

**Using a conceptual change approach to improve
learners' understanding of ions in aqueous
solutions in Physical Sciences.**

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DECLARATION

I declare that “*Using a conceptual change approach to improve learners’ understanding of ions in aqueous solutions in Physical Sciences*” is my own work and that it has not been submitted for any degree or examination in any other university. All the sources I have used and quoted have been indicated and acknowledged by complete references.

Nomvuyo Mboxwana

Date: 24/04/2017

Signature:



DEDICATION

First and foremost, to my heavenly father who made it possible for me to undertake this study and to my lovely family, the Mboxwana's and the Silwana's, thank you for the love and support that you gave me.

I love you always

Nomvuyo



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ABSTRACT

The purpose of this study was to investigate how the use of a conceptual change approach could contribute to enhancing the teaching and learning of ions in aqueous solutions in Grade 10 Physical Science. More specifically, the study attempted to answer the main research question, namely, *How can the conceptual change approach be used to teach ions in aqueous solutions in Physical Sciences?* This study was underpinned by the theories of constructivism and conceptual change. The concept of effective teaching practice is based on approaches that promote conceptual change and provides learners with skills on learning how to learn and making meaning out of their learning - which is part of the constructivist view of learning.

The sample of this research consisted of a single class in a school where the researcher is teaching. The class has 26 learners of mixed gender. The study adopted a single case study approach and was designed to allow for the use of multiple data collection methods. Data was collected through a pre- and post-tests, intervention lessons, classroom observation as well as semi-structured focused group interviews. The use of qualitative and quantitative methods of data collection proved useful and provided in-depth data and allowed for triangulation. The data was analysed both quantitatively and qualitatively.

The results of the research showed that learners performed better in the post-test than in the pre-test. The learners mentioned the fact that the intervention lesson played an important role in making them understand the concept better. The results also showed that, while the majority of the learners seemed to have made some progress in their conceptual development as a result of their exposure to the conceptual change method of teaching, others struggled with the approach.

DEFINITION OF TERMS

Misconceptions: Constructed knowledge which is not scientifically accepted.

Traditional teaching approach: Teaching approaches which do not afford learners the opportunity to be actively involved in the learning process, but instead involve passive learning.

Meaningful learning: It is an act of relating or linking new knowledge and concepts to relevant concepts already known for a better understanding of new concepts.

Constructivism: The view which encourages construction of knowledge and considers learners' prior knowledge in order to make new schema of knowledge.

Salts: A compound formed by the reaction of an acid with a base.

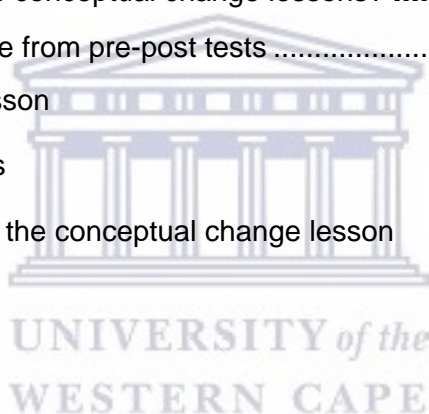
Dissolved salts: When salts totally ionise in water forming the constituent's ions.



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CHAPTER 1

RATIONALE OF THE STUDY

1.1 Introduction

This chapter provides an introduction to the research into the application of a conceptual change approach to teach the concept of ions in aqueous solutions, an area in the Grade 10 Physical Science syllabus. The chapter introduces the background to the study and highlights the context in which the study will be conducted. It describes the research problem and the research question as well as the significance and limitations of the study.

1.2 Background

As with other disciplines of science, chemistry forms part of our everyday lives. It can be found in different parts of our everyday living such as our home, bodies, clothes, etc. Chemistry is therefore described as answering questions of events happening in our lives. However, chemistry is challenging for learners to understand and to use to explain various areas of life. Nieswandt (2001) states that the major reason lying behind most of the challenges in learning and understanding chemistry is that it is considered as a science which is not related to daily life and is seen only as an academic science.

