

**APPLICATION OF A CONCEPTUAL CHANGE
APPROACH TO TEACH THE QUANTITATIVE ASPECTS
OF CHEMICAL CHANGE**

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Declaration

I, Zanele Ginyigazi, declare that the work **APPLICATION OF A CONCEPTUAL CHANGE APPROACH TO TEACH THE QUANTITATIVE ASPECTS OF CHEMICAL CHANGE** is my own original work and has not been submitted to any other university for a degree. All sources have been fully acknowledged in the text and a list of references have been provided.

Zanele Ginyigazi

Date



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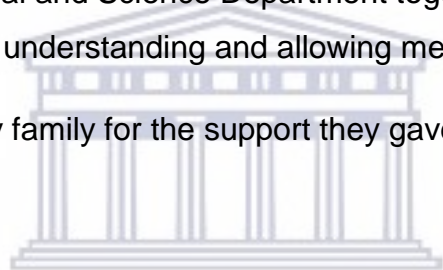
In presenting this thesis, I thank God for granting me the opportunity to be one of the students in the Masters' class, and for giving me strength and wisdom throughout this research.

I also like to express my heartfelt gratitude to my supervisor, Professor Hartley and his team. It has been his words of encouragement, effort and patience that have been the key ingredients to produce this piece of work.

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Finally, I am grateful to my family for the support they gave to me during this study. It is highly appreciated.



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Dedication

This work that came through sweat, sleepless nights, 24 hour shifts, perseverance and simply God's grace I dedicate to the following:

My Spiritual family. My God-given family, always seeing me through in the unlikeliest of times. They have always made sure that in time of need and desperation I do not stand in desolation and feeling helpless. They have shown me what mercy, grace and Love truly mean.

To my children: Bongekile, Zanozuko, Makabongwe and Siseko. I was always absent; I know you needed me during the time I was busy with this piece of work. I am indescribably grateful for your tolerance to the end.

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Zanozuko, my first son. Practical and creative, my future engineer. Always trying your best to be the best you can be. I love you.

Makabongwe, my carefree, happy, hospitable and friendly busy-boy. You are always on a mission to make someone laugh and share in your joy. You are very much loved by your mom.

Siseko, my last and loved son. You always make sure that you make your way to my side. My baby, strong, wonderfully mature for your age and full of love.

ABSTRACT

The purpose of this study was to investigate the use of a conceptual change approach to improve learners' understanding of the quantitative aspects of chemical change. The poor performance in physical science in the National Senior Certificate examination in the Eastern Cape was the catalyst for the study. This study is underpinned by the theories of constructivism and conceptual change. A purposive sample of a Grade 11 physical science class of 50 learners was selected. Twelve learners from the class were selected to be interviewed. A case study and mixed approach with qualitative and quantitative instruments were used in the data collection process. A pre-test was used as a baseline evaluation of the misconceptions. Intervention in the form of a lesson presentation was administered to address the four stages of the conceptual change approach. A post-test was given immediately after the lesson presentation to evaluate whether conceptual change had occurred.

Analysis of the pre-test and post-test results showed an improvement on learners' scientific understanding of the concept quantitative aspect of chemical change. This study provided evidence that a Conceptual Change Framework was effective in changing learners' misconceptions and facilitated greater conceptual understanding. Thus, syllabi should be developed and implemented to ensure that all learners have the opportunity to learn and understand difficult concepts using the conceptual change framework. This key recommendation promotes the use of a well-designed Conceptual Change instructional approach that leads to significantly better acquisition of scientific concepts.

Key Words: Chemistry, mole, stoichiometry, chemical change, conceptual change

Contents

CHAPTER 1	10
Rationale of the study	10
1.1 Introduction	10
1.2 Background	10
1.3 State of science education in South Africa	13
1.4 Interventions in science education in the Eastern Cape Province	15
1.5 Context of the study	16
1.6 Research Problem	17
1.6.1 Research questions	18
1.7 Significance of the study	18
1.8 Limitations of the study	18
1.9 Structure of the thesis	19
1.10 Conclusion	19
CHAPTER 2	21
LITERATURE REVIEW	21
2.1 Introduction	21
2.2 Theoretical Framework	21
2.2.1 Constructivism	21
2.2.2 The conceptual change theory	26
2.2.3 Teaching for Conceptual Change	30
2.2.4 Teaching of quantitative aspects of chemical change	36
2.2.5 Review of research on teaching strategies in international and national science education	38
2.3 Conclusion	45

CHAPTER 3	46
METHODOLOGY	46
3.1 Introduction	46
3.2. Research design	46
3.3 Case study	48
3.4 Sampling	49
3.6. RESEARCH INSTRUMENTS.....	55
3.6.1. Pilot Study	55
3.6.2. Chemistry Achievement Test (CAT)	56
3.6.3. The development of CAT	56
3.6.4 Interviews	57
3.5.1 Advantages and disadvantages of interviews and focus group interviews	58
3.6. Data Analysis.....	59
3.7 Validity and Reliability	59
3.8 Research ethics.	60
3.9 Conclusion	60
CHAPTER FOUR	62
RESULTS AND DISCUSSION.....	62
4.1. INTRODUCTION	62
4.2. Learners' initial understanding of the quantitative aspects of chemical change.....	62
4.3. Conceptual Change Approach	64
4.3.1. Dissatisfaction.....	65
4.3.2 Intelligibility	70
4.5 Comparing pre-test and post-test results.....	83
4.7 Learners' perceptions of the conceptual change approach	89
CHAPTER 5	92

CONCLUSION AND RECOMMENDATIONS	92
5.1. Introduction	92
5.2. Overview of the scope of the study	92
5.3. Major findings of the study	93
5.3.1. What are learners' initial understanding of quantitative aspects of chemical change?	94
5.3.2. To what extent can conceptual change approach as a teaching strategy improve learners' understanding of the quantitative aspects of chemical change?	95
5.3.3. What were learners' understanding of chemical change after the conceptual change lesson?.....	96
5.3.4. What were learners' perception of the conceptual change approach?	96
5.4. Implications of the study.....	96
5.5. Limitations of the study	101
5.6. Recommendations for future studies.....	101
A. 8	127
References.....	114
Appendices.....	125

TABLES

Table 1	Overall performance for physical sciences (2011-2014) nationally	12
Table 2	National, provincial and district results for three consecutive years (2013-2016)	13

Table 3	Sample sizes	48
Table 4	Research data collection plan	49
Table 5	Pre-test scores in the form of percentages	62
Table 6	Relative atomic mass,number of moles(worksheet)	69
Table 7	Post-test results	86
Table 8	The distribution of the number (percentages) of learners across the codes identified from interviews	88
Table 9	Comparison of pre- and post-test results	94

FIGURES

Figure 1	Overall performance for physical sciences (2011-2014)	12
Figure 2	Average mark per question	17
Figure 3	Constructivism	25
Figure 4	Graph of pre-test results	63
Figure 5	Concept maps for group A	65
Figure 6	Concept map for group C	66
Figure 7	Analogy (theoretically)	71
Figure 8	Analogy (sandwich)	71
Figure 9.1-9.2	Concept map	72
Figure 10	Chemical reaction (model)	72
Figure 11	Model equation	73
Figure 12	Stoichiometric triangles	74
Figure 13	Post-test results	86
Figure 14	Pre and Post-test results	95

CHAPTER 1

Rationale of the study

1.1 Introduction

This study explored the problem of poor performance in physical science in national examination among secondary school learners in the Eastern Cape. Although this problem is commonly found in many countries, it is peculiarly acute in the Eastern Cape as indicated later in this thesis. This introductory chapter provides an overview of the study. The chapter is organized into sections namely the background and context of the study, the state of science education in South Africa, interventions in science education in South Africa and Eastern Cape Province, the research problem and the research questions of the study.

1.2 Background

Education and training during apartheid was characterized by the under-development of human potential generally and that of blacks in particular. The teaching and learning of mathematics, science and technology were the hardest hit (Department of Education, (DoE, 2001). Mji and Makgato (2006) argued that if this country is to participate in the technologically advancing global village, it is necessary that research should inform policy and drive transformation to a mathematically and scientifically literate society.

Physical sciences seem to be one of the subjects which are trailing behind when matric results are analyzed especially in the Eastern Cape Province. Although when you are looking at the trend, the pass rate seems to be increasing but still trailing behind compared to other subjects. Table 1 and Figure 1 below illustrate the decrease in the number of learners that are doing physical science. They also indicate that there is a decline in their performance.

Table 1 and Figure 1 depict the results of physical sciences nationally including one from disadvantaged areas. Mokoena (2006,11) paraphrased Nifcorp's (2005) definition

of disadvantaged communities as consisting of black individuals who were, by design, socially, economically, educationally and otherwise prejudiced against and underprivileged communities referred solely to black people comprised of African, Coloured and Indians. The schools in these communities lack of resources yet these schools are expected to render educational services similar to schools in more affluent communities with access to various resources.

Table 1: Overall performance for physical sciences (2011-2014) nationally

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	180 585	96 441	53.4	61 109	33.8
2012	179 194	109 918	61.3	70 076	39.1
2013	184 383	124 206	67.4	78 677	42.7
2014	167 997	103 348	61.5	62 032	36.9

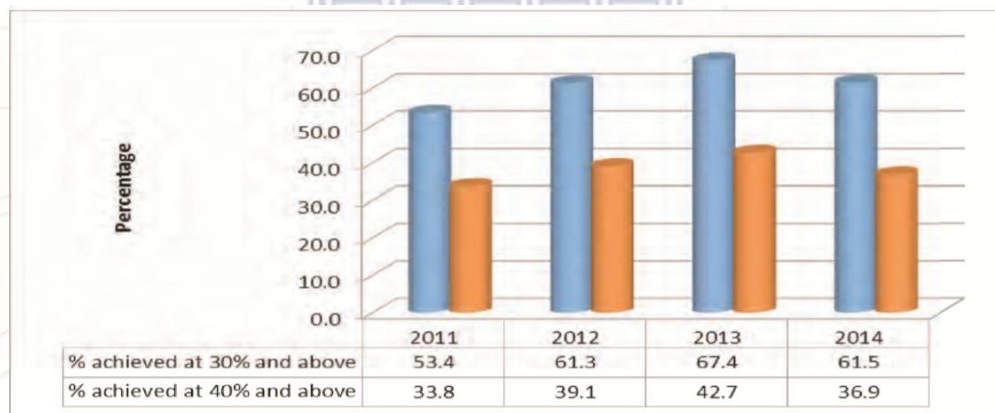


Figure 1: Overall performance for physical sciences (2011-2014): Diagnostic Report Grade 12. (2014)

The performance of learners in science is a great concern in secondary school education in the whole of South Africa science education system as it is also one of the learning areas that uplift the economy of South Africa. Since the start of democratic

government in South Africa, there has been a great emphasis on promotion of science, mathematics and technology.

These fields are seen as critical basis for socio- economic development of the country (Suping, 2003). This statement is also supported by many researchers that mathematics, science and technology education have been nationally priority in South Africa for several years as evidence for example by national strategy for mathematics, science and technology education (Scott & Usher, 2011). These fields are seen as the critical basis for socio-economic development of the country (Mpofu.2000; Kriel & Grayson, 2009). The motive behind nationalizing or framing policy considering these learning areas was to improve the quality of education that will better address the economic requirements of the country. This idea has been strongly supported and motivated by the following statement:

To address these problem such as under qualified teachers and too few students taking mathematics and science related subjects a number of initiative programs have been developed at national and provincial level as well as by higher education institutions (Mji, 2009).

From the government side a typical example is setting up of Dinaledi schools which are to be increased up to about 400. The Dinaledi Project is described as part of the national strategy for science, mathematics and technology to increase the number of learners studying mathematics and science in grade 10 to 12. **Table 2.** below show national provincial and the research district results for three consecutive years (2013-2016). Diagnostic Report Grade 12. (2016)

Table 2: National, provincial and district results from 2013 to 2016.

Year	National	Eastern Cape	District
2013	67.4	64.9	50.2
2014	61.5	51.5	51.0
2015	58.6	49.5	56.0

2016	62.0	49.6	49.5
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1.3 State of science education in South Africa

The recent curriculum reforms in South Africa were politically motivated. After the first democratic elections in 1994, new education policies were adopted in South Africa in order to change the unjust and discriminating policies of the Apartheid regime. These reforms also presented the curriculum developers the opportunity to incorporate new educational methods, based on recent research on how learning happens and how it can be made more effective (Christie, 2008). In 1998, a new curriculum, Curriculum 2005 (C2005), was introduced in South African schools. This curriculum was developed within the Outcome-Based Education (OBE) framework.

The OBE framework specifies intended outcomes of the curriculum and these outcomes provide targets for teachers that learners must achieve. It places an emphasis on producing learners who are critical thinkers, capable of solving problems and who are responsible for their own learning. Curriculum 2005 aimed to produce learners who not only have the knowledge, but also the skills, attitudes and values in order to become competent, responsible and critical citizens. While these aims are important for individual learners, they are also important for South Africa as a developing country. In support of the implementation of Curriculum 2005, a national strategy was developed for mathematics, science and technology education in South Africa, which included the preparation of qualified and competent teachers in these learning areas as well as providing adequate resources for classrooms (Department of Education, 2001).

The implementation of the new curriculum and its purposes was of the good ideas if it was catering for every learner equally in South Africa, but unfortunately it was not. South Africa has some of the least-knowledgeable primary school mathematics teachers in sub-Saharan Africa. Many of these mathematics teachers, especially those that serve poor and rural communities, have below-basic levels of content knowledge. In many instances these teachers cannot answer questions their pupils are required to answer

according to the curriculum (Department of Education, 2001). The Annual National Assessments (ANAs) are one of the most important and needed policy innovations since the transition to democracy, but given the way that these tests are currently implemented including the formulation, marking, invigilation and moderation procedures they cannot be used as a reliable indicator of progress.

The sub-standard quality of education provided to most South African youth has severe economic consequences for those affected. Furthermore, the economic prospects of the youth appear to be deteriorating over time. The percentage of 18-24 year olds who are not in education, employment or training (NEET) has increased from about 30 per cent in 1995 to 45 per cent in 2011 while the percentage enrolled in education has decreased from 50 per cent to 36 per cent over the same period.

The unemployment rate for the youth has also increased from 36 per cent in 1995 to 50 percent in 2011, standing at twice the national unemployment rate in 2011. Furthermore, of those unemployed in 2011, more than 70 per cent had never been employed before. Perhaps most disconcertingly, for the youth, completing Grade 12 does not markedly increase one's chances of finding employment relative to 18-24 year olds with less than the NSC. Rather, the value of matric lies in opening up opportunities to acquire some form of tertiary education, an opportunity available to only a small minority (Department of Education, 2001).

While the low-level equilibrium that South Africa finds itself in has its roots in the apartheid regime of institutionalized inequality, this fact does not absolve the current administration from its responsibility to provide a quality education to every South African child. After 19 years of democratic rule most black children continue to receive an education which condemns them to the underclass of South African society, where poverty and unemployment are the norm, not the exception. This substandard education does not develop their capabilities or expand their economic opportunities, but instead denies them dignified employment and undermines their own sense of self-worth. In short, poor school performance in South Africa reinforces social inequality and leads to

a situation where children inherit the social station of their parents, irrespective of their motivation or ability. Until such a time as the DBE and the ruling administration are willing to seriously address the underlying issues in South African education, at whatever political or economic cost, the existing patterns of underperformance and inequality will remain unabated (Spaull, 2013).

1.4 Interventions in science education in the Eastern Cape Province

To address the problem of poor performance in science and mathematics and also of few learners taking science related subjects at high schools and at universities, a number of initiatives and programmes have been developed at national and provincial levels as well as by higher education institutions. From the government side, a typical example is the setting up of *Dinaledi* schools, which are to be increased to about 400.

The Dinaledi Focus Schools Project is part of the National Strategy for Science, Mathematics and Technology, to increase the number of learners studying mathematics and physical science in Grades 10–12; to increase the number of quality passes by learners in these subjects especially girls and formerly disadvantaged learners; to increase the pass rate in physical sciences (Mji, 2009).

In the Eastern Cape Province Education Department there is a section called Mathematics, Science and Technology (MSTE) unit which is focusing in these three learning areas. This section is supported by Dinaledi to pilot schools with the purpose of improving Mathematics and Science results (Mji,2009). They are training teachers to become experts in these subjects and also supply the schools with the resources. (MSTE) also set up programs for learners that motivate them towards the field of sciences. These section is encouraging schools to take learners to national science festival which is held in Graham's town each year during March/April. There is also science week every year around May where learners are encouraged to do science activities as young scientists. The Science expo for young scientists is a programme that runs every year starting from regional level to national level and is one the programs that motivate and encourage learners to do science at their school level. Fortunately, the

researcher is one of the educators trained by the department of education. The program of the University of the Western Cape is one of the interventions organized by the department Education. Educators were trained from ACE Physical Science (FET) and they are still being trained up to Masters level in science education.

1.5 Context of the study

The research has been conducted at a school in the Lady Frere District of the Eastern Cape Province. The school is situated in a deep rural area. The learners from this society cannot get help from their parents when doing homework, as their parents were victims of the apartheid era and are therefore illiterate. One can imagine the situation whereby the learners are coming from poor backgrounds whereby even the government does not provide enough supporting resources according to the curriculum requirements and yet are expected to produce good results in mathematics and science. Kriek and Grayson (2009) explained that there are multiple, complex problems that contribute to learners' poor performance. These include poverty, resources, learning culture, infrastructure of schools and low teacher qualifications.

The poor performance of learners forms the basis for this study which focused on certain challenging concepts in grade 11 physical sciences. The learners in my class experience great difficulty with the quantitative aspects of chemical change. Specific concepts of the topic in the field of quantitative aspects of chemical change are moles, molar masses and stoichiometry. The quantitative aspects of chemical change are carried over to the entire grade 12 chemistry.

The poor performance of the learners in this topic could be one of the major reasons why learners are having difficulty in handling chemistry in grade 12. This is echoed in Table 1, which represents the overall performance for Physical sciences as reported the National Diagnostic Report (2014). The national diagnostic report (2014) points out a concern that the matriculants performed very badly in the questions that were based on this concept. For example, from the above graph learner's achievements in Q5, Q6 and Q7 are all below 50%. More especially Q5 as most of the questions were based in this

concept. In the diagnostic report it was clearly stated that in Question 5 the stoichiometry calculation was a challenge for most candidates. In Question 6 that deals with chemical equilibrium, it has been reported that the performance in this question remains the same from year to year. Diagnostic report (2014) also highlighted that stoichiometry is still a huge problem in most schools as can be seen in Figure 2. Teachers must ensure that learners are proficiency in performing this calculation.

