Learners were asked to give some examples of exothermic and endothermic reactions that occur in our everyday lives.

The teacher then gave learners the following examples in addition to what they know:

ENDOTHERMIC REACTIONS

- Photosynthesis

Is a chemical reaction that takes place in green plants, which uses energy from the sun to change carbon dioxide and water into food that the plants need to survive and which other organisms can eat so that they too can survive. The equation for this reaction is:



This is an endothermic reaction. Energy in the form of sunlight is absorbed during this chemical reaction.

- Thermal decomposition of lime stone

In industry, the breakdown of limestone into quicklime and carbon dioxide is very important. Quicklime can be used to make steel from iron and to neutralize soil that is too acidic. Limestone must be heated before decomposition reaction can take place. The equation for the reaction is:



EXOTHERMIC REACTIONS

- Cellular respiration

In this reaction, oxygen reacts with glucose to give water, carbon dioxide and energy. It happens inside the cells of living organisms. The reaction is:



The reaction in car airbags is exothermic. This reaction generates high temperatures and causes the formation of a gas that expands rapidly. This inflates airbags.

- Fuels

Methanol and ethanol are used as an alternative fuel in vehicles. Their combustion results in carbon dioxide, water and heat energy and therefore exothermic. The reactions are:

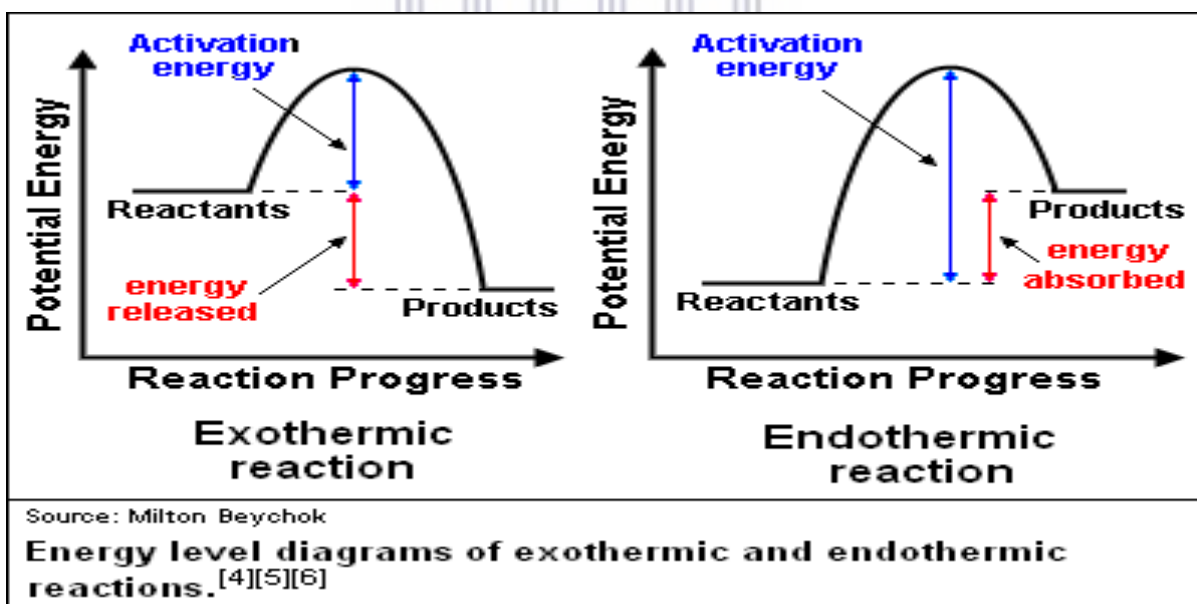
Methanol combustion: $\text{CH}_3\text{OH} + \text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + \text{heat energy}$

Ethanol combustion: $\text{CH}_3\text{CHOH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O} + \text{heat energy}$.

- Hot and cold packs

Often used by athletes to treat minor injuries such as inflammation and sprains. A hot and cold pack has two separate compartments. One contains water and the other one contains salt. When the seal between the compartments is broken and the packs are shaken vigorously, the salt dissolves in the water. Depending on the salt, the reaction can either be exothermic or endothermic.

Summary of the lesson



In terms of the energy changes that take place during chemical reactions, a reaction may be either **exothermic** or **endothermic**, terms which were first coined by the French chemist Marcellin Berthelot (1827 – 1907).

The meaning of those terms and the difference between them are discussed below and illustrated in the adjacent diagram of the energy profiles for exothermic and endothermic reactions.