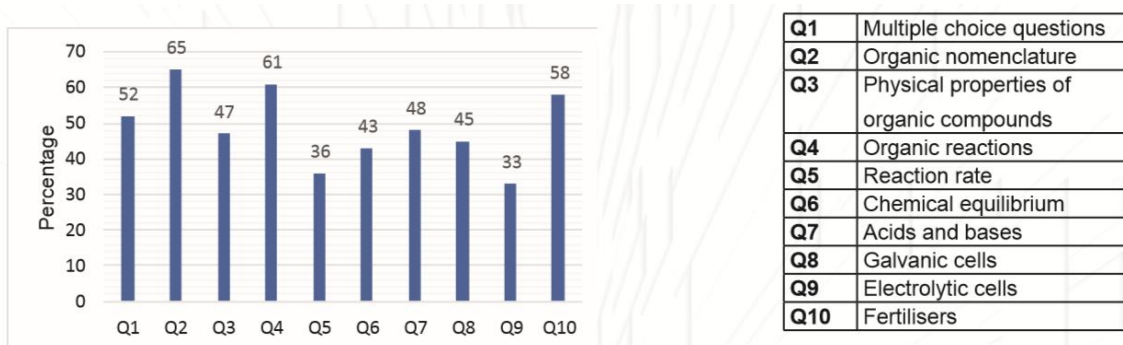


Figure 2. Average marks per question expressed as a percentage: chemistry

1.6 Research Problem

The National Diagnostic Report (2014) as part of the analysis of learners' achievement in the various sections of the Physical Science curriculum has identified stoichiometry and its calculations as a section in the curriculum that learners have been struggling with over a number of years. Various reports by the Department of Basic Education as well as National Diagnostic Report encourage teachers to consider various approaches and strategies in their teaching in order to make these challenging sections more accessible to learners. It is in the conceptual understanding of the curriculum content that learners find difficulty as they cling to their own alternative conceptions. In order to allow learners to make the jump from their own conception to the scientific understanding of the concepts in stoichiometry, a conceptual change process needs to be put in place. This study investigated the use of a conceptual change approach to improve learners understanding of the quantitative aspects of chemical change.

1.6.1 Research questions

The study was conducted to address the following main research question:

To what extent can conceptual change as a teaching strategy be used to improve learners' understanding of the quantitative aspects of chemical change?

The following research sub-questions will be addressed to answer the main research question:

- (i) What was the learners' initial understanding of the quantitative aspects of chemical change?
- (ii) How was the conceptual change approach implemented to improve learners' understanding of the quantitative aspects of chemical change?
- (iii) What was the learners' understanding of quantitative aspects of chemical change after the conceptual change approach?
- (iv) What were the learners' perceptions of conceptual change approach?

1.7 Significance of the study

The findings of the study could:

- Contribute to efforts aimed at identifying the difficulties that learners have on quantitative aspects of chemical change
- Identify some of the alternative conceptions about this topic that learners hold thus providing the necessary platform for remedial instruction.

1.8 Limitations of the study

Limitations are conditions beyond the control of the researcher that will place restriction on the conclusion of the study and its application (Best and Kahn, 1989). Being a case study design the study draws conclusions from a limited number of sites and participants. The second limitation was that the study was conducted in one school in a sample of 50 physical sciences grade 11 learners. The sample size is not big enough to make general conclusion for the district or the whole country. There were no

comparative dimensions in the study since research was in one school. Repeating a lesson to the same learners could positively affect learners' understanding.

1.9 Structure of the thesis

The study is presented across six chapters.

Chapter one describes the overall orientation of the research study and defines its concern: The research context is outlined by the aims of the study. This chapter provides the rationale for the research and research questions that guided the study as well as the significance and possible limitations of the study.

Chapter two outlines the conceptual framework of this study. The chapter reviews related literature of conceptual change theory approach to enhance teaching concept in physical sciences. The characteristics of its effectiveness in developed countries and developing countries such as South Africa are discussed.

Chapter three outlines the research design and methodology adopted in the study. It provides an in-depth discussion of the sample selection and instruments used for data collection. The chapter highlights the data analysis process and reports on ethical considerations, reliability and validity.

Chapter four is a descriptive report on the findings of the research and a discussion of the findings.

Chapter five is the concluding chapter of the study. The findings presented in chapter four are synthesized to produce valid conclusions. The chapter further presents the implications of the study and recommendations for future research.

1.10 Conclusion

This chapter provided an outline of this study, highlighting what it aimed to achieve, and what this study entailed. The introduction and background to this study were presented. The significance of the study, its theoretical framework, and the research methods and

design used, are also presented. The next chapter provides the theoretical basis of the research.



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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The previous chapter has provided the background to the study, rationale, the research problem and the research question of the research. In keeping with the purpose of the study to investigate the effect of teaching the quantitative aspects of chemical change using the conceptual change strategy, this chapter reviews literature regarding the effect of using the conceptual change teaching strategy to teach Physical science concepts.

The literature review highlights the theoretical framework on which this study is based and reviews literature that are relevant to the study. Henning, van Rensburg & Smith. (2004) reaffirm the three purposes of literature reviews as firstly the contextualisation of one's study, to argue a case and to identify a niche to be occupied by one's research. Secondly the literature review is also used to synthesise the literature on the selected topic and to engage critically with it. The third instance where literature reviews are useful is where you explain the data and show the relevance of the findings in relation to the existing body of literature.

2.2 Theoretical Framework

The study is underpinned by the theories of constructivism and conceptual change.

2.2.1 Constructivism

The meaning of constructivism varies according to one's perspective and position. Within the educational contexts there are philosophical meanings of constructivism, as well as personal constructivism as described by Piaget (1967), social constructivism outlined by Vygotsky (1978), radical constructivism advocated by von Glasersfeld

(1995), constructivist epistemologies, and educational constructivism (Mathews, 1998). Social constructivism and educational constructivism (including theories of learning and pedagogy) have had the greatest impact on instruction and curriculum design because they seem to be the most conducive to integration into current educational approaches. Below is the variation of definitions for constructivism in education.

The mind can "put together those ideas it has, and make new complex ones." (Lock, 1947). It is assumed that learners have to construct their own knowledge individually and collectively. Each learner has a tool kit of concepts and skills with which he or she must construct knowledge to solve problems presented by the environment. The role of the community other learners and teacher is to provide the setting, pose the challenges, and offer the support that will encourage mathematical construction (Davis, Maher, Noddings, 1990).

Constructivism is not a theory about teaching, it is a theory about knowledge and learning. The theory defines knowledge as temporary, developmental, socially and culturally mediated, and thus, non-objective (Brooks & Brooks, 1993). Knowledge, no matter how it be defined, is in the heads of persons, and that the thinking subject has no alternative but to construct what he or she knows on the basis of his or her own experience (von Glasersfeld, 1995). The doctrine itself holds that 'language users must individually construct the meaning of words, phrases, sentences and texts (Suchting, 1998; von Glasersfeld, 1989). Constructivists allege that it is we who constitute or construct, on the basis of our theorizing or experience, the allegedly unobservable items postulated in our theories (Nola, 1998).

The central principles of this approach are that learners can only make sense of new situations in terms of their existing understanding. Learning involves an active process in which learners construct meaning by linking new ideas with their existing knowledge (Naylor & Keogh, 1999). Constructivists of different persuasion (hold) a commitment to the idea that the development of understanding requires active engagement on the part of the learner. (Jenkins, 2000). One of the common threads of constructivism that runs

across all these definitions is the idea that development of understanding requires the learner actively engage in meaning-making. In contrast to behaviorism, constructivists argue that "knowledge is not passively received but built up by the cognizing subject" (Von Glasersfeld, 1995). Thus, constructivists shift the focus from knowledge as a product to knowing as a process.

Constructivism is an epistemological view of knowledge acquisition emphasizing knowledge construction rather than knowledge transmission and the recording of information conveyed by others. Constructivism proposes that learner conceptions of knowledge are derived from a meaning-making search in which learners engage in a process of constructing individual interpretations of their experiences. The role of the learner is conceived as one of building and transforming knowledge. But what does it mean to construct knowledge? Within constructivism there are different notions of the nature of knowledge and the knowledge construction process. Moshman (1982) has identified three types of constructivism: exogenous constructivism, endogenous constructivism and dialectical constructivism.

In exogenous constructivism, as with the philosophy of realism, there is an external reality that is reconstructed as knowledge is formed. Thus one's mental structures develop to reflect the organization of the world. The information processing conceptualizations of cognitive psychology emphasize the representation view of constructivism, calling attention to how we construct and elaborate schemata and networks of information based on the external realities of the environments we experience (Moshman, 1982).

Endogenous constructivism or cognitive constructivism (Cobb, 1994; Moshman, 1982) focuses on internal, individual constructions of knowledge. This perspective, which is derived from Piagetian theory (Piaget 1977, 1970), emphasizes individual knowledge construction stimulated by internal cognitive conflict as learners strive to resolve mental disequilibrium. Essentially, children as well as older learners must negotiate the meaning of experiences and phenomena that are discrepant from their existing schema. Students

may be said to author their own knowledge, advancing their cognitive structures by revising and creating new understandings out of existing ones. This is accomplished through individual or socially mediated discovery-oriented learning activities.

Dialectical constructivism or social constructivism (Brown, Collins, & Duguid, 1989; Rogoff, 1990) views the origin of knowledge construction as being the social intersection of people, interactions that involve sharing, comparing and debating among learners and mentors. Through a highly interactive process, the social milieu of learning is accorded centre stage and learners both refine their own meanings and help others find meaning. In this way knowledge is mutually built. This view is a direct reflection of Vygotsky's (1978) sociocultural theory of learning, which accentuates the supportive guidance of mentors as they enable the apprentice learner to achieve successively more complex skill, understanding, and ultimately independent competence.

The fundamental nature of social constructivism is collaborative social interaction in contrast to individual investigation of cognitive constructivism. Through the cognitive give and take of social interactions, one constructs personal knowledge. In addition, the context in which learning occurs is inseparable from emergent thought. This latter view known as contextualism in psychology becomes a central tenet of constructivism when expressed as situated cognition. Social constructivism captures the most general extant perspective on constructivism with its emphasis on the importance of social exchanges for cognitive growth and the impact of culture and historical context on learning.

Prawat (1992) argues that while there are several interpretations of what constructivist theory means, most agree that it involves a dramatic change in the focus of teaching, putting the students' own efforts to understand at the centre of the educational enterprise. Thus despite the differences sketched above, there is important congruence among most constructivists with regard to four central characteristics believed to influence all learning: 1) learners construct their own learning; 2) the dependence of new learning on learners' existing understanding; 3) the critical role of social interaction and;

4) the necessity of authentic learning tasks for meaningful learning (Bruning, Royce, & Dennison, 1995; Pressley, Harris, & Marks, 1992).

All of the above characteristics that influence learning in constructivism have been taken into consideration in the methodology of this study. For example, during the intervention stage, the lesson plan has been designed such that it addresses the teaching and learning strategies used in reconstructing existing knowledge so that learning could make meaning by using effective learning tasks in the process.

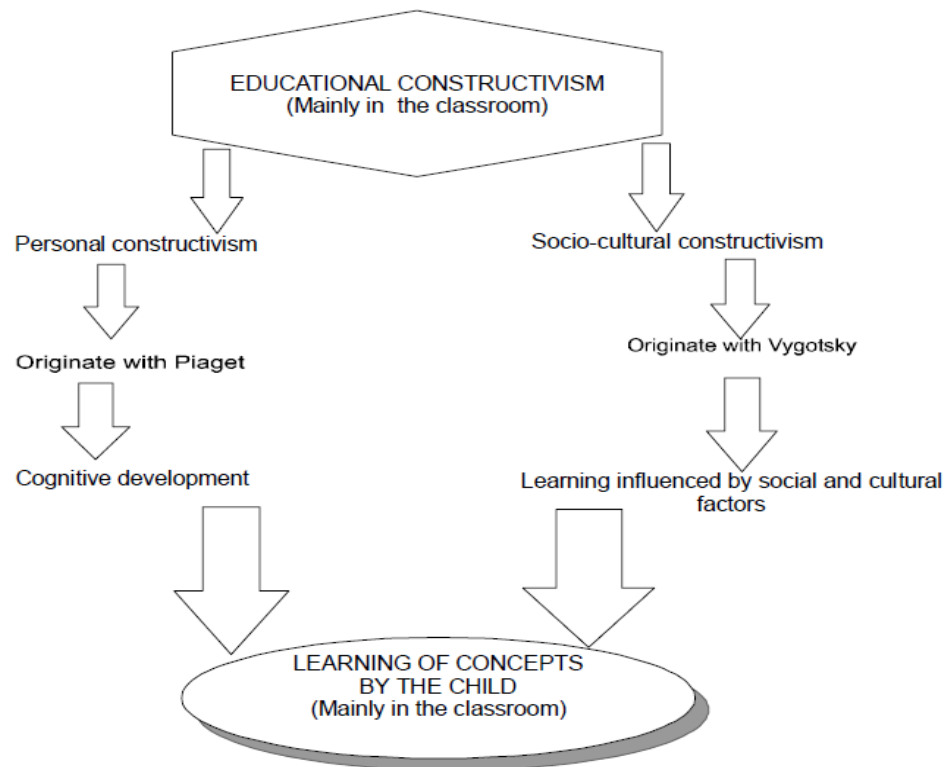


Figure 3: Constructivism obtained from Matthews (2000:494)

For the learner to construct meaning, he must actively strive to make sense of new experiences and in so doing must relate it to what is already known or believed about a topic. Learners develop knowledge through an active construction process, not through the passive reception of information (Brophy, 1992). In other words, learners must build

their own understanding. How information is presented and how learners are supported in the process of constructing knowledge is of major significance. The pre-existing knowledge that learners bring to each learning task is emphasized too.

Matthews (2000) mentions three major types of constructivist traditions, namely, educational constructivism, philosophical constructivism and sociological constructivism. Of importance to this study is educational constructivism illustrated in Figure 3. Learners' current understandings provide the immediate context for interpreting any new learning. Regardless of the nature or sophistication of a learner's existing schema, each person's existing knowledge structure will have a powerful influence on what is learned and whether and how conceptual change occurs. For Tytler (1997): these conceptions in many cases form useful prior knowledge that a teacher can build on. In some cases, however, learners' "trusted" conceptions can interfere with ideas that teachers would want to develop. learners' "alternative conceptions" have proved surprisingly difficult to shift, and can offer a serious impediment to effective teaching.

2.2.2 The conceptual change theory

Over the past two decades, a number of authors have proposed models of classroom teaching for science. Some of these models are described in the following, they were chosen to represent a range of approaches to constructivist-informed teaching, but it is recognized that the list is by no means exhaustive. They are presented roughly in chronological order and the authors' references to motivation have been identified. For the purpose of comparison, some of the classical or earlier models (i.e., the early 1980s to the early 1990s) were described and analysed first, then some recent models (from the late 1990s onwards) were treated. There is absolutely no doubt that the most cited and most influential model of conceptual change was proposed by Posner, Strike, Hewson, and Gertzog (1982) "PSHG" The previous chapter of this study has provided the background which clarifies the background to the study, rationale for the study, the research problem and the research question of the research project. In this chapter, the researcher referred to the conceptual change model as "PSHG" throughout the following article. This model, which was mainly inspired by the Piagetian concept of

accommodation (Piaget, 1968) and by the Kuhnian concept of “scientific revolution” (Kuhn, 1962), addresses the difficult problem of making learners modify the “misconceptions” they hold about how the physical world works.

Stella Vosniadou (2008) defines the “classical approach” of conceptual change as the leading paradigm that guided research and instructional practices in the classroom for many years. According to it, the student is like a scientist, the process of (science) learning is a rational process of theory replacement, conceptual change is like a gestalt shift that happens over a short period of time, and cognitive conflict is the major instructional strategy for promoting conceptual change (Vosniadou, 2008). Among the models that belong to the classical tradition, model of conceptual change is a strong example (Nussbaum & Novick, 1982). This model suggests that teachers should (1) expose alternative frameworks, (2) create a conceptual conflict, and (3) encourage accommodation.

The same kind of sequence was proposed in PSHG’s model. In short, it proposed to (1) provoke learners’ dissatisfaction toward their own misconceptions by any means necessary (as in Nussbaum’s “exposing event” [1982]), and then present the scientific conception to learners in order for it to be (2) intelligible, (3) plausible, and (4) fruitful.

According to the model, following these criteria would encourage learners to “replace” (Posner et al., 1982) their therefore discredited non-scientific conceptions with the programmed ones or, at least, accommodate them with the presented “discrepant events.” The order in which these pedagogical operations has to be conducted is not always perfectly clarified, but most of the time dissatisfaction is presented as “the first crucial step” (Nussbaum & Novick, 1982). PSHG’s and NN’s models can be considered as prototypical examples of the classical tradition of conceptual change, which has “cognitive conflict” as its central concept (Chan, Burtis, & Bereiter, 1997). It also became somewhat implicit to almost the entire field that conceptual or cognitive conflict has to be the “first step to achieve conceptual change” (Limon, 2001). Scott also talks

about the strategies “where conflict must be recognized by the student in the early stages of teaching if learning is to occur” (Scott, Asoko, & Driver).

The classical conceptual change approach involved the teacher making students’ alternative frameworks explicit prior to designing a teaching approach consisting of ideas that do not fit the students’ existing ideas and thereby promoting dissatisfaction (Duit & Treagust, 2003). Following Dewey (1910), it is generally agreed that accommodation necessitates first of all recognition by the learner of a problem and his inability to solve it with his existing conceptions (Nussbaum & Novick, 1982). Before an accommodation will occur, it is reasonable to suppose that an individual must have collected a store of unsolved puzzles or anomalies and lost faith in the capacity of his current concepts to solve these problems (Posner et al., 1982).

Many other models of conceptual change were subsequently proposed by authors in order to go beyond the classical model tradition. Some were mostly derivatives (Hewson, 1981) of the PSHG model, while others mainly provided analogies (Giordan, Potvin, 1991). Some were quite difficult to grasp (diSessa, 1993) or to concretely apply (Vosniadou, 1994; Vosniadou & Brewer, 1992), while others were effective only in certain contexts or were limited to specific content knowledge. We believe that these “second-generation” models belong to what Ohlsson (2009) might describe as “transformation-of-previous-knowledge” models, that opposed the classical tradition by rejecting the idea that initial conceptions can be abandoned. Furthermore, “not all of these second-generation models were developed to be applied to the context of school learning” (Limon, 2001). One cannot say that the models that followed were inefficient or uninteresting, or that they did not contribute significantly to the field; however, we believe that none of them reached enough teachers and researchers to become a leading model and supplant the ones that belong to the classical tradition.

To construct a holistic picture of learning, it is both possible and beneficial to consider a learning situation from more than one theoretical perspective of conceptual change. For example, rather than only considering conceptual changes in knowledge that a student constructs in moving from, say a pre- scientific notion to a scientific view of a concept, a

more complete and informative picture would be painted if these changes were viewed from a multidimensional perspective. The way the student views a concept in terms of its status (Posner, et al., 1982), its ontological category (Chi, et al., 1994) and the motivational and contextual factors (Pintrich, et al., 1993) can provide a more holistic picture of conceptual change. Consequently, a multi-dimensional framework utilising differing perspectives of conceptual change to view a learning situation has merit though the affective domain needs to be more fully elaborated. It appears to be most valuable to view the issue of motivation and interest in science and science teaching from the perspective of conceptual change.

An important aim of science instruction is to develop interest in much the same way as to develop learner's pre-instructional conceptions towards the intended science concepts. From the epistemological perspective, learners' conceptions are viewed based on how they describe the concepts being investigated; while from the ontological perspective, students' conceptions are viewed based on how they view the nature of the concepts being investigated. This means that these epistemological descriptions and ontological considerations of learners on the concepts being investigated can form patterns in learner's conceptions (categories of conceptions). Therefore, to identify and categorize learners' conceptions, this study follows an inclusive perspective that involves learners' epistemological descriptions and ontological considerations of concepts in the quantitative aspects of chemical change.

Researchers have found that learners' preconceptions can be extremely resilient and resistant to change, as demonstrated in Heather's story from the A Private Universe. A major criticism of the original conceptual change theory is that it presents an overly rational approach to student learning--an approach that emphasizes and assumes logical and rational thinking (Pintrich, Marx, & Boyle, 1993). Pintrich et al. refer to this approach as "cold conceptual change," because it ignores the affective (e.g., motivation, values, interests) and social components of learning. In particular, the notion of conceptual ecology was criticized because it focuses solely on the learner's cognition and not on the learner as a whole. Furthermore, it does not consider other participants

(i.e., the teacher and other learners) in the learning environment and how these participants influence the learner's conceptual ecology, thus influencing conceptual change. Strike and Posner (1992) also recognized similar deficiencies in their original conceptual change theory and suggested that affective and social issues affect conceptual change

Social constructivist and cognitive apprenticeship perspectives have also influenced conceptual change theory (Hewson, Beeth, & Thorley, 1998). These views on learning encourage discussion among students and instructor as a means of promoting conceptual change. Thus, conceptual change is no longer viewed as being influenced solely by cognitive factors. Affective, social, and contextual factors also contribute to conceptual change. All of these factors must be considered in teaching or designing learning environments that foster conceptual change (Duit, 1999).

2.2.3 Teaching for Conceptual Change

As mentioned above, learner preconceptions are resistant to change because learners have depended on these existing notions to understand and function in their world, they may not easily discard their ideas and adopt a new way of thinking. Thus, simply presenting a new concept or telling the learners that their views are inaccurate will not result in conceptual change. Teaching for conceptual change requires a constructivist approach in which learners take an active role in reorganizing their knowledge. Cognitive conflict strategies, derived from a Piagetian constructivist view of learning, are effective tools in teaching for conceptual change (Duit, 1999). These strategies involve creating situations where learners' existing conceptions about particular phenomena or topics are made explicit and then directly challenged in order to create a state of cognitive conflict or disequilibrium. Cognitive conflict strategies are aligned with Posner et al.'s theory of conceptual change in that their common goal is to create the four conditions necessary for conceptual change. That is, learners must become dissatisfied with their current conceptions and accept an alternative notion as intelligible, plausible, and fruitful.

In the Conceptual Change Instructional Model, cognitive conflict can have been used as the basis for developing a number of models and strategies for teaching for conceptual change. Among these are the Generative Learning Model (Cosgrove & Osborne, 1985), the Ideational Confrontation Model (Champagne, Gunstone, & Klopfer, 1985), and an instructional strategy using anomalous data (Chinn & Brewer, 1993). Although these models suggest different methods and techniques, they share a structure similar to the conceptual change teaching strategy proposed by Nussbaum and Novick (1982):

- Reveal student preconceptions
- Discuss and evaluate preconceptions
- Create conceptual conflict with those preconceptions
- Encourage and guide conceptual restructuring
- Reveal Student Preconceptions

A basic assumption in teaching for conceptual change is "the key constructivist idea that construction of new conceptions (learning) is possible only on the basis of already existing conceptions" (Duit, 1999, p. 275). Even though existing knowledge (be it correct or incorrect) allows us to make our way through the world, we are not necessarily conscious of it. Thus, the first and most significant step in teaching for conceptual change is to make learners aware of their own ideas about the topic or phenomenon under study. To elicit learners' conceptions, instruction begins with an exposing event. The exposing event is any situation that requires learners to use their existing conceptions to interpret that event. Exposing events may be of two types: a situation for which outcome is not known or one in which the outcome is known (Chinn & Brewer, 1993). In the "unknown" case, the teacher asks learner to predict the outcome and explain the basis for their prediction. In the "known" case, students make no predictions; however, they must provide an explanation of the event. However, the teacher could have employed an "unknown" exposing event.

Learners can represent their ideas in many ways. They can write descriptions, draw illustrations, create physical models, draw concept maps, design web pages, or create any combination of these to evidence their understanding of a particular concept. If

computers and the appropriate software are available, learner can develop presentations (using PowerPoint or other software), create models or simulations, or construct concept maps. Regardless of the method, the goal of this step is to help students recognize and begin to clarify their own ideas and understandings. Once learners' conceptions are made explicit, teachers can use them as the basis for further instruction.

The goal of this step is to have learners clarify and revise their original conceptions through group and whole-class discussions. If this is the teacher's first conceptual change learning activity, it is wise to begin with the latter; such discussions allow the teacher to model the evaluation process before learners evaluate each other's ideas in smaller groups. To begin, the teacher asks various students to describe their representations (conceptions). After all conceptions are presented, the teacher leads the class in evaluating each for its intelligibility, plausibility, and fruitfulness in explaining the exposing event. Nussbaum and Novick (1982) suggest that the teacher accept all representations and avoid value judgments.

The teacher should also refer to the representations by learner name. After the whole-class discussion, learners with differing conceptions work in pairs or groups to evaluate each other's ideas. Each group selects one conception (or a different conception modified through evaluation), provides a rationale for the selection, and presents that rationale to the whole class. Learner motivation can be increased by allowing the learners to vote for the conception that they think well explains the exposing event. As learners become aware of their own conceptions through presentation to others and by evaluation of those of their peers, learners become dissatisfied with their own ideas; conceptual conflict begins to build. By recognizing the inadequacy of their conceptions, learners become more open to changing them.

To create greater conflict, the teacher creates a discrepant event. The discrepant event is a phenomenon or situation that cannot be explained by the learners' current conceptions but can be explained by the concept that is the topic of instruction. At this

point, if no learner has offered the "correct" conception, then the teacher may suggest it as one given by a learner in a previous class. If the teacher does not know the range of learner (mis)conceptions about a topic or phenomenon before the conceptual change activities begin, it may not be possible to plan a discrepant event in advance. In such cases, the teacher should ask the learners to suggest a test or method to determine which of the learners' (and possibly "planted") conceptions best explains the "exposing event." If the subject is science, the learners may suggest some type of experiment. The teacher could also create a discrepant event by presenting anomalous data evidence that contradicts the students' current conceptions (Chinn & Brewer, 1993).

Learners should be given time to reflect on and reconcile differences between their conceptions and the target theory. The teacher should incorporate reflective activities into lessons to promote cognitive accommodation or restructuring of the student preconceptions. A cooperative learning environment is necessary for successful conceptual change instruction. There must be opportunities for discussion; learners must feel safe in sharing their viewpoints as they consider and evaluate other perspectives (Bruning, Schraw, & Ronning, 1999; Scott, Asoko, & Driver, 1991). The "safety factor" is especially important when the teaching employs the cognitive conflict strategy presented above. One research study (Dreyfus, A., Jungwirth, E., & Eliovitch, R., 1990) found that low achieving students experienced a loss of self-confidence, viewing the conflict as another failure. For successful implementation of the conceptual change instructional strategy, the teacher and students should have some experience with constructivist learning and cooperative learning groups. Learners who are accustomed to a transmission style of teaching (i.e., direct instruction) may be less motivated to participate in discussion-based activities (Scott, Asoko, & Driver, 1991). The teacher must be adept in managing class groups and able to assume a facilitative role.

Teaching for conceptual change is not an easy process; it is more time-consuming than traditional, rote teaching methods. It requires a supportive classroom environment in which students feel confident in expressing and discussing their ideas. Conceptual

change instruction also requires that the teacher possess well-developed facilitation skills and a thorough understanding of the topic or phenomenon in question. Conceptual change learning results in better conceptual understanding by the students. Consistent evaluation and clarification of conceptions helps students develop meta-conceptual awareness; that is, they come to understand how they develop their beliefs (Vosniadou, 1994).

Although a specific instructional approach has been presented here, other constructivist teaching approaches may also promote conceptual change learning. The unique features of conceptual change instruction are that learners make their conceptions explicit so that they become aware of their own ideas and thinking, and that learners are constantly engaged in evaluating and revising their conceptions. The goal of teaching for conceptual change is for learners to adopt more fruitful conceptions while discarding the misconceptions they bring to the learning environment. Learners are more likely to rid themselves of conceptions that they have evaluated than those that they have not examined at all.

Several types of computer tools and Web-based instructional materials can be used in teaching for conceptual change. These tools are used to create concept maps. A concept map is a diagram consisting of boxes or graphics that represent concepts and labelled lines that represent relationships between the concepts. Learners can create concept maps to present their conceptions about a particular topic at the beginning and throughout the instructional sequence. Concept maps allow students (and the instructor) to see how their conceptions change over time. Two recommended concept mapping tools are Inspiration and IHMC Concept Mapping Software or C-Map. Concept maps created in C-Map can be shared across a network. C-Map is a free download, and Inspiration can be downloaded for a free 30-day trial. Sample concept maps and background information about concept mapping are available at the C-Map web site.

Computer simulations are used to support conceptual change. The use of appropriate interactive visualization simulated software available for teaching concepts of physics in the classroom has become important to overcome the limitations of real experiments and helps learners to construct their knowledge through less guided exploration (Urban-Woldron, 2009). In addition, computer simulations are used to provide discrepant events in conceptual learning because they have the capacity to provide learners with an exploratory learning environment (Zacharia & Anderson, 2003). Computer simulations can also motivate and actively engage learners towards construction of their knowledge.

Education Technology (PhET) project (Wieman et al., 2008a) particularly related to simulation and learner's motivation has developed more than 60 interactive simulations on the topics of physics. These simulations are freely available on the website (<http://phet.colorado.edu>) and can be easily run online or may be downloaded to a local computer or installed to a CD (Wieman et al., 2008b). This has the advantage that learners can freely experience, explore, and manipulate the micro-world by changing the parameters and visualizing immediately the consequences of their actions (Papert, 1980; Bliss & Ogborn, 1989). In this way, learners can interpret and reflect on the domain of knowledge represented by the micro-world, formulate and test hypotheses, and reconcile any conceptual conflict between their ideas and observations in the micro-world. All these require learners to reflect on and make explicit their conceptions and this is conducive to conceptual change.

Computer simulations have been shown to be effective in fostering conceptual change in several studies (Zietsman & Hewson, 1986; White & Horwitz, 1988; McDermott, 1990; Gorsky & Finegold, 1992). In particular, Zietsman and Hewson (1986) used a computer simulation to diagnose and remediate alternative conceptions of velocity. Their results show that computer simulations can be credible representations of reality and that remediation produced a significant conceptual change in students holding the alternative conception. Computer simulations also provide students with highly focused objects for reflection and discussion. Working in small groups, students can discuss and argue about their ideas and negotiate meaning. When confronted with discrepant results, they

have to reflect on their ideas, discuss and try new approaches, and rerun the program. Students' conversational interactions while working together on the program can provide valuable data for eliciting their conceptual development (Krajcik, Simmons, & Lunnetta, 1988). Moreover, if students in groups are given a chance to run the simulations, then the simulations can offer them opportunities to actively interact in their learning at reasonable scale and time frame. In short, the simulations are designed to be interactive, engaging, and also to make explicit certain visual representations (Wieman et al., 2008b). Rutten et al. (2012) reviewed 51 articles between 2001 and 2010 and found that simulations are useful for visualisation and reported large effect sizes of well-designed simulation-based instruction.

2.2.4 Teaching of quantitative aspects of chemical change

Determination of learners understanding of chemistry concepts is an important issue in science education. Studies have revealed that students often hold misconceptions within the domain of chemistry, such as mole concept, (Sevgikingir,2011). It is through effective teaching practice where learners are engaged actively in the learning process that promotes the achievement of intended objectives of producing scientific literate citizens with minimum misconceptions of chemistry concepts especially on quantitative aspects of chemical change.

The strategies which promote active learning depend on how they are applied to a particular group of learners, the available resources and the environment under which teaching and learning takes place (Janssen and Rohrer-Murphy, 1999; Crawford, 2007; Higgins, 2010). Geban, (2011) explained how conceptual change was conducted in teaching chemistry, at the beginning of the treatment, the learners in (experimental) were administered with test toward chemistry particularly on quantitative aspects of chemical change as pre-tests. During the treatment the content on quantitative aspects of chemical change was covered as part of the regular classroom curriculum in the chemistry. In the experimental group, Conceptual Change Based Instruction Accompanied by Demonstrations (CCBIAD) was used. This instruction was designed to

address learners' misconceptions related to quantitative aspects of chemical change concepts and to eliminate them by considering four conditions for conceptual change (Posner et. al, 1982), which were dissatisfaction, intelligibility, plausibility, and fruitfulness.

While starting to the lesson, the teacher asked some questions related to the topic to the learners in order to make learners aware of their misconceptions and dissatisfied with their existing conceptions (dissatisfaction). Then, the concepts were explained through the use of a demonstration 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 students (intelligibility). After that, new examples, especially daily life examples, related to this topic were given to learners to enhance their understanding the rate of reaction concepts deeply (plausibility).

Finally, the learners were asked to use new concept in explaining a new situation (fruitfulness.) designed chemistry instruction was applied. During the instruction, the teacher used lecturing and discussion methods in the classroom. The sessions in this group were mainly based on teacher's presentation of the topics. The lessons began with the teacher introducing the topic to the class. When the learners did not understand the subject, they asked questions and the teacher made extra explanations by giving daily life examples. However, the teacher taught the subjects without considering students' misconceptions and previous knowledge. After teacher's solving an exercise related to that topic, the students were asked to solve some exercises from either textbook or other supplementary books. The teacher asked mostly quantitative questions to students. During these practices, students sometimes discussed the key points related the topic. At the end of the lesson, the teacher made a summary of the topic to clear up it for the students. Finally, some homework was assigned to the students.

2.2.5 Review of research on teaching strategies in international and national science education

Conceptual change is based on cognitive conflict and the resolution of conflicting perspectives. It is also based on building on the learner's existing ideas and extension thereof. Conceptual change ensures that learners play an active role in restructuring their knowledge. Furthermore, the design of appropriate interventions by teachers provides scaffolding for the new way of thinking.

Şahin & Çepni (2010) introduces the concept cartoon, animation and diagnostic branched tree as the teaching materials that can support conceptual change texts related to gas pressure in grade 8. As the conceptual change texts activate the learners' prior knowledge, concept cartoons will be used to diagnose misconceptions. Animation could be used to concretise abstract concepts. The diagnostic branched tree could be used as the springboard for discussion in the classroom that will effect conceptual change. It is the responsibility of the teacher to create an environment conducive for classroom discussion so that learners can understand scientific knowledge. This was a great conference presentation that enlightened many researchers as far as the learner-teacher support materials for conceptual change is concerned. Conceptual change can now be tackled from this perspective. This is a challenge to Physics teachers with a curriculum that puts the learner at the centre of the learning process.

Igwebuike (2012) sought to find out if higher achievers in integrated science taught using the conceptual change pedagogy will achieve significantly better than their counterparts taught using the expository strategy. An experimental group was taught using the conceptual change pedagogy while a second group was taught using the expository method. No statistically significant difference was found between the two groups. However, a significant difference was found in affective achievement between the two groups. All the parts of the research link well. What is said in the introduction of the study is what one comes across throughout the study. The researcher approves the use of three research instruments for triangulation. Moreover, the instruments are piloted before the actual research. The instructional treatment is explained in great detail. There

is a link between the school curriculum and the items in the tests and between the school curriculum and the items in the interview schedule. However, the details of when and how the conditions of conceptual change are implemented have not been reported on.

Nwankwo & Madu (2012) examines the effects of the analogy teaching approach on the conceptual understanding of the concepts of refraction of light in Physics. Data was collected from 111 Physics learners of Nigeria using the pre-test and the post-test. The results showed that the usage of analogy teaching model had a positive effect on learners. The researcher recommends that Physics teachers and all stakeholders in education should endeavour to incorporate analogy instructional model as one of the approaches to be adopted in Nigerian secondary schools. The following gaps were spotted in the research: Firstly, the reason for the purposive sampling technique was not stated. Secondly, the author is quiet about the intervention programme where analogy is used for conceptual change, not to mention the analogy used and how it was used in ensuring that all the four conditions for conceptual change are addressed. Thirdly, ethical considerations are not taken seriously and thus not stated. Fourthly, one cannot see where the study fits in in relation to other related works. One can only guess that maybe the analogy was used for the first time to investigate its effect on conceptual understanding of refraction of light. In closing, all these gaps resulted in the study not linking so well in some parts. Now looking on the bright side of the study, the authors reviewed literature well. Consequently, the methodology employed is understood and followed well. In addition, the results were presented well. Nwankwo and Madu (2012) ensured that all the research questions and hypotheses have been answered well.

Kaboro et al (2015) reports on the effect of using a dance analogy derived from learners' socio-cultural environment on secondary school physics students' conceptualisation of heat concepts. The results were compared with those of teaching using the conventional methods. Results showed that teaching the traditional dance analogy led to higher conceptual gains of physical heat concepts compared to teaching using conventional methods. It was recommended that teachers should often consider students' socio-

cultural knowledge as the basis of selecting and designing analogies to facilitate conceptual change in teaching abstract science concepts.