Exothermic reactions

Exothermic chemical reactions release energy. The released energy may be in the form of heat, light, electricity, sound or shock waves ... either singly or in combinations.

A few examples of exothermic reactions are:

- Mixing of acids and alkalis (releases heat)
- Combustion of fuels (releases heat and light)

Endothermic reactions

Endothermic chemical reactions absorb energy. The energy absorbed may be in various forms just as is the case with exothermic reactions.

A few examples of endothermic reactions are:

- Dissolving ammonium nitrate (NH_4NO_3) in water (absorbs heat and cools the surroundings)
- Electrolysis of water to form hydrogen and oxygen gases (absorbs electricity)
- Photosynthesis of chlorophyll plus water plus sunlight to form carbohydrates and oxygen (absorbs light)

Equation for the reaction is:



- The thermal decomposition of limestone. In industry, the breakdown of limestone and carbon dioxide is very important. Quicklime can be used to make steel from iron and also to neutralise soils that are too acidic.

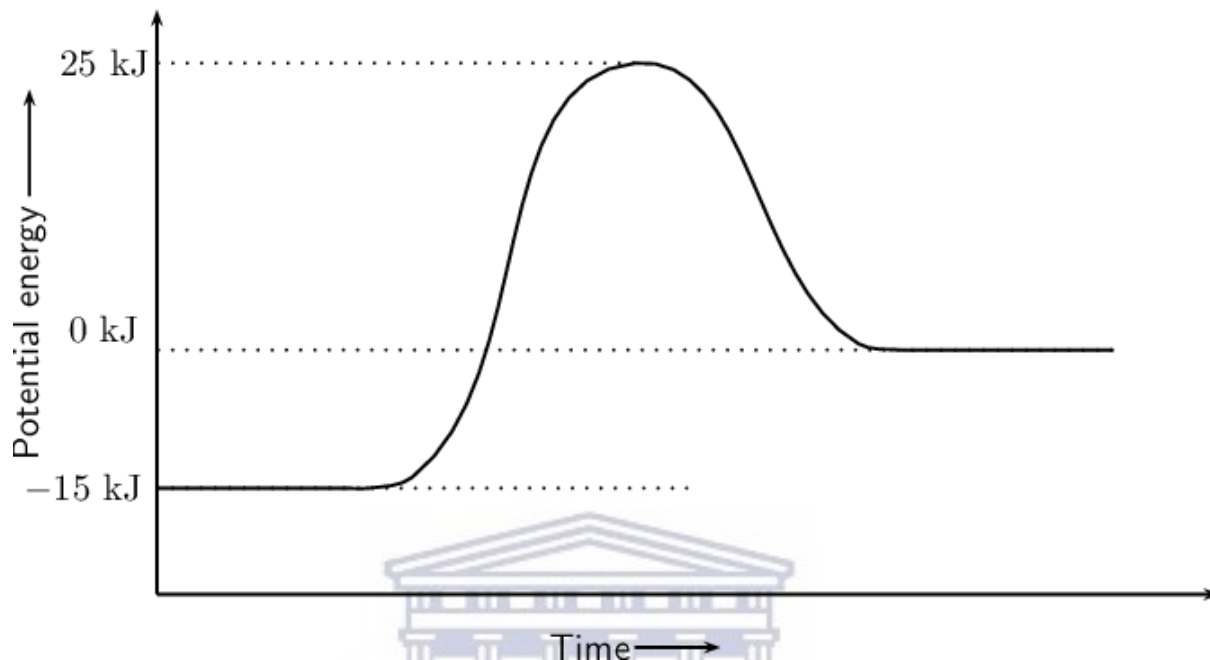
The equation for the reaction is:



Test your understanding of exothermic and endothermic reactions:

Individual activity:

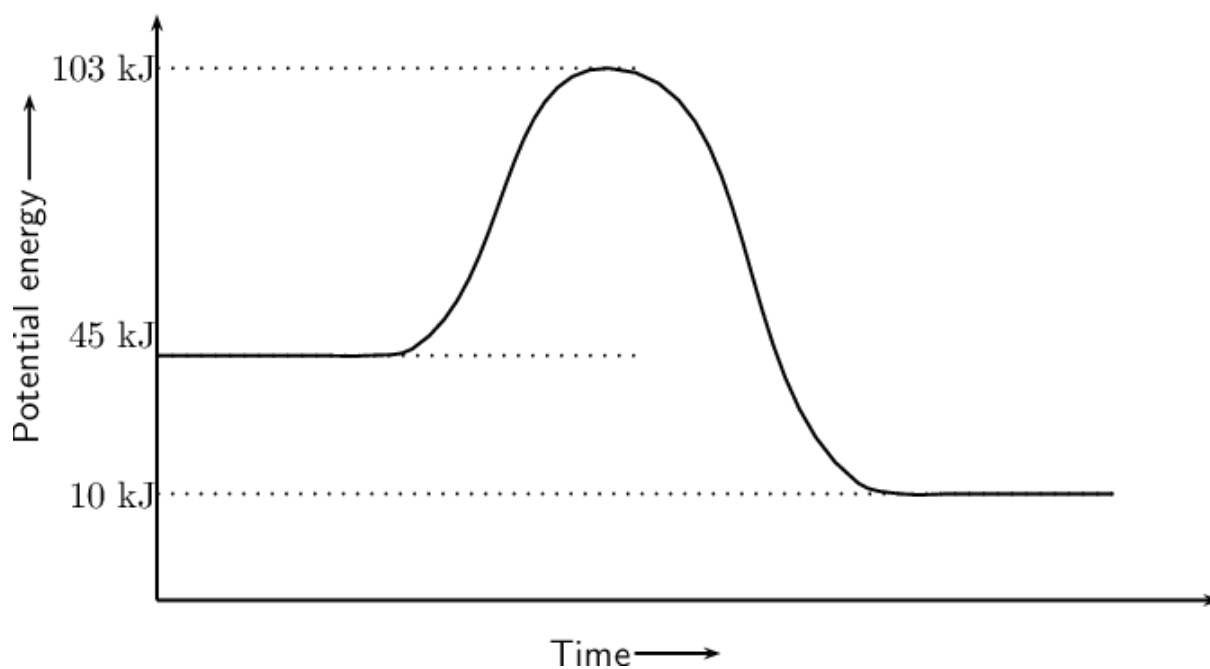
1. Refer to the graph below and then answer the questions that follow:



- a. What is the energy of the reactants? /1/
- b. What is the energy of the products? /1/
- c. Calculate ΔH . /3/
- d. What is the activation energy for this reaction? /2/

[7]

2. Refer to the graph below and then answer the questions that follow:



- a. Calculate ΔH . /2/
- b. Is the reaction endothermic or exothermic and why? /3/
- c. Calculate the activation energy for this reaction. /3/

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Appendix10.2.4: Interview schedule

Date: -----

1. Do you feel that physical science is a difficult subject? Why?
2. What is your advice to other learners with regard to taking physical science as a subject at school?
3. What do you know about the amount of energy required to break the bonds of the reactants compared to the amount of energy released when the products are formed in an exothermic reaction?
4. Did you perform the same in your pre-test and a post-test?
5. What do you think made you perform the way you did?
6. You observed the experiments and demonstrations. What clues are there that you observed that a chemical reaction is taking place?
7. What benefits does learning chemical reactions have in our everyday life?
8. Do you now feel that you understand the concept of chemical reactions? If yes, explain how it has improved.
9. What is your comment on the experience you gained when the lesson was presented in class?
10. Can you give a difference between a chemical change and a physical change?
11. What makes you change from the way you understood chemical reactions and chemical changes before you were taught to your present understanding?
11. What would a reaction that gets cooler be known as?
12. What makes you change from the way you understood chemical reactions and chemical changes before you were taught to your present understanding?
13. What is a difference between an exothermic reaction and an endothermic reaction?
14. In a physical change, like changing state from a solid to a liquid, the substance doesn't really change. How is a chemical change different from a physical change?

Appendix 10.2.5: Observation schedule

LEARNER Participation in science lesson

Dimension	Indicator	Occurrence/tally	Comment
1. Dissatisfaction	1.1. Learners discussed questions presented individually. 1.2. Learners formed groups to discuss questions by using their prior knowledge about chemical change. 1.3. Learners formed groups to discuss questions by using their prior knowledge about chemical reactions. 1.4. The teacher did not interfere with learners. 1.5. Each group presented their explanations of conflicting situations.		
2. Intelligibility.	2.1. The teacher helped learners to realise that some of the misconceptions they hold are not with agreement with that of scientific explanations. 2.2. The teacher adequately discussed why learners' misconceptions are wrong.		
3. Plausibility	3.1. The teacher explained analogies presented in CCTs effectively. 3.2. Learners participated actively during practical		

	activities.		
4. Fruitfulness	<p>4.1. Teacher and learners gave proper daily life example.</p> <p>4.2. Learners were able to solve problems related to real life situations.</p>		



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