On the positive note, the researchers made it clear that what is learnt during instruction depends on learners' prior ideas, the cognitive strategies they have available and their own particular interests and purposes. In addition, their work is logically structured and the topic has been covered adequately. It reads well and is not confusing. Again, the authors are not controversial. Other writers in the field are engaged as well as in "The results of this research suggest that there is a general trend in the way conceptions are constructed and modified (Calik, AyasandColl 2009; DikkersandThijs, 1998; OrgillandBodner, 2004)". Most of all, researchers have use an analogy from all the learners' socio-cultural environment, the traditional dance of Kenya. On a low note, researchers did not make mention of the ethical considerations which are of prime importance when conducting a research. Secondly, the research method used is stated as the quasi-experimental research which beginner researchers cannot tell whether the research approach used is qualitative or quantitative.

Zeynel (2015) investigated the effect of enriched 5Es model of grade 7 learners' conceptual change levels about electric current. Within the enriched 5Es model, animation, simulations, refutational text and worksheet were employed. A conceptual questionnaire with twelve items was use to collect data. The results indicated that the experimental group outperformed in conceptual understanding as compared to the control group. Given the results of the enriched 5Es model in remedying the related alternative conceptions, it is recommended that it should be deployed to teach the other abstract science concepts. A good lesson learnt from this piece of work is that it is important to look for a gap from previous related literature where new research can fit in. The gap was on the use of different teaching and learning activities within the enriched model to facilitate conceptual change of electric current concepts.

However, the following important pillars of a research were not taken into consideration. Firstly, the 5Es model and how each phase of the 5Es model will be used was not

explained nor linked to constructivism or conceptual change although they do because literature was not reviewed. Secondly, the same instead of similar instrument, the questionnaire was used for the pre- and post-tests to collect data. Thirdly, the instrument was not tested for validity. Lastly, there are no tables or graphs showing data analysis are presented. Results are given in text form only.

Gyoungho & Taejin (2011) s' study focused on the relationship between cognitive conflict and responses to anomalous data when learners are confronted with a counterintuitive demonstration in the form of a discrepant event. Cognitive conflict initiates the first step in the process of conceptual change. On the other hand, Zhon (2012) argues that the outcome of the classroom discourse cannot be oriented to be the replacement of the learners' intuitive conceptions, rather co-existence between scientific understanding and culture based views is considered to be a reasonable and realistic goal.

Özkan (2012) presents studies that have proven the effectiveness of the conceptual change strategies in recovering learners' misconceptions. These studies also explain all the details of conceptual change. Özkan & Şelcuk (2013) presents examples of the conceptual change texts that physics teachers will benefit from in the teaching and learning of sound in physics. The conceptual change texts on sound have not been found in any current literature and this gesture is appreciated. The authors advise that the texts can be used in crowded classrooms.

McGregor (2014) reports on the conceptual change theory that can contribute to a deeper understanding of concepts if there is transdisciplinarity. The learner must understand the concepts related to the physics topic and other disciplines, and then the learner will be able to solve complex concepts. That learner knows how to learn through the inquiry-based approach, learn to do through project based learning, learn to live with others through collaboration on a local and global scale, and learn to discover oneself. The learner with the 21st century skills will be able to understand complex problems in life.

Coming to the South African context, Dega (2012) investigates the effect of conceptual change through cognitive perturbation using physics interactive simulations in electricity and magnetism. The categorization of students' conceptions was based on the epistemological and ontological descriptions of these concepts. In qualitative results, six categories of alternative conceptions were identified. They are naïve physics, lateral alternative conceptions, ontological alternative conceptions, mixed conceptions and loose ideas. It was concluded that there is a statistically significant difference between cognitive perturbation using physics interactive simulations (CPS) and cognitive conflict using physics interactive simulations (CCS) in changing students' alternative conceptions. It was suggested that in conceptual areas of electricity and magnetism, cognitive perturbation through interactive simulations is more effective than cognitive conflict through interactive simulations in facilitating conceptual change and thus, should guide classroom instruction in the area. Dega's report flows logically from the introduction to the conclusion and each and every term or process that makes this piece of work understandable is explained in great detail. What the author introduced at the beginning of every chapter is reported on explicitly. The context of the study links well with all the parts of the report. The collection of data, its analysis and the results addressed the research questions. The research questions were used well in guiding the research methodology to the conclusion of the study.

Of all the articles reviewed on the conceptual change approach, Dega is the first researcher that has dug deep into the evolutionary process of conceptual change than the revolutionary process and the results were positive. The researcher had clearly stated that revolutionary processes of conceptual change had shortcomings and many studies attest to that. Secondly, the author gives a detailed account of research instruments to be used prior, during and after the intervention; and how the intervention will be conducted so as to slowly and gradually assist the learners in understanding the scientific knowledge better. The recommendations towards the end of the study are an eye opener to other researchers. The researcher recommends that researchers should

undertake an inclusive, multi-perspective conceptual change research because conceptual change is a complex process.

Rankhumise (2014) reports on the findings of the study that investigated the effect of a bicycle analogy in alleviating alternative conceptions and other conceptual difficulties about electric circuits. The research methodology is not clearly stated. Only one research instrument was used for the pre- and post-tests, a test and as such this instrument is unreliable because it was not triangulated. The learning strategy perspective supporting the analogy used for conceptual change was not stated. Even the learning events that triggered conceptual change were not explained under the intervention stage. However, Data analysis showed a normalized gain score of 0, 4 between the pre and post-tests. The results signified that the instructional intervention, involving the use of the sandwich analogy had been effective in significantly alleviating the alternative conceptions and other conceptual difficulties about mole ratio held by the participants.

Kapartzianis (2014) investigates the vocational students' conceptual understanding of electricity by proposing a multi-dimensional and pragmatic approach to conceptual change. Unlike the previous researcher, the mixed methods employed are clearly stated. The research instruments for collecting data are the test, the interview schedule and the field notes to triangulate data collected. Test scores indicated that there was a statistically significant difference between the students' pre- and post-test scores. The majority of learners during post pre-test interviews justified their answers incorrectly, but more than 80% answered correctly in the post-test interview. Qualitatively, the interviews and field notes were analysed.

In summary, a review of the related literature indicates that misconceptions are one of the factors that lead learners to failure in the learning of Physics. To teach Physics effectively, misconceptions must be spotted and overcome through the usage of the effective teaching approach. The conceptual change approach impacts positively on the teaching and learning of Physics 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 students' alternative conceptions and scientific conceptions. In addition, the learning of science is complex and idiosyncratic. These findings have a significant bearing on my research, which focuses on teaching for conceptual change at the secondary level. The next section presents the teaching of the quantitative aspects of chemical change using the conceptual change approach.

The effects of the use of the teaching strategies that can promote conceptual change in the teaching of the quantitative aspects of chemical change. Pitchimal et al. used the predict-observe-explain (POE) teaching strategy whereas Rankhumise et al. used the inquiry-based teaching strategy. Both authors used the pre- and the post-tests as the research instrument for collecting data although one is in the form of a questionnaire whereas the other is in the form of multiple-choice questions. The data of both studies were statistically analysed. The results signified that teaching strategies used in the instructional intervention were effective in reducing learners' alternative conceptions of quantitative aspects of chemical change.

There is a gap in both studies where a further research can fit in. Both studies view conceptual change from the epistemological and ontological points of view because in the individual intervention programs concepts being investigated are described and their nature viewed. The affective view was not considered nor implemented. A good teacher teaches but a great teacher inspires. Creating an environment that supports learning motivates learners to learn. Secondly, integrating technology into teaching and learning, the 21st century skill in the form of computer simulations has not been used so far a learning tool that can support conceptual change in the teaching of the abstract concept, quantitative aspects of chemical change.

2.3 Conclusion

This chapter is looking at the literature review and the theoretical framework relevant to the study. Various forms of literature would be reviewed to establish the objectives of the research. This study uses conceptual change theory and constructivism. The next chapter deals with the research design for this study, which includes the research approaches used. The participants and sampling procedures are explained. Data collection and data analysis methods are explored. The trustworthiness of the research is also justified. This chapter provides the methodology employed to collect data to answer the research questions.



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CHAPTER 3

METHODOLOGY

3.1 Introduction

The previous chapter highlighted the literature that underpins this study. This chapter provides the methodology employed to collect data to answer the following main and sub-questions of the research study:

To what extent can conceptual change as a teaching strategy improve learners understanding of the quantitative aspects of chemical change?

- What was the learners' initial understanding of the quantitative aspects of chemical change?
- How can the conceptual change approach be implemented to improve learners' understanding of the quantitative aspects of chemical change?
- What was the learners' understanding of quantitative aspects of chemical change after the conceptual change approach?
- What was the learners' perception of the conceptual change approach used in their physical sciences class?

3.2. Research design

Research design refers to the strategy to combine the different components of the research in a consistent and logical way (Babbie & Mouton, 2001). For the purpose of this research, a mixed method design was used, i.e. both quantitative and qualitative research methodology were employed. Using such an approach affords the researcher an opportunity to utilize what is best from both qualitative and quantitative approaches (Creswell, 2003). Creswell & 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 whether the learners' answers to several questions are consistent.

Qualitative data provide a source of well-grounded, rich descriptions and explanations of processes in identifiable local contexts (Matthew et al. 1994). With qualitative data, one can see which events led to which consequences and which explanations are arrived at.

Quantitative research requires evidence that is observable and testable (Balnaves and Caputi, (2001). It is this evidence that enables the researcher to draw logical conclusions about a variety of quantifiable variables Green, Caracelli, Valerie and Graham (1989) identified the following five advantages of using mixed methods.

- Triangulation: Tests the consistency of the findings obtained through different instruments. This study made use of interviews, questionnaires in the form of pre-test, post-test and lesson plans.
- Complementarity: Clarifies results from one method with the use of another. In this study, discussions during the intervention and responses from interviews qualified scores on the questionnaires.
- Development: Results from one method shape subsequent methods or 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 tool.
- Initiation: Stimulates new research questions or challenges results obtained through one method.
- Expansion: Provides texture and detail to the study, exploring specific features of each method. This study will encourage learners to take physical science as one of their specialized subject and to study it further at tertiary institutions.

3.3 Case study

This study was conducted as a case study as it was conducted in one school and in one Grade 11 physical science class. A case study is characterized by observing or probing the characteristics of an individual unit - a child, a clique, a class, a school, or a community' (Cohen & Manion, 1980). Cohen & Manion (1980) regard the purpose of observing as intended to probe deeply and to analyze intensely the multifarious phenomena that constitute the life cycle of the unit with a view to establishing generalizations about the wider population to which that unit belongs.

This case study enabled the researcher to explore and describe the nature of processes which occur over the period during which the data was collected. The findings were interpreted with reference to the particular group in this case, grade 11 physical science learners. According to Bacon (2001), "Case study methods involve systematically gathering of enough information about a particular person, social setting, event, or any group to permit the researcher to effectively understand how it operates or functions."

Case studies are useful in that they offer insights and illuminate meanings that expand readers' experiences (Merriam, 1978). A case study is a particularly appealing design for applied fields of study such as education. Its appeal in education comes from the fact that educational processes, problems, and programmes can be examined to bring about understanding that in turn can affect and perhaps even improve practice. Merriam (1978) states further that case studies have proven particularly useful for studying educational innovations, for evaluating programmes and for informing policy.

Since this study is about evaluating the usefulness of an instructional tool in rural school setting, the researcher felt that the case study method could be of great value. Another strength of case studies, besides the fact that they can inspire insights, is that they can even be a breeding ground for hypotheses that may be pursued in subsequent studies. The scientific benefit of case studies is that they offer information that can be seen as useful beyond the individual case provided the procedure did not involve too many subjective decisions made by the investigator (Bacon, 2001).

Table 3: Sample sizes

ACTIVITY	SAMPLE SIZE	SAMPLING TECHNIQUE	CRITERIA
Pretest and post-test	50 Grade 11 Physical Sciences learners	purposive	The entire Physical Sciences class
Conceptual change lessons	50 Grade 11 Physical Sciences learners	Purposive	Entire Physical Sciences class
Interviews	12 of the 50 learners	randomly selected from each defined group	4 Lower, 4 middle 4 High performing Learners

3.4 Sampling

Sampling refers to a process of selecting a portion of the population to represent the entire population (Johnson & Christensen 2008). The research site was a secondary school in deep rural area. Looking at some factors that may lead to the delays or impossibilities to collect the data from a target population, it is therefore easier to access the information from a small group that can represent a bigger picture of a certain population. The information obtained is the representative of the total population. Huysamen (1994) defines sampling as the process of selecting a unit of analysis from amongst a population which is representative of the population or group.

This study selected a purposive sampling. The sample consisted of one grade 11 physical science class which had a total of 50 learners. Purposive sampling was also used for semi-structured interviews. Twelve out of 50 learners that were sampled were selected to be interviewed. They were sampled according to their performance which included four learners each that achieved low, average and high marks in the pre-test. Four learners within each group were randomly selected. Table 4 represents a summary of the sample.

Table 4: Research Data Collection Plan

RESEARCH QUESTION	METHOD	INSTRUMENT	RESPONDENTS	ANALYSIS
<i>To what extent can conceptual change as a teaching strategy be used to improve learners' understanding of the quantitative aspects of chemical change?</i>				
Step 1: What was the learners' initial understanding of the quantitative aspects of chemical change?	Test	Pre-test	50 learners	Test scores
Step 2: (ii) How was the conceptual change approach implemented to improve learners' understanding of the quantitative aspects of chemical change?	Intervention lesson that was video-taping for observation purposes	Lesson plan (addressing four stages of conceptual change) to address conditions of conceptual change, namely dissatisfaction, intelligibility, plausibility and fruitfulness and observation schedule	50 learners	Observation and thick descriptions
Step 3: What was the learners' understanding of quantitative aspects of chemical change after the conceptual change approach?	Post- test	Marking memo	learners	Test scores
Step 4: What were the learner's perceptions of the conceptual change approach used in their physical sciences class?	Interviews	Interview schedule	12 selected of sample of 50 learners	Coding for themes

3.5 Data Collection Plan

The data collection process was designed based on the research sub-questions that follow and those steps are identified in Table 6 below.

(i) What was learners' initial understanding of quantitative aspects of chemical change?

The first step was a pre-test (see Appendix 8) in the form of multiple-choice questions and was used to establish learners' alternative conceptions. The pre-test is based on conceptual content of quantitative aspects of chemical change. It is a multiple-choice test with a combination of conceptual knowledge as a correct answer and alternative conceptions as distracters, because so far no test has been developed to test alternative conceptions alone. The test was also used to develop lessons for the intervention program. The pre-test had 10 multiple-choice questions with four options each.

(ii) How was the conceptual change approach implemented to improve learners' understanding of the quantitative aspects of chemical change?

The first and most significant step in teaching for conceptual change is to make learners aware of their own ideas about the topic under study. The pre-test was used to determine the learners' alternative conceptions and as a guide in the preparation of intervention lessons.

The lesson implementation followed, using the conceptual change approach. Carefully prepared lesson (Appendix 8) incorporating practical work and computer simulations to support conceptual change teaching strategies were prepared and the sample population of fifty learners taught intensively. The interactive simulations were meant to support the learners learning of the Quantitative aspects of chemical change. These simulations were selected from the PhET website <http://PhET.colorado.edu> online free distribution. The basis for their selection was the contents of the concepts selected for this study. In short, the simulations were believed to support and make learners interactive in their learning of the selected concepts for this study. These lessons involved an exposition of quantitative aspects of chemical change to allow learners to

compare their conception with the scientific knowledge. The lessons were prepared such that they meet the four conditions of conceptual change.

Lessons explored the mole concept, molar mass, stoichiometry that are involved in the Quantitative aspects of chemical change. The four conditions of conceptual change were taken into consideration when the three lessons were prepared.

Intervention in the form of a lesson plan

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 grade 11 chemical change curriculum. The contextualized approach involved laboratory and everyday experiences. An intervention lesson plan is attached as appendix 10.

Conceptual change texts were constructed by use of Posner et al.'s (1982) conceptual change model as described in Section 2.5. In the conceptual change text, the topics were introduced with questions to activate misconceptions in the students' minds, specify students' misconceptions, clarify their reasons, and explain why they are not good enough with solid examples. 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 Vygosky.

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 11. This was reinforced with the analysis of the video-tapes.

In doing the experiments, the students had to work in groups. When the students 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. According to Reid and Yang (2002) letting the learners work in groups gives them the opportunity for their previous knowledge and working memory space to be combined. 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 to make clear 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.

The use of experiments in this study was inspired by the fact that the grade 10, 11 and 12 Science 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 provides 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 the topic 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, 1983).

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 researcher filled in the observation schedule (see Appendix 10.2.5.).

(iii) What was learners' understanding of the quantitative aspects of chemical change after the conceptual change lesson?

Learners had to construct concept maps after instruction to inform the interview items to be included in the interview schedule, A list of concepts from the selected conceptual areas were provided to them in referring to the widely used standard textbooks for the grade. In addition to the concepts provided, the students were allowed to add more related concepts (if they had some) to their own concept maps. A memorandum for the concept map appears as Appendix 9.

(iv) What were learners' perceptions of the Conceptual Change Approach?

Semi-structured interviews were conducted in the researcher's school after the post-test. The interviewees were the twelve selected from the same Grade 11. The twelve learners were grouped into three focus groups of four learners. A focus group is defined as a research technique that collects qualitative data through group interaction on a topic determined by the researcher (Morgan, 1996). An interview schedule (see Appendix 10) was drawn up and face-to-face interviews conducted during lunch breaks. Interviewees were allowed to respond in the language of their choice and all responses were video-recorded. This study strengthens the data obtained with both quantitative and qualitative methods. This means, the results of the focus groups interviews help to understand the quantitative results of data collected with diagnostic pre-test and concept maps.

3.6. RESEARCH INSTRUMENTS

This research was conducted in one school with only one grade 11 physical science class. In order not to compromise the reliability and validity of the findings, the research used a variety of data collection instruments to triangulate the results.

3.6.1. Pilot Study

In order to gain a greater sense of confidence and maximum benefit from using pre and post- test, it was crucial that the instruments were piloted. The tests used in this study were first examined by my 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 science teachers from neighbouring schools. The teachers provided feedback on the clarity of, instructions and layout. Altogether four different types of instruments were used in this study.

3.6.2. Chemistry Achievement Test (CAT)

Chemistry Achievement Test (CAT) based on quantitative aspects of chemical change, which was in the form of the pre- and post-test (see Appendix 8) for determining the learners' conceptions were administered in this study. The test was developed by researcher by examining related literature, and textbooks. Items in the test were related to the concept of quantitative aspects of chemical change, in grade 11 Curriculum and Assessment Policy Statement (CAPS). The test consisted of 10 multiple choice questions, with different cognitive levels. The data collected through the CAT were analysed in terms of quantitative description. Most of the questions in the test required learners to think critically; that is, with doing some calculation and predict the correct answer where the alternatives are designed so that they reflect students' misconceptions. The tests were used to explore:

- (i) on basic concepts of quantitative aspects of chemical change
- (ii) The learners' perceptions of the lesson on basic stoichiometry.
- (iii) The learners' perceptions of the stoichiometric calculations.

3.6.3. The development of CAT

The CAT was developed to determine the learners' conceptions on quantitative aspects of 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. The multiple-choice questions (MCQ) were obtained from everyday life chemical reactions and content - based questions derived from the syllabus. These questions were designed to bring forth information about the learners' misconceptions on quantitative aspects of chemical change knowledge and reasoning. Multiple-choice questions are a diagnostic tool for identifying learners' conceptions about a given scientific subject (Soudani et. al., 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.

3.6.4 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 and/or spoken (Cohen, Manion & Morrison, 2011). Dolo (2012) further explained that an interview is an appropriate and effective method of which information can be gathered and has a direct bearing on research. An access to the information that is inside a person's head can be gathered by the researcher through the help of an interview (Takman, Cohen and Manion, 1989).

Questions asked in an interview can either be open-ended or closed (also known as fixed response questions). In an open-ended interview (unlike a close ended one), 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 to express himself/herself freely on a subject matter. Cohen & Crabtree (2006) argue 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 field work.

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 is 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 quantitative aspects of chemical change and their attitudes towards learning physical science. 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 groups 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 three groups of four learners each who participated in the research project. Respondents were asked the same basic questions in the same order, which provided consistency. An interview schedule is attached as appendix 6. 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.

3.5.1 Advantages and disadvantages of interviews and focus group interviews

Advantages of interviews.

- Interviews help the researcher to have control over the topic as well as the format of the interview.
- Prompting may be included regarding questions and if an inappropriate question asked.
- Assist the researcher to record the data on why no responses were made (David and Sutton, 2004:160)

Disadvantages of interviews

- Interviews adhering too closely to the interview guide and may be the cause of not probing for relevant information.
- Respondents may hear and interpret questions in a different manner since there is a set of interview guide (David and Sutton, 2004:161)

3.6. Data Analysis

The concept maps measure the improvement from the previous concept map according to the Crippen (2008) scoring method. The analysis of the first concept map indicated and inform the researcher the key concepts that need the lesson time. Thereafter the analysis of the follow-up concept maps indicated the same as well as whether conceptual change is taking place.

Interviews were analyzed immediately after in order to draw the necessary conclusion whilst still fresh. The process of noting key points and linkages was usually termed as 'codifying' the data and will be done by the interviewer through transcripts. This known as the open coding process which involves the breaking data down into themes (McMillan Schumacher, 2001). The final written analysis will be printed under a series of headings related to the research question

3.7 Validity and Reliability

All instruments were tested for validity and reliability to ensure that the study and the instruments measure what they purported to measure (Ogunniyi, 1992) and further what they would provide consistent results in two or more similar situations. To meet the requirements of these indices, all instruments were given to a panel consisting of ten teachers for scrutiny purposes. They were specifically required to assess:

- (i) The appropriateness of the level of language used to the target students;
- (ii) The clarity of the questions;
- (iii) Whether or not there were any overlapping questions and
- (iv) Whether or not the content was at the level of the students and measured what would be taught.

Validity

Validity refers to how well an instrument measures what it is supposed to measure. In this study the used of the detailed rubric in the form of questionnaire for the concept mapping and interview schedule for interviews to ensure the triangulation of the data.

Reliability.

Reliability is the degree to which an instrument produces stable and consistent results. According to Puiz-Primo & Shavelson (1996) reliability is a term used in research which refers to the consistency or generalization (replicable) of the research. Or in other words how the concept maps are scored and whether or not it can be done again. To ensure the reliability (Golashafsharni, 2003) the trustworthiness of the research is very important. Whereas Puiz-Primo & Shavelson (1996) to ensure the reliability of the concept map scoring, the maps were scored using an expert's map. Each learner's map will be cross-referenced with the expert's map. Colleagues in the same field will be requested to review the observation schedule for the concept mapping and the interview schedule to ensure the reliability of the research.

3.8 Research ethics.

I hereby declared that all participants in this research were voluntarily and remained anonymous. All findings, outcomes and procedures are confidential and the privacy of all the participants were not been violated. Ethical clearance for the study were obtained from the University of the Western Cape (Appendix 1) and written consent were obtained from the Eastern Cape Education Department (Appendix 3) parents, educator and school governing bodies, (Appendix 2 and appendix 4). I avoided harm in any way to the participants. Participants did not suffer any harm through my research or as result of my research.

3.9 Conclusion

This chapter examined the research methodology and techniques used in the study.

The following chapter presents the findings of the interviews conducted with the key informants to identify the criteria for a learning styles assessment instrument relevant for the effective teaching and learning of quantitative aspects of chemical change in grade 11.



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CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. INTRODUCTION

The previous chapter gave a description and focused on how the research was approached and coordinated. This chapter summarizes the findings and report on the analysis of data using both qualitative and quantitative methods. In addition to the qualitative descriptions the learner's responses to the interviews are used to elaborate on their performance on both tests. Further, the study attempted to find out the effectiveness of the conceptual change approach in facilitating the learner's understanding of quantitative aspects of chemical change. Hence, the study was aimed to answer the main research question:

To what extent can conceptual change approach as a teaching strategy improve learners' understanding of the quantitative aspects of chemical change?

The following were the research sub questions addressed to answer the main research question:

- (i) *What was the learners' initial understanding of the quantitative aspects of chemical change?*
- (ii) *How can the conceptual change approach be used to improve learners' understanding of the quantitative aspects of chemical change?*
- (iii) *What were the learner's understanding of quantitative aspects of chemical change after the conceptual change approach?*
- (iv) *What were the learner's perceptions of conceptual change approach?*

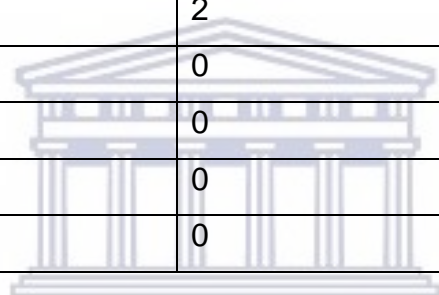
4.2. Learners' initial understanding of the quantitative aspects of chemical change

The grade 11 physical science learners were reminded of the terms on quantitative aspects of chemical change. The learners were then given a pre-test to test their

understanding of the quantitative aspects of chemical change from the previous grades. Table 6 and Figure 7 illustrate the results of the pre-test.

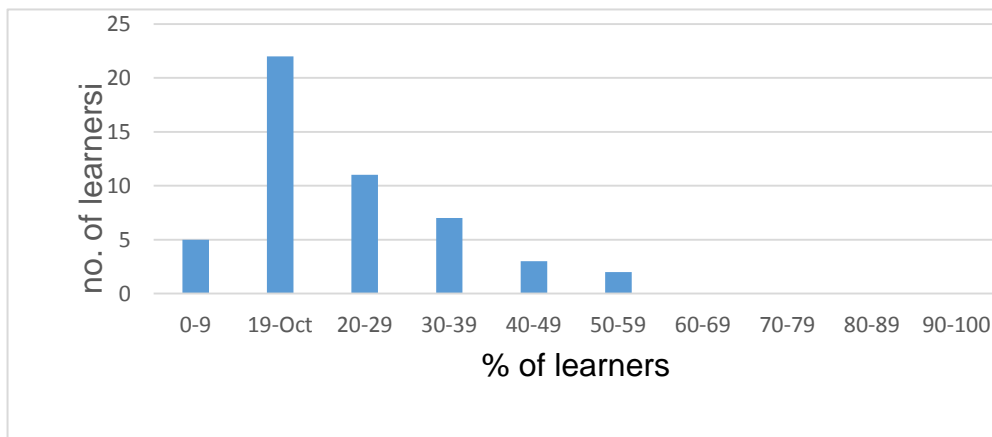
Table 5. Pre-test scores in the form of percentages.

Percentages	Learner frequency
0-9	5
10-19	22
20-29	11
30-39	7
40-49	3
50-59	2
60-69	0
70-79	0
80-89	0
90-100	0



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Figure 4. The graph of pre-test scores.



The graph shows that 90% of the learners achieved less than 40% and no learners managed to reach 60% and above. The pre-test result gave the impression that most of the grade 11 physical science learners were unable to answer the questions on the quantitative aspects of chemical change. Without further intervention to this problem, it may extend to further difficulties in this section in Grade 12. Hence the study proposed the conceptual change approach to address the problem.

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4.3. Conceptual Change Approach

Learners were taught through the conceptual change approach through the use of different approaches like relevant texts that address this section, and demonstrations that took misconceptions into account. It focused on the explanations that would maximize the plausibility and intelligibility of scientific conceptions. Conceptual change texts were prepared by the researchers (3.6) in the quantitative aspects of chemical change.

While constructing the conceptual change texts, the following points were taken into consideration:

(a) each text aimed at transforming learners' misconceptions into scientific conceptions; and

(b) it identified common misconceptions about quantitative aspects of chemical change.

These kinds of considerations suggest that there are several important conditions which

must be fulfilled before the conceptual change is likely to occur. The following four conditions put forward by Posner, Strike, Hewson & Hertzog (1982) were used to implement conceptual change:

1. Dissatisfaction: Learners must become dissatisfied with their existing concepts;
2. Intelligibility: The new concept must be intelligible;
3. Plausibility: The new concept must appear plausible; and
4. Fruitfulness: The new concept must be fruitful (Posner et al.,1982).

4.3.1. Dissatisfaction

In order for the learners to master the concept of quantitative aspects of chemical change, they need to be able to define and relate the terms around this concept. The results of the pre-test had shown very low levels of understanding of the concept. Hence, the teacher decided to use a video lesson before interaction in the form of discussions. Teacher came into the grade 11 physical science class. The teacher wrote the topic on the chalk board, quantitative aspects of chemical change. The topic was introduced by revision of grade 10 work. It started with revision of a mole concept i.e. a mole as an amount of a substance. The teacher asked a number of questions after learners viewed the video. For example: What is a substance? Learners responded as follows:

A substance is anything we can think of [Learner 1].

My pen is a substance [Learner 2]

Learners mentioned many substances like books, chairs, desks. the teacher posed a question to the learners:

What is the scientific name given to anything that occupies space?

Learners started to recall from Grade 8-10 work.

It is an atom. [learner 3]

It is a proton. [learner 5]

It is an electron. [learner 6]

Material. [learner 7]

I think it is matter. [learner8]

They were stating different answers whether correct or incorrect and their answers were written on the board. This form of discussion helped the teacher to come closer to the concept from what they know according to Bloom's taxonomy which states that the learner learns better when they learn from the known to the unknown, from the concrete concept to the abstract. Although some of the answers were not correct, they were throwing terms that were related to each other.

The teacher divided the learners into 5 groups of 10 learners each. The teacher took the learners' responses to create activity out of them. Learners were asked to construct concept maps from the terms that were written on the board. The terms were; substances, material, matter, atom, protons, electrons. The groups were given charts, Koki pens and prestik to draw their concept maps and paste them on the wall during presentations. The following concept maps were the responses from group [A] and group [C]

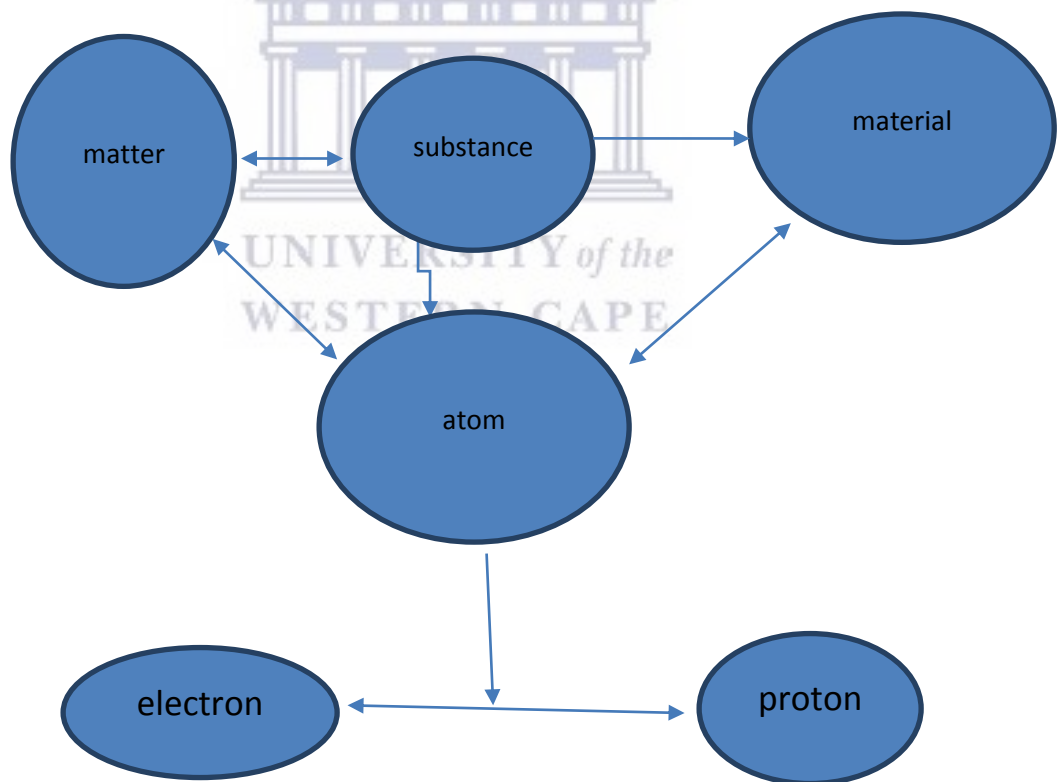


Figure 5: The concept map from group [A]

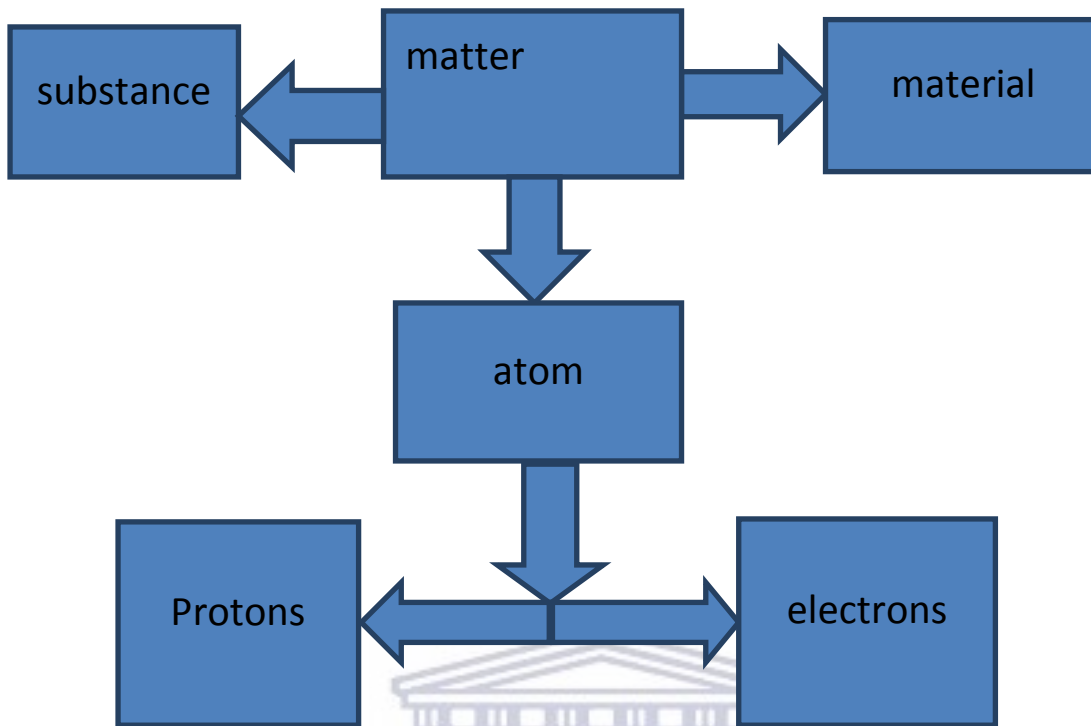


Figure 6: The concept map from group [C]

During presentation, learners were asking questions from the group that was presenting at that particular time. For example, Group D posed the following question to the class:

Why do you put matter, material and substance in the same line? [Group [D].

The other groups responded:

They have the same meaning; they are made up small particles called atoms. Atom consists of particles, electrons and protons. [Group C]

Matter is the scientific name given to anything that occupies space, matter can be classified into mixtures and pure substances. [Group A]

Pure substances are further classified as elements and compounds. The bottom line is; they are all made up of atoms. Generally, substances are made up of different materials. [Group A]

The above learner diagrams led to a discussion around matter and what constituted matter. The link between matter and atoms were debated by the two groups. In the final analysis of this activity learners who had a different understanding of the scientific view

were positively influenced towards the scientific viewpoint. They therefore became dissatisfied with their initial understanding. In order to explore further the concepts in this section the teacher started to introduce the mole concept (which learners were exposed to in the previous grade) and defined it as an amount of a substance. Learners dealt with the word substance but had difficulty with the word 'amount'? The teacher asked learners to take their dictionaries to look for the word 'amount'. They came up with different answers but with the same meaning as 'many' or quantity.

During the discussion of these terms, the learners were asked to come up with the examples of substances of which they knew the quantities. They mentioned as many like 10kg of sugar, 12,5kg of mealie meal, dozens of eggs.

How many eggs are there in one dozen of eggs? [The teacher]

There are twelve eggs in one dozen of eggs. [Group B]

How many grains of sugar are there in 10kg of sugar? [The teacher]

Mh! they are too many I cannot count them. [Group D]

How do you think they manage to pack those substances with small grains like sugar mealie meal et.'?

The question was boldly answered that they are being weighed hence they are calibrated in kg. [Group A]

The teacher explained the mole as scientific quantity of substances. Learners were given a hand-out (see Appendix 8) that was used as part of the lesson. The learners were also given periodic tables, asked to look at the elements on the periodic table. The teacher explained to the learners that sometimes it is important to know exactly how many particles (e.g. atoms or molecules) are in a sample of a substance, or what quantity of a substance is needed for a chemical reaction to take place. In one mole of any substance, there are 6.023×10^{23} particles. It means there are many particles. This is known as Avogadro's number. The teacher tried to convince the learners about the scientific concepts referring to the learner's discussions like sugar grains could be weighed to 1kg,5kg 10kg but many particles inside each pocket.

Learners indicated that they now had an understanding of what the 'mole' meant. Learners indicated that initially they had wrong understanding of the mole. For example learners indicated that:

I thought the mole had to do with the atomic number [Learner 1]

I learnt the definition of a mole but never quite understood what it meant. [Learner 2]

We could never understand what this big number (meaning Avogadro's number) meant and where it fitted in with atoms and particles. [Learner 3]

Having established an element of dissatisfaction with learners in terms of their previous understanding of key concepts such as matter, atoms, mole, Avogadro's number, the teacher continued to reinforce the scientific viewpoint through an explanation and work sheets of these concepts. Questions for discussion were given in the form of exercise. The teacher explained that this a step further, if you were to weigh out samples of a number of elements so that the mass of the sample was the same as the relative atomic mass of that element, you would find that the number of particles in each sample is 6.023×10^{23} . So, 24.31 g of magnesium (relative atomic mass = 24.31 u) for example, has the same number of atoms as 40.08 g of calcium (relative atomic mass = 40.08 u). This result is so important that scientists decided to use a special unit of measurement to define this quantity: the mole or 'mol'. A mole is defined as being an amount of a substance which contains the same number of particles as there are atoms in 12 g of carbon. In the examples that were used earlier, 24.31 g magnesium is one mole of magnesium, while 40.08 g of calcium is one mole of calcium. A mole of any substance always contains the same number of particles. The mole (abbreviation 'n') is the SI (Standard International) unit for 'amount of substance'. It is defined as the amount of substance that contains the same number of particles (atoms, molecules or other particle units) as there are atoms in 12 g carbon.

After the explanation the learners were given the worksheets to complete in their groups answers discussed in the classroom to clear their dissatisfaction.

4.3.2 Intelligibility

The individual must be able to grasp how experience can be structured to by a new concept sufficiently to explore the possibilities inherit (Posner et al 1982).

The teacher brought the apparatus into the class for learners to accommodate factors that promotes new ideas that seemed to be abstract. The teacher gave the balance scale in each group and chemical together with the filter paper. Group A was given iron fillings, Group B given magnesium powder, Group C given sulphur powder, Group D zinc powder and group E was given copper fillings. The teacher gave the worksheet to the learners to fill and periodic table as the support material.

Table 6. Complete the following table:

Element	Relative atomic mass	Sample mass	Number of moles in the sample
Iron			
Magnesium			
Copper			
Sulphur			
Zinc			

The metals were rotating among the groups so that each group to be able to fill all the spaces in the table. The teacher moved around to facilitate group work and to answer the questions that came out from the groups like,

The periodic table has got more than one number around each element, we do not know which one is correct to choose [Group E]

The teacher explained to the whole class that the number on top of the element in the periodic table stands for atomic number and the one at the bottom stands for atomic mass of that particular element. Up to this stage the teacher was trying to transfer the knowledge as the fact to the learners through discussions questions, explanations and demonstrations. Learners were directly involved and actively participating in the construction of their new scientific knowledge.

4.3.3 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.

The learners were exposed to the new scientific knowledge and the teacher had to lead the learners to the factor that would influence cognitive restructuring. The teacher tried to comprehend chemical concepts with problem solving problems using conceptual change theory. The teacher gave examples of problem solving analogically (2.2.2). The examples enhanced the learners to acquire problem solving skills that would enable them to solve higher order cognitive level questions including quantitative problems or conceptual questions that require analysis and synthesis procedure problem solving capabilities, making connections and critical evaluation thinking.

The calculation involved in the study evolved around:

Steps Involved in Solving Mass-Mass Stoichiometry Problems

- Balance the chemical equation correctly
- Using the molar mass of the given substance, convert the mass given to moles.
- Construct a molar proportion (two molar ratios set equal to each other)
- Using the molar mass of the unknown substance, convert the moles just calculated to mass.

The examples were based on steps given in the above. The learners would be able to conceptualize the problems that should be solved.



Figure 7. Analogy (theoretically)

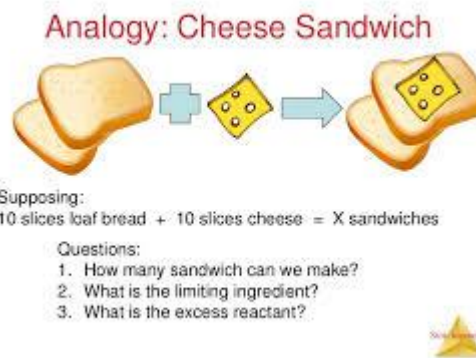


figure 8. Sandwich analogy

The teacher started to go deeper to calculations using chemical equation which was already introduced in grade 10. The teacher reminded the learners about chemical change which is taking place during chemical reactions that the new substance is being formed. Analogy, referring to figure 1 during baking the ingredients are mixed according certain amount of measurements to produce certain amount of product. It happened that one of the ingredients is in excess. for example, flour might be more than all other ingredients. It meant therefore the product depended on the ingredients that were lesser than the others. According to chemical reaction that is called limiting reactant or limiting reagent.

Learners were to answer the questions in figure 9.

Question 1

How many sandwiches that can be produced from the above scenario. There are 10 slices of bread and 10 slices of cheese, two slices of bread take 1 slice of cheese therefore 10 slices make 5 sandwiches and 5 slices of cheese will remain [Group C]

Question 2

Identify the limiting ingredient for this scenario.

Slices of bread are the limiting ingredient for the scenario [Group A]

Question 3

Which ingredient is in excess?

Cheese is in excess because there are some slices of cheese remained. [Group D]

The teacher tried to come closer to the scientific concepts by giving the examples similar to the previous activity but scientific so that learners might relate to new scientific concepts gained in previous lessons. The teacher summarized the concepts by using concept maps

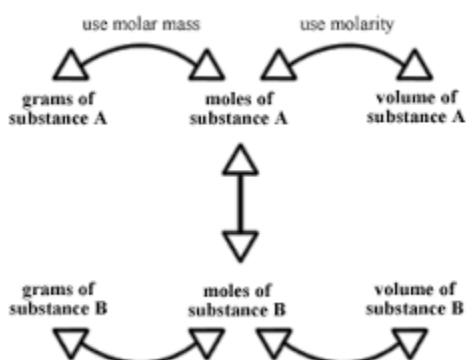


Figure 9.1. Concept map.

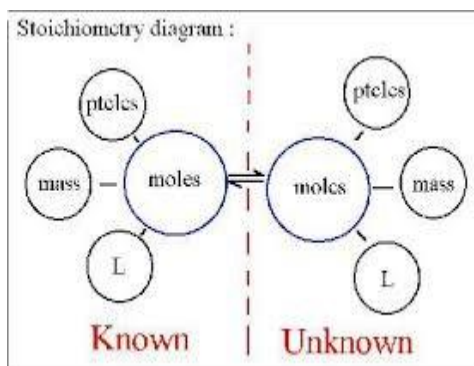


Figure 9.2. Concept map

The teacher referred to figure 10 to explain the chemical equation starting from the reactants that can be in the form of molecules or atoms. The reactants could be in the form of solid or solution hence could be termed in mass or volume Figure 10 summarises ..

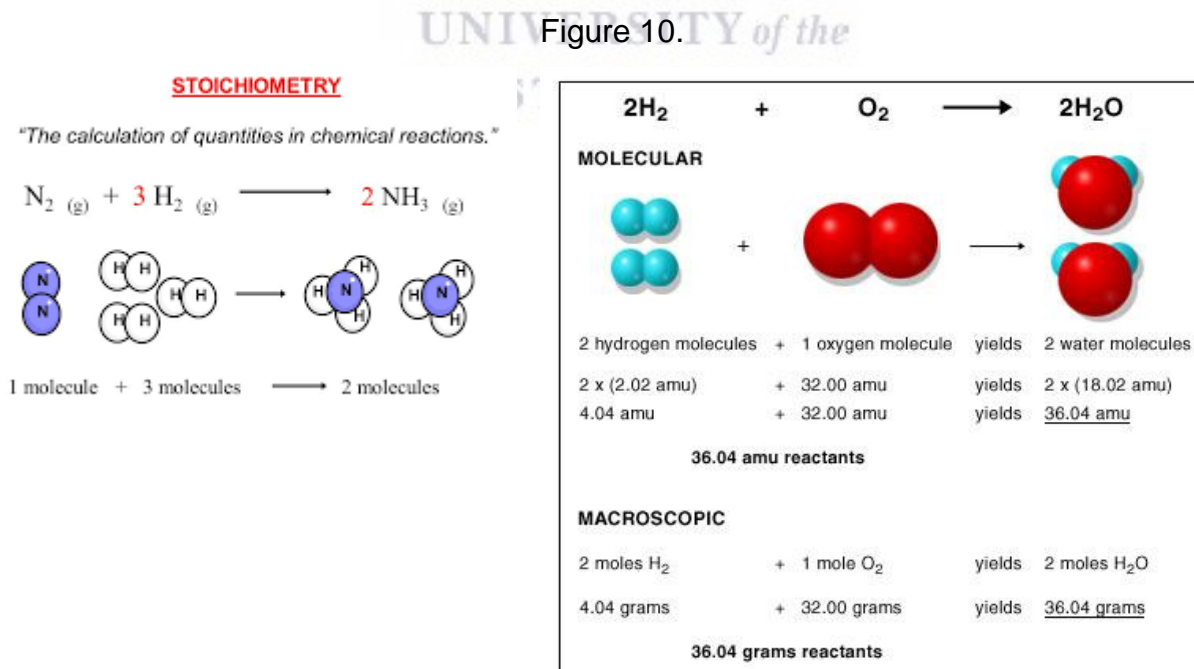


Figure 11: The model equation

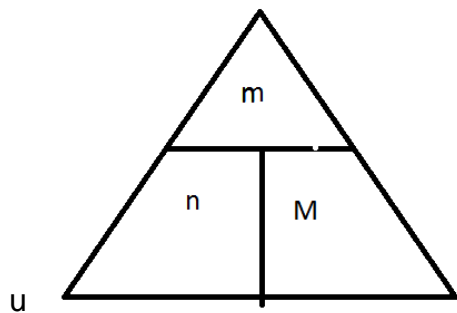
The chemical equation was shown in model form to give a clear picture of what is happening during chemical reaction when a new substance is formed from reactants. The teacher even gave the learners balloons to make models of what they see. The learners were taught about the molecules (H_2) and introduced to mole ratios in quantitative aspects of chemical change. The teacher said

it is very important to know exactly how many particles (e.g. atoms or molecules) are in a sample of a substance or what quantity of a substance is needed for a chemical reaction to take place. In the above equation one molecule of oxygen reacts with two molecules hydrogen to form two molecules of water.

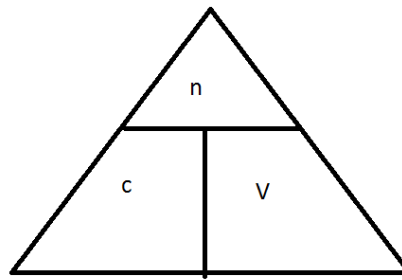
Since it is not easy to measure gasses learners were given the following chemicals Iron powder and Sulphur powder as reactants and they asked to write down a balance equation when these two chemicals react and furthermore the learners were to weigh and interpret the masses in terms of mole according to their balanced equation. They came out with $Fe + S \rightarrow FeS$. Learners weighed about 55.85g of Iron and 32g of Sulphur powder and interpreted it as one mole of Iron reacted with one mole of Sulphur to produce one mole of Iron sulphide.

The teacher continued to explain that there are various ways of calculating the quantities of substances.

The following tables are used for different stoichiometric formulae. For example, triangle 1 may help to remember the relationship between these three variables. You need to imagine that the horizontal line is like a 'division' sign and that the vertical line is like a 'multiplication' sign. So, for example, if you want to calculate 'M', the remaining two letters in the triangle are 'm' and 'n' and 'm' is above 'n' with a division sign between them. In your calculation, 'm' will be the numerator and 'n' will be the denominator'.



12.1figure



figure

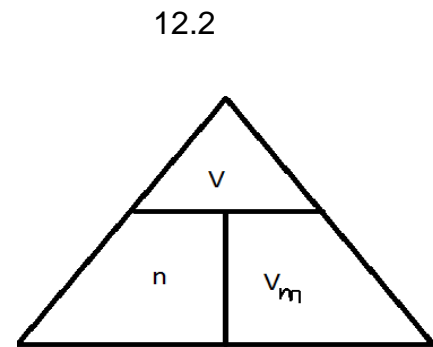


Figure 12.3

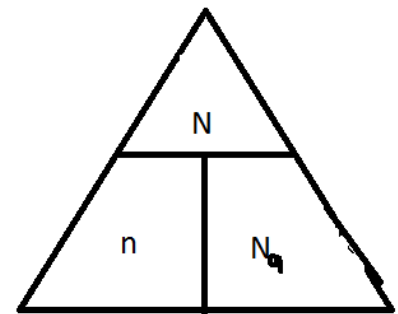


Figure 12.4

The teacher and learner used the triangles as reference to calculate mass from moles and atoms.

Worked example 1.

Question: You have a sample that contains 5 moles of zinc.

1. What is the mass of the zinc in the sample?
2. How many atoms of zinc are in the sample?

Learners were guided to follow the steps to solve the problems the step were written on the chalkboard.

Answer

Step 1. Find the molar mass of zinc. Molar mass of zinc is $65.38 \text{ g}\cdot\text{mol}^{-1}$, meaning that 1 mole of zinc has a mass of 65.38 g .

Step 2: Calculate the mass of zinc, using moles and molar mass. If 1 mole of zinc has a mass of 65.38 g , then 5 moles of zinc has a mass of $65.38 \text{ g} \times 5 \text{ mol} = 326.9 \text{ g}$ (answer to a)

Step 3 Use the number of moles of zinc and Avogadro's number to calculate the number of zinc atoms in the sample. $5 \times 6.023 \times 10^{23} = 30.115 \times 10^{23}$

There after the learners were given worksheet to complete on their own. In keeping with the Physical Sciences curriculum content the teacher provided additional exercises for learners to do taking them from simple and elementary examples to more complex problems that learners had to solve. The teacher allowed learners to discuss the problems, ask questions of each other and the teacher and continue to working towards a solution. As each stated problem involved more complex analysis, learners' application of what they learnt became more plausible to them as they could resolve issues by discussion and argumentation with each other and the teacher. The following are some other exercises that the teacher used in the lesson to assist learners in understanding the content.

Exercise: Moles and molar mass

1. Give the molar mass of each of the following elements:
(a) hydrogen (b) nitrogen (c) bromine
2. Calculate the number of moles in each of the following samples:
(a) 21.62 g of boron (B) (b) 54.94 g of manganese (Mn) (c) 100.3 g of mercury (Hg)
(d) 50 g of barium (Ba) (e) 40 g of lead (Pb)

More advanced worked examples were done in group discussions together with the teacher as a facilitator. For example, the learners were given another worked examples after they have marked the worksheet exercise. The teacher kept on trying to explain the concept of quantitative aspects of chemical change.

So far, we have only discussed moles, mass and molar mass in relation to elements. But what happens if we are dealing with a molecule or some other chemical compound? Do the same concepts and rules apply? The answer is 'yes'. However, you need to remember that all your calculations will apply to the whole molecule. So, when you calculate the molar mass of a molecule, you will need to add the molar mass of each atom in that compound. Also, the number of moles will

also apply to the whole molecule. For example, if you have one mole of nitric acid (HNO_3), it means you have 6.023×10^{23} molecules of nitric acid in the sample. This also means that there are 6.023×10^{23} atoms of hydrogen, 6.023×10^{23} atoms of nitrogen and $(3 \times 6.023 \times 10^{23})$ atoms of oxygen in the sample. In a balanced chemical equation, the number that is written in front of the element or compound, shows the mole ratio in which the reactants combine to form a product. If there are no numbers in front of the element symbol, this means the number is '1'. For example $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ (writing on the chalkboard). In this reaction, 1 mole of nitrogen reacts with 3 moles of hydrogen to produce 2 moles of ammonia.

Worked Example 2: **Calculating molar mass**

Question: Calculate the molar mass of H_2SO_4 .

Answer

Step 1: Use the periodic table to find the molar mass for each element in the molecule.

Hydrogen = 1.008 g.mol^{-1} ; Sulphur = 32.07 g.mol^{-1} ; Oxygen = 16 g.mol^{-1}

Step 2: Add the molar masses of each atom in the molecule $M(\text{H}_2\text{SO}_4) = (2 \times 1.008) + (32.07) + (4 \times 16) = 98.09 \text{ g.mol}^{-1}$

The learners were able to calculate molar masses since this was dealt with in the previous grade. The teacher worked from known to unknown.

Worked Example 3: **Calculating moles from mass**

Question: Calculate the number of moles there are in 1kg of MgCl_2 .

Answer

Step 1 : Write the equation for calculating the number of moles in the sample. $n = m/M$

Step 2 : Calculate the values that you will need, to substitute into the equation

1. Convert mass into grams $m = 1\text{kg} \times 1000 = 1000\text{g}$

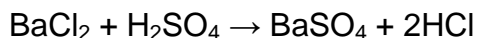
2. Calculate the molar mass of MgCl_2 . $M(\text{MgCl}_2) = 24.31 + (2 \times 35.45) = 95.21 \text{ g.mol}^{-1}$

Step 3: Substitute values into the equation: $n = 1000/ 95.21 = 10.5\text{mol}$. There are 10.5 moles of magnesium chloride in a 1 kg sample.

The learners were working easier with the help of the triangles also referring to the concept maps in figure 1 and 2.

Worked Example:4. Calculating the mass of reactants and products

Question: Barium chloride and sulphuric acid react according to the following equation to produce barium sulphate and hydrochloric acid.



If you have 2 g of BaCl_2 ...

1. What quantity (in g) of H_2SO_4 will you need for the reaction so that all the barium chloride is used up?
2. What mass of HCl is produced during the reaction?

Answer

Step 1 : Calculate the number of moles of BaCl_2 that react. $n = \frac{2}{208.24} = 0.0096 \text{ mol}$

Step 2: Determine how many moles of H_2SO_4 are needed for the reaction. According to the balanced equation, 1 mole of BaCl_2 will react with 1 mole of H_2SO_4 . Therefore, if 0.0096 moles of BaCl_2 react, then there must be the same number of moles of H_2SO_4 that react because their mole ratio is 1:1.

Step 3: Calculate the mass of H_2SO_4 that is needed. $m = n \times M = 0.0096 \times 98.086 = 0.94 \text{ g}$
(answer to 1)

Step 4: Determine the number of moles of HCl produced.

According to the balanced equation, 2 moles of HCl are produced for every 1 mole of the two reactants. Therefore, the number of moles of HCl produced is (2×0.0096) , which equals 0.0192 moles.

Step 5: Calculate the mass of HCl.

$$m = n \times M = 0.0192 \times 35.73 = 0.69 \text{ g}$$

Learners were given more complex stoichiometric calculations but before they work on their own the teacher went through with them in some examples. The teacher emphasised the importance of balancing the equation during stoichiometric calculations. The teacher said:

by knowing the ratios of substances in a reaction, it is possible to use stoichiometry to calculate the amount of reactants and products that are involved in the reaction. Some examples are shown below.

Worked Example 5: **Stoichiometric calculation 1**

Question: What volume of oxygen at S.T.P. is needed for the complete combustion of 2dm³ of propane (C₃H₈)? (Hint: CO₂ and H₂O are the products in this reaction)

Answer

Step 1: Write a balanced equation for the reaction. $\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$

Step 2: Determine the ratio of oxygen to propane that is needed for the reaction.

From the balanced equation, the ratio of oxygen to propane in the reactants is 5:1.

Step 3: Determine the volume of oxygen needed for the reaction.

1 volume of propane needs 5 volumes of oxygen, therefore 2 dm³ of propane will need 10 dm³ of oxygen for the reaction to proceed to completion.

Worked Example 6: **Stoichiometric calculation 2**

Question: What mass of iron (II) sulphide is formed when 5.6 g of iron is completely reacted with Sulphur?

Answer

Step 1: Write a balanced chemical equation for the reaction. $\text{Fe}(\text{s}) + \text{S}(\text{s}) \rightarrow \text{FeS}(\text{s})$

Step 2: Calculate the number of moles of iron that react. $n = m/M = 5.6/55.85 = 0.1\text{mol}$

Step 3: Determine the number of moles of FeS produced. From the equation 1 mole of Fe gives 1 mole of FeS. Therefore, 0.1 moles of iron in the reactants will give 0.1 moles of iron sulphide in the product.

Step 4: Calculate the mass of iron sulphide formed $m = n \times M = 0.1 \times 87.911 = 8.79\text{g}$

The mass of iron (II) sulphide that is produced during this reaction is 8.79 g.

The teacher pointed out that:

A closer look at the previous worked example shows that 5.6 g of iron is needed to produce 8.79 g of iron (II) sulphide. The amount of sulphur that is needed in the reactants is 3.2g. What would happen if the amount of sulphur in the reactants was increased to 6.4 g but the amount of iron was still 5.6 g? Would more FeS be produced?

The teacher gave examples and exercises in order to ensure that the concepts of the study are more plausible to the learners through various scenarios and past examination questions because this concept (quantitative aspect of chemical change) is broad with many topics.

4.3.4 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 new concept should suggest the possibility of a fruitful research programme. It should have potential to be extended to open up areas of research linking to the real world situation. To answer the question in worked example 8, learners were referred by the teacher to figure 2, the analogy of sandwiches and relate that scenario with the scientific scenario. One of the learners quickly put the hand up, and indicated that:

if much sulphur is added to the system, the amount of iron (II) sulphide will not increase because there is not enough iron to react with the additional sulphur in the reactants to produce more FeS. When all the iron is used up the reaction stops.
[G1L3]

In this example, the iron is called the limiting reagent. Because there is more Sulphur that can be used in the reaction, it is called the excess reagent. [Teacher]

At that stage the learners the learners were ready to link the scientific knowledge with the real world situation, but the teacher had to make sure by giving more examples for group discussion. Learners were highly participating voluntarily writing answers on the chalkboard, enthusiastically discussing them, with the teacher being the facilitator of the process. Learners were given worksheets as individual work.

Exercise: Stoichiometry related to world situation

1. Diborane, B_2H_6 , was once considered for use as a rocket fuel. The combustion reaction for diborane is $B_2H_6(g) + 3O_2(l) \rightarrow 2HBO_2(g) + 2H_2O(l)$

If we react 2.37 grams of diborane, how many grams of water would we expect to produce?

2. Sodium azide is a commonly used compound in airbags. When triggered, it has the following reaction: $2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$. If 23.4 grams of sodium azide are reacted, how many moles of nitrogen gas would we expect to produce?

3. Photosynthesis is a chemical reaction that is vital to the existence of life on Earth. During photosynthesis, plants and bacteria convert carbon dioxide gas, liquid water, and light into glucose ($C_6H_{12}O_6$) and oxygen gas.

(a) Write down the equation for the photosynthesis reaction.

(b) Balance the equation.

(c) If 3 moles of carbon dioxide are used up in the photosynthesis reaction, what mass of glucose will be produced?

The teacher explained further the necessity of the concept of quantitative aspects of chemical change that the industries depend on it in order to know if they are productive or not.

4.4. Learners' understanding of quantitative aspects of chemical change after the intervention

The post-test was similar to 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 6 and figure 4)

The purpose of the pre-test was to determine the nature of grade 11 physical science misconceptions in quantitative aspects of chemical change. This was necessary to know what strategy could be useful to overcome their misconception of the concept. In that regard sampled grade 11 physical science learners were exposed to three-weeks lesson intervention programme using conceptual change approach as an instructional strategy. (mentioned in question 4.3) above.

TABLE 7. Post -Test. Results.

%	Post- test
0-9	2
10-19	3
20-29	5
30-39	5
40-49	7
50-59	6
60-69	7
70-79	10
80-89	4
90-100	3

A close examination of table 11 reveals that the results were positively influenced by the intervention process. 60% of the learners obtained more than 50% meaning that more

learners had understood the concept. Only 20% obtained less than 30% .10% obtained between 30% and 40%.

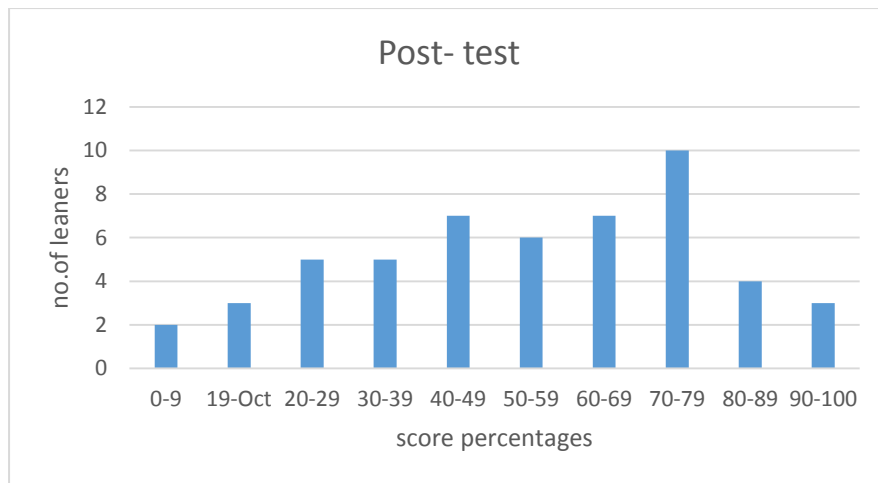


Figure 13. post test results

4.5 Comparing pre-test and post-test results

The Alternative Conceptions about quantitative aspects of chemical change 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 24% and that of the post-test was 80%. The results show that there was an improvement in the results from the pre-test to the post-test, after they have been taught by Conceptual Change approach. These findings showed that learners revealed significantly higher performance levels in the post-test than in the pre-test. The results of the pre-test and the post-test were analysed and illustrated by Table 12 and Figure 15.

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 quantitative aspects of chemical change even after the intervention.

Table 9. Comparison of pre- and post-test results.

	PRE-TEST	POST –TEST
%	Number of learners	Number of learners
0-9	5	2
10-19	22	3
20-29	11	5
30-39	7	5
40-49	3	7
50-59	2	6
60-69	0	5
70-79	0	10
80-89	0	4
90-100	0	3

Comparison of the pre-test and post-test shows a clear picture of what had really happened. The results in table 10 above show that before the intervention, almost all the learners had misconceptions about quantitative aspects of chemical change. It elevated a great concern to the researcher as it is examinable in grade 12, each and every topic in the chemistry paper consists of this concept, (quantitative aspects of chemical change). The results from the table, is evident that only 5 learners who obtained levels 3 and above, 2 learners obtained level 4 and 3 learner obtained level 3 who This is evident that 90% of the learners came to class with misconceptions with regard to quantitative aspects of chemical change.

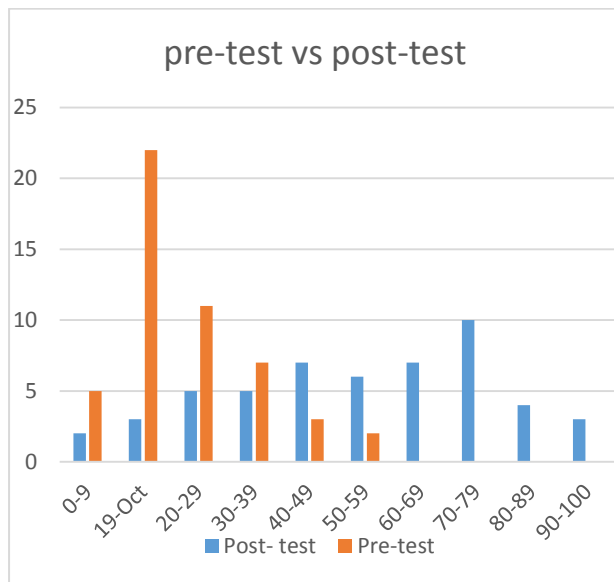


Figure 14. Performance of Learners in terms of levels in a pre-test and a post-test

Figure 15 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 from pre-test to post-test and the number of learners who obtained higher percentage decreased. There were 38 learners who obtained level 1 in a pre-test as compared 13 learners who obtained level 1 in the post test, 7 learners obtained level 2 in a pre-test whereas only 5 learners obtained level 2 in a post test. 3 learners obtained level 3 in the pre-test and 4 learners obtained level 5 in the post-test. 2 learners obtained level 4 in the pre-test but 6 learners obtained level 4 in the post-test. No learners obtained level 5, 6, 7 in the pre-test but 7 learners obtained level 5, 10 learners obtained level 6 and 7 learners obtained level 7. That means, the level of learners' previous knowledge in quantitative aspects of chemical change was generally low before the intervention. When comparing pre-test and the post-test, there were about 15 learners who underperformed even after the intervention those got level 2 and below in both tests, this indicates that these 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 their misconceptions

about quantitative aspects of chemical change. The number of learners who obtained level 7 increased from zero in a pre-test to 7 in a post-test. This shows that after the intervention, most learners were dissatisfied with their initial conceptions about quantitative aspects of chemical change. When post-test scores were compared with corresponding pre-test scores, there was a considerable improvement in learners' understanding and achievement of the quantitative aspects of chemical change.

4.6 Analyses of learners' perceptions to the interview questions.

In this study, focus group interviews were conducted with 12 grade 11 physical science learners. Learners were divided into three groups. Three groups had 4 learners each and were code as (FL). The purpose of the interviews was to find the experience gained by learners during the intervention. The learners were a mixture of high-, medium-, and low-achievers in the group of fifty learners.

4.6.1 Attitude of learners towards taking physical science as a subject of specialisation at school

With regard to attitudes of learners towards taking physical science as a subject of specialisation, learners showed a positive attitude. During interviews, learners were asked whether Physical Science 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 science 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:

After you have taught us, I realised that physical science is not a difficult subject. [Learner 12]

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. [Learner 1]

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 living in rural areas, the subject appears more challenging. For example, he said “For us living 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 Science because when you have Physical science, there are lot of opportunities like engineering and biomedical science”.

4.6.2 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 themes were obtained: activities, experiments, learner participation, group activities, writing activities and preference of approach.

Table 8 The distribution of the number (percentages) of learners across the themes identified from interviews

THEMES	NUMBER OF LEARNERS (PERCENTAGE)
Activities and Experiments	50(100%)
Learner Participation and group Activities	50(100%)
Writing Activities and Preference Approach	50(100%)

4.6.3 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.
[Focus group 1, Learner 5]

Another 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. [F2L3]

All learners stated that they usually take notes, but this time they wrote laboratory reports which increased their knowledge retention.

4.6.4 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 [F1L4]

Some learners stated that group activities increase their friendship, participation in class and social skills.

4.6.5 Writing activities and Preference approach

Learners compared writing activities during their learning. They stated that they usually write down notes that the teacher writes on the board when their teacher taught them but in this lesson they have learnt to write and answer questions. 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 and could ask questions while I was writing, I learnt more [F2L7]

Another learner expressed that

I enjoyed writing by myself and being able to ask questions to improve my understanding [F2L9]

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.

4.7 Learners' perceptions of the conceptual change approach

After the post-test, focus group interviews were used to examine learners' understanding in detail. Interviews were conducted to examine learners' ideas about quantitative aspects of 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 given concepts and were asked to make concept maps, they could not relate the concepts of quantitative aspects 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. [Learner 4]

The other learner said

I understood all what you taught us in this lesson. The lesson was interesting and we enjoyed the lesson. The concepts were more understandable, and we are not going to forget them easily. [Learner 2]

Learners stated experiments, group work, (discussions), playing with concepts during concept mapping 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. The following are the answers given by some of the learners. 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 experiment and demonstrations we did in class. That motivated me a lot and made me to realise that physical science is not difficult. [G1L2]

Improvement in learners' attitudes towards chemistry were supported by the previous studies (Günel et al., 2010; Erkol et al., 2008, Kabatas et al., 2008). Students' 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 student achievement in science significantly influences their attitudes toward science (Park et al., 2009). Interview and posttest results revealed that some learners still have some misconceptions after the intervention.

4.8 Conclusion

The results obtained in this chapter showed that instruction based on conceptual change approach caused significantly better attainment of concepts related to quantitative aspects

of 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 clear 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. The results of the study support the results obtained in the previous studies (Hewson & Hewson, 1983, Beeth, 1993, Suits, 2000, Sanger & Greenbowe, 1997, Eryilmaz, 2002, Niaz, 2002, Ayah, 2004, Ceylan, 2004, Piquette & Heikkinen, 2005). As a summary of the findings from the study, one can say that conceptual change texts are very efficient in detecting and overcoming learners' misconception problem.



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CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1. 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 approach accompanied by concept mapping as tool can be used to improve learners' understanding of quantitative aspects of chemical change in a grade 11 physical science learners using.

5.2. Overview of the scope of the study

In Chapter one the background and content of the study were presented. 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. On the other hand, physical sciences have been a problem nationally and internationally with poor learner performance. Statistics related to the pass rate of grade 12 South African learners with regard to physical sciences showed a decline in the number of learners taking physical sciences and learner performance, as mentioned in Chapter 1, (table 1 and 2 and figure 1 and 2). It is therefore, most important that research be conducted to address the issue of poor performance in physical sciences. To address these problems, it is imperative to highlight the factors that might lead to the poor performance of physical science as speculated by the research study. The Chapter highlights the research problem and identifies the research questions used in this study.

In Chapter two 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 quantitative aspects of chemical change or any other subject matter in chemistry. 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 chapter highlighted the theoretical frameworks used as foundation. This study was underpinned by the conceptual change theory by Posner et al (1982) and the 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. The chapter also identified previous studies that were relevant to the research as a means to reflect on the findings of this study compared to findings of other researchers in this field.

Chapter 3 provided the methodology for the research. The sample of learners who participated in this study were grade 11 learners taking Physical Science in a school in one of the districts in the Eastern Cape Province. In this 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 research, 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 used in this study to ensure triangulation and clarification of the results. Triangulation was used in this study in gathering data in order to strengthen the findings and to prove their trustworthiness. All instruments were piloted for validity and reliability to ensure that the study and the instruments measure what they supposed to measure. Maximum efforts have been made to ensure adherence to the necessary ethical standards.

Chapter four presented the findings and discussion of the research data. It provided an outline of the data collected to answer the research questions and presented a discussion of the findings based on the purpose of the research.

5.3. 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: *To what extent can*

conceptual change approach as a teaching strategy improve learners' understanding of the quantitative aspects of chemical change?

Emanated from the overall objective of the study were the research sub-questions outlined below: What were the learners initial understanding of quantitative aspects of the chemical change?

- *How can the conceptual change approach be used to teach the concept of quantitative aspects of chemical change?*
- *What were the learners understanding of quantitative aspects of chemical change after the conceptual change approach?*
- *What were the learners' perception after the conceptual change approach?*

5.3.1. What are learners' initial understanding of quantitative aspects of chemical change?

To answer this research question, learners were first given a pre-test. Data analysis from the first part exposed a pattern of misconceptions that learners had with respect to quantitative aspects of chemical change. The most predominant misconceptions among learners were shown by analysis of results of the pre-test

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 50) learners obtained 24% and below composed of 76% of the sample (see figure 4).

5.3.2. To what extent can conceptual change approach as a teaching strategy improve learners' understanding of the quantitative aspects 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.

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 achievement 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 (Dole & Niederhauser, 1990; Hynd & Alverman, 1986; Guzetti et al., 1993; Basili & Sanford, 1991; Ebenezer & Gaskell, 1995, Hewson & Hewson, 1983, Eryilmaz ,2002, Pekmez,2002, Ayhan, 2004, Ceylan, 2004, Piquette & Heikkinen, (92005). 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.

5.3.3. 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 difference between learners' pre-test (24%) and post-test (80%) 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 an increase on learners' understanding of scientific conceptions instructed using Conceptual Change Framework.

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

To answer this research question, learners were interviewed. During interviews, more than 80% 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 quantitative aspects of chemical reactions.

5.4. 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. 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, syllabi should be developed and implemented to ensure that all learners can have the opportunity to learn and understand concepts difficult to understand such as stoichiometry.

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 quantitative aspects 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 individuality during a matter transformation.

Development of learners' understanding of quantitative aspects 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 et al., 1995). In order to enhance learners' conceptual understanding of quantitative aspects 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 quantitative aspects of chemical change concepts at grade 11 enhances learners' understanding of questions based on stoichiometric calculations which are appearing across the chemistry question paper during final examination including chemical equilibrium concepts, 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 establishing 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 (Pinarbaşı 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 (CCA) 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 (CCT) 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 Science, 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.

5.5. Limitations of the study

The study was conducted in one school and therefore a case study. It was limited to 50 learners doing Physical Science in one high school only indicating a small proportion of the population. The results for the study are generalised only for one school and not for other schools. The school where the study was performed is at deep rural remote area, most of the parents are illiterate

The school had insufficient Physical Science 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.

5.6. Recommendations for future studies

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

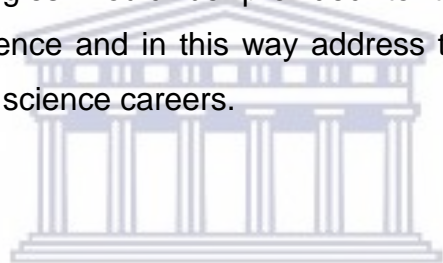
1. Similar research studies can be conducted with a larger sample size and in different high schools for the comprehensive view of the findings to a larger population.
2. The Conceptual Change Approach can be implemented for different grades and different subjects.
3. The Conceptual Change Approach can be used for teaching different science topics.
4. 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.
5. Different teaching strategies based on CCA can be employed to remediate learners' misconceptions.

6. Further research in determining unexpected misconceptions and effective techniques for changing these concepts could be done.

5.7. 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.

The study provided an exposition of how conceptual change as a teaching strategy could be used to teach challenging topics in Physical science. It is hoped that through studies like this pedagogical strategies would be provided to teachers to improve learners' achievement in Physical science and in this way address the national challenge that the country faces in science and science careers.



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APPENDIX 1:**University of the Western Cape**

Faculty of Education, Private Bag X17, Bellville, South Africa

Background information sheet

Dear Sir/Madam,

My name is Ginyigazi zanele, a Masters student in SSME Department of the Faculty of Education at the University of the Western Cape. I am conducting research on teaching the quantitative aspects of Chemical Change using a Conceptual Change Approach

Research Title: teaching the quantitative aspects of chemical change using a conceptual change approach the research study is guided by the following research questions: What is the impact of conceptual change approach in the teaching of the quantitative aspects of chemical change?

The research participants will comprise one class of grade 11 physical science learners. Data collection will be in the form of tests and interviews. Participation in this study is voluntary. Participants have the right to withdraw from the research at any stage of the research process without having to give any explanations. Participants are guaranteed utmost confidentiality regarding all information collected from them. Pseudonyms or a system of coding will be used to protect their identity.

Should you wish to find out more about the research, you are welcome to contact my supervisor, Professor M,S.Hartley whose contact details are provided below or indeed me.

Yours sincerely

Researcher: Mrs: Ginyiazi Zanele

Supervisor: Prof. M.S.Hartley

Contact number: 073799 0488

Tel. 021-9592680

Email: ginyigazi@mail.com

Email: shartley@uwc.ac.za

Signature of the researcher: Date:.....



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APPENDIX 2: PERMISSION LETTER



University of the Western Cape

Faculty of Education, Private Bag X17, Bellville, South Africa

THE EASTERN CAPE EDUCATION DEPARTMENT (WCED)



UNIVERSITY *of the*
WESTERN CAPE

X SECONDARY School
POBOX631
LADY FRERE
5410

The Research Director
EASTERN Cape Education Department
P/B X0032
Bisho

Dear _Sir_____

Re: Permission to conduct research at X School

My name is Zanele Ginyigazi, a Masters student in the SSME Department of the Faculty of Education at the University of the Western Cape. . I am conducting a research on the impact of conceptual change approach in the teaching of the quantitative aspects of chemical change. The target group will be the Grade 11 Physical Science learners.

I would like to request your permission to observe Grade 11 learners' in the physical science class. I also request your permission to interview the Grade 11 learners.

The research will not interfere in any way with the functioning of the school or with learning in the classroom. In addition, participation will be voluntary and so participants will be free to withdraw at any time without giving reasons should they feel uncomfortable with my research. Their participation in the study will remain anonymous. Information received as part of the study will be used for research purposes only. It will not be used in any public platform for any purposes other than educational.

Should you wish to find out more about the research, you are welcome to contact my supervisor, Professor Hartley, whose contact details are provided below or indeed me.

Yours sincerely,

Researcher: Mrs.zanel Ginyiazi

Supervisor: Prof. M.S. Hartley

Tel.0737990488

Tel. 021-5952680

Email: ginyigazi@gmail.com

Email: shartley@uwc.ac.za

Signature of the researcher: Date:.....

APPENDIX 3: PERMISSION LETTER TO



University of the Western Cape

Faculty of Education, Private Bag X17, Bellville, South Africa

THE PRINCIPAL X SECONDARY SCHOOL

X Secondary school
PO BOX 631
LADY FRERE



UNIVERSITY of the
WESTERN CAPE

Dear __Sir_____

Re: Permission to conduct research in your School

My name is Zanele Ginyigazi a Masters student in the School of Science and Maths Education Department of the Faculty of Education at the University of the Western Cape. I am conducting a research on the impact of conceptual change approach in the teaching of the quantitative aspects of chemical change. The target group will be the Grade 11 Physical Science learners.

I would like to request your permission to observe Grade 11 learners in the physical science class. I also request your permission to interview the Grade 11 learners.

The research will not interfere in any way with the functioning of the school or with learning in the classroom. In addition, participation will be voluntary and so participants will be free to withdraw at any time without giving reasons should they feel uncomfortable with my research. Your participation and that of the learners in the study will remain anonymous. Information received as part of the study will be used for research purposes only. It will not be used in any public platform for any purposes other than educational purposes.

Should you wish to find out more about the research, you are welcome to contact my supervisor, Professor Hartley, whose contact details are provided below or indeed me.

Yours sincerely,

Researcher: Mrs.zanele Ginyigazi

Supervisor: Prof. M.S.Hartley

Contact number: 0737990488

Tel. 021-9592680

Email: ginyigazi @mail.com

Email: shartley@uwc.ac.za



Signature of the researcher: Date:.....

APPENDIX 4: PERMISSION LETTER



University of the Western Cape

Faculty of Education, Private Bag X17, Bellville, South Africa

THE PARENTS

X Secondary School

PO BOX 631

LADY FRERE

5410

Dear Sir/Madam_____



UNIVERSITY of the
WESTERN CAPE

Re: Permission for your child's participation in a research

My name is Zanele Ginyigazi a Masters student in the School of Science and Maths Education Department of the Faculty of Education at the University of the Western Cape. I am conducting research on the impact of conceptual change approach in the teaching of the quantitative aspects of chemical change. The target group will be your Grade 11 Physical Sciences learners.

I would like to request your permission to use your child in the physical science class in the research on conceptual change approach. I would also like to observe her/his written

activities and interview him/her about their experiences on learning physical science on the quantitative approach of chemical change.

The research will not disrupt the class schedules or teaching and learning in the classroom. In addition, participation will be voluntary, so participants will be free to withdraw at any time without giving reasons should they feel uncomfortable with my research. The identity of the learners in the study will remain anonymous. Information received as part of the study will be used for research purposes only. It will not be used in any public platform for any purposes other than educational purposes.

Should you wish to find out more about the research, you are welcome to contact my supervisor, Professor Hartley, whose contact details are provided below or indeed me.

Yours sincerely,

Researcher: Mrs Zanele Ginyigazi

Supervisor: Prof. Hartley

Contact number: 0737990488

Tel. 021-9592650/2442

Email: ginyigazi@gmail.com

Email: shartley@uwc.ac.za



Signature of the researcher: Date:.....

Appendix 5: Participants 'Informed Consent form:**University of the Western Cape**

Faculty of Education, Private Bag X17, Bellville, South
Africa

I agree to be part of the study and I am aware that my participation in this study is voluntary. If, for any reason, I wish to stop being part of the study, I may do so without having to give an explanation. I understand the intent and purpose of this study.

I am aware the data will be used for a Master's thesis and a research paper. I have the right to review, comment on, and/or withdraw information prior to the paper's submission. The data gathered in this study are confidential and anonymous with respect to my personal identity, unless I specify or indicate otherwise. In the case of classroom observations and interviews, I have been promised that my personal identity and that of the school will be protected, and that my duties will not be disrupted by the researcher.

I have read and understood the above information. I give my consent to participate in the study.

Participant's signature

Date

Researcher's signature

Date

Appendix 6**Interview Schedule: Ginyigazi Zanele****Study Title:** The impact of conceptual change approach in the teaching of the quantitative aspects of chemical change.**Interviews with learners (Grade 11)**

Interviewee _____ Date _____

Age _____ Home Language _____

Gender _____

Education Background _____

Village/Place _____

Time of Interview _____

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Duration of Interview _____

1. Why did you choose physical science as your learning subject?
2. How did your teacher explain the concepts of quantitative aspects of chemical change in grade 10? (E.g. mole, molar masses etc.)
3. How often do you have class discussions where you were able to share ideas?
4. Before you were exposed to this lesson were you able to link the relationship between the concepts of quantitative aspects of chemical change?

5. Now that you are exposed to the new approach. Will you be able to link the concepts?

6. Has the new approach made any difference in your understanding of this topic?

7. Will you recommend it to be used in other topics? why do you say so?



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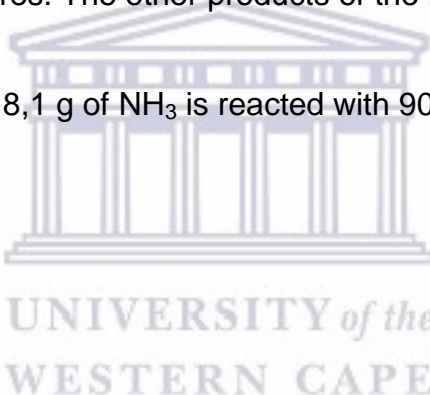
Appendix 7

Pre-test

CHEMICAL AND PHYSICAL CHANGE - 1

1.	<p>Given the balanced equation:</p> $2\text{Na} + \text{S} \rightarrow \square \text{Na}_2\text{S}$ <p>What is the total number of mole of S that reacted when 4 mole of Na completely reacted?</p> <p>A. 1 mol B. 2 mol C. 0,5 mol D. 4 mol</p>
2.	<p>Which compound contains the greatest percentage of chlorine by mass?</p> <p>A. HCl B. FeCl₂ C. NaCl D. ZnCl₂</p>
3.	<p>A compound consists of 25,9% nitrogen and 74,1% oxygen by mass. What is the empirical formula of the compound?</p> <p>A. NO B. N₂O C. NO₂ D. N₂O₅</p>
4.	<p>During a reaction, glucose, C₆H₁₂O₆(s), reacts with oxygen gas to form carbon dioxide gas and hydrogen gas.</p>

	<p>How many mol of $C_6H_{12}O_6(s)$ are needed to produce 24 mole of carbon dioxide?</p> <p>A. 1 mol B. 4 mol C. 12 mol D. 24 mol</p>
5.	<p>Given the reaction:</p> $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ <p>What is the total number of dm^3 of $O_2(g)$ at STP needed to produce $6,02 \times 10^{23}$ molecules of $H_2O(l)$?</p> <p>A. 11,2 B. 22,4 C. 33,6 D. 44,8</p>
6.	<p>What is the empirical formula of a compound that contains 28% iron, 24% sulphur, and 48% oxygen by mass?</p> <p>A. $FeSO_3$ B. $Fe_2(SO_3)_3$ C. $FeSO_4$ D. $Fe_2(SO_4)_3$</p>

7.	<p>Consider the following chemical reaction represented by the following equation:</p> $\text{CH}_4(\text{g}) + 2 \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2 \text{H}_2\text{O} (\ell)$ <p>The volume of oxygen required for the complete combustion of 16 dm³ of methane (CH₄), at a given temperature and pressure, is _____ dm³.</p> <p>A. 8 B. 16 C. 32 D. 44,8</p>
8.	<p>Nitrogen gas can be prepared by passing gaseous ammonia over solid copper (II) oxide at high temperatures. The other products of the reaction are solid copper and water vapour.</p> <p>If a sample containing 18,1 g of NH₃ is reacted with 90,4 g of CuO, how many gram of N₂ will be formed?</p> <p>A. 10,64 B. 14,84 C. 31,92 D. 61,6</p> 
9.	<p>Which of the following represent the largest number of molecules?</p> <p>A. 10g CH₃Cl B. 10g CH₄ C. 10g CCl₄ D. 10g C₂H₆.</p>
10.	<p>Silver nitrate, AgNO₃, reacts with iron (III) chloride, FeCl₃, to give silver chloride, AgCl, and iron (III) nitrate, Fe(NO₃)₃. In a particular experiment, it was planned to mix a solution containing 25 g of AgNO₃ with another solution containing 45 g of FeCl₃.</p> <p>What is the maximum number of gram of AgCl that could be obtained?</p> <p>A. 13,25</p>

	B. 21,09 C. 50,26 D. 119,25
--	-----------------------------------

CHEMICAL CHANGE - 1**ANSWERS:**

1. **B**
2. **A**
3. **D**
4. **B**
5. **A**
6. **D**
7. **C**
8. **A**
9. **B**
10. **B**



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Appendix 8

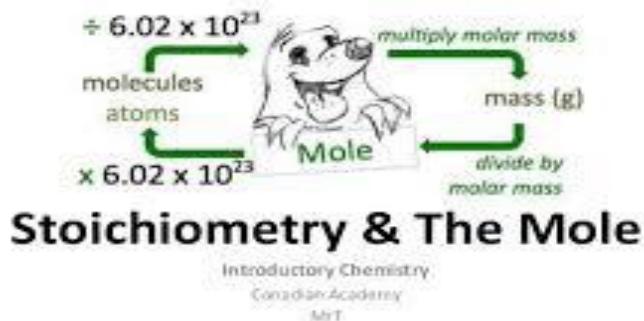


Figure 7

Definition: Avogadro constant the number of particles in a mole, equal to 6.023×10^{23} . It is also sometimes referred to as the number of atoms in 12 g of carbon-12. Interesting fact. The teacher referred to the periodic table trying to explain what is in the table. Further explaining that unlike the answer which was given by the learner in group [4] the sample contains as many particles as Avogadro's number.

Table 7. Table showing the relationship between the sample mass, the relative atomic mass and the number of atoms in a sample, for a number of elements.

	The sample mass	the relative atomic mass	Number of atoms in a sample
Hydrogen	1.01	1.01	6.023×10^{23}
Carbon	12.01	12.01	6.023×10^{23}
Magnesium	24.07	24.07	6.023×10^{23}
Sulphur	32.07	32.07	6.023×10^{23}
Calcium	40.08	40.08	6.023×10^{23}

Table 8: The relationship between relative atomic mass, molar mass and the mass of one mole for a number of elements. Element Relative atomic mass (u)
Molar mass (g.mol)

Elements	Relative masses	Molar mass	mass of one mole of element
Magnesium	24.31	24.31	24.31
Lithium	6.94	6.94	6.94
Oxygen	16	16	16
Nitrogen	14.01	14.01	14.01
Iron	55.85	55.85	55.85

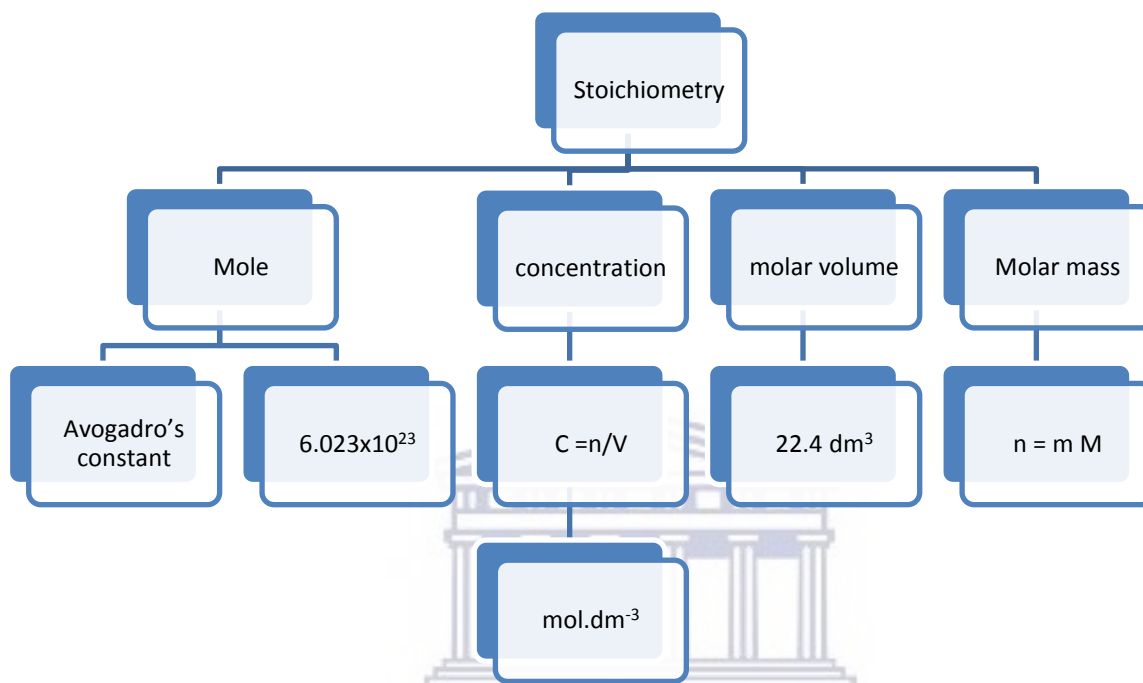
Exercise: Moles and mass

Table 9. Complete the following table:

Element	Relative atomic mass	Sample mass	Number of moles in the sample
Hydrogen	1.01	1.01	
Magnesium	24.31	24.31	
Carbon	12.01	24.02	
Chlorine	35.45	70.9	

Appendix 9

EXAMPLE OF CONCEPT MAP



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Appendix 10
LESSON PLAN: PHYSICAL SCIENCE

Content: chemical change			
Context: Quantitative aspects of chemical change			
Activity 1	1	2	3
Dissatisfaction	<p>Individually: Learners use their textbooks and the internet to write the definition of concepts of quantitative aspects of chemical change, e.g. mole, atomic mass, molar mass, stoichiometry, concentration, Avogadro's number or constant etc.</p>	<p>In groups Learners were exposed to animations around the topic to address their misconceptions of the concepts.</p>	<p>In groups: Learners were interacting with each other sharing the information, also answering the questions during class discussions.</p>

	:		
Teaching method and approach	Inquiry, cooperative learning, direct instruction Learners weighing some of atomic masses Demonstrations.		
Assessment strategies	Self, peer, group, teacher		
Forms of assessment	Class work, homework, presentation, group discussion		
Resources	Textbook, internet, flash cards		
Teacher reflections	Evaluating learners' responses. Providing feedback on their responses Provision of additional support.		
Teacher reflections	Evaluating learners' responses. Providing feedback on their responses Provision of additional support.		

Appendix 11

OBSERVATION SCHEDULE

DIMENSION	INDICATOR	OCCURRENCE(TALLY)	COMMENTS
1.Disatisfaction	1.exposing event created		
	learner to learner interaction		
	Learner initiated questions		
2.Intelligibility	Comment of the teacher		
	Learner active involvement.		
3.Plausibility	Analysis and interpretation.		
	Explanation by learners		
	Investigations		
4.Fruitfulness	Problem solving		