The nature of chemistry is different from other subjects and it exists on three levels which are difficult to understand at the same time (Johnstone, 2000). The three levels are the macroscopic, sub-microscopic and the symbolic. The macroscopic level, which is the observed phenomenon, has to be explained through the sub-microscopic level that involves movement, arrangement and particles' behaviour. The macroscopic and the sub-microscopic levels are then translated into scientific notation which is now the symbolic level. The three levels are intertwined and learners need to be able to understand how they are related.

Researchers indicate that science is considered as an abstract and difficult subject to learn by learners (Nieswandt, 2001; Chittleborough, Treagust & Mocerino, 2002).

Due to its abstract nature it can result in learners having misconceptions about a certain concept. It is therefore of importance for educators to find ways which will prevent learners from having misconceptions about the subject while encouraging and promoting meaningful learning and enhancing learners' interest which will improve science learning.

Therefore, different teaching methods should be used to overcome misconceptions and facilitate learning. These teaching methods are based on the constructivist view of learning where each learner must be seen and made to be actively engaged in constructing knowledge and making links between new information and prior knowledge (Posner,1982). Moreover, several researchers indicated the importance of conceptual change instruction in overcoming learners' misconceptions of science concepts (Dole & Niederhauser, 1990; Chambers & Andre, 1997).

The South African curriculum offers Physical Sciences as a subject comprising Physics and Chemistry at the Further Education and Training (FET) band (from Grade 10 to Grade 12). The chemistry part comprises of three sections which are matter and materials, chemical change and chemical systems. Understanding the concept of 'ions in aqueous solutions' requires a firm understanding of chemical change which will help learners with better understanding of chemical equilibrium, Le Chateliers Principle, effects of concentration on equilibrium and acids and bases.

In a recent report, the 5th Financial Development Report, the World Economic Forum (WEF) ranked South Africa 62nd out of 62 countries on the pillar measuring the quality of its mathematics and science education .The pass rate of learners taking Physical Sciences is currently an issue of major concern nationally and internationally (Department of Education, 2010). Therefore, it becomes very important to pay more attention to the teaching of Physical Sciences. When one looks at the recent history of Physical Sciences Grade 12 results for the past five years during the National Senior Certificate (NSC) examinations in South Africa, the results are not very encouraging (Department of Education, 2014), as depicted in Table 1 below.

Table 1: Learner performance in Physical Science, 2010-2016

Year	National pass rate	%	Provincial pass rate	%	District pass rate	%	School pass rate	%
2010	61		51		49,5		36,4	
2011	54		59		52,4		37,5	
2012	73		53		61,9		31,6	
2013	67,4		64,9		70,7		67	
2014	61,5		57,5		77,7		33,3	
2015	56,6		49,5		63		52,6	
2016	62		49,6		81		83,3	

As can be seen from the results presented in Table 1 the results in the Eastern Cape were consistently lower than the national average over the period 2010 to 2016. The pass rate of the education district where the research school site is located was higher than the national and provincial average. The pass rates of the research school have improved over the last two years but are still not at an acceptable level.

1.3 State of science education in South Africa

Amongst other challenges that the Education Department is faced with are outdated teaching practices, a lack of subject knowledge by teachers and a large number of under qualified or unqualified teachers who teach in overcrowded and poorly equipped classrooms. These challenges create many problems for learners which include, amongst others, a number of misconceptions, and inadequacy in science knowledge, attitudes, skills and values. The National Teacher Education Audit of 1996 followed by the mathematics and science audit of 1997 produced statistical revelations about teachers and teaching in these areas. Whilst policies and programmes have been produced on a general scale, very little has happened at a systemic level to address the challenges of providing quality mathematics and

science teachers. In fact, the mathematics and science audit revealed that more than 50% mathematics and 68% science teachers have had no formal subject training (DoE, 2001a). The problem of inadequate training was particularly identified in the general education phase of the schooling system. The Education for All (EFA) 2000 assessment (2005) also reported that, in spite of approximately 85% of mathematics educators being professionally qualified, only 50% have specialized in mathematics in their training. Similarly, with 84% of science educators professionally qualified, only 42% are qualified in science. An estimated 8000 mathematics and 8200 science educators therefore need in-service training to address their shortcomings in these subjects (DoE, 2001a).

Another problem is that very few learners graduating with mathematics and science choose teaching as a career. Therefore, not many learners are taking mathematics and science related subjects at university level resulting in an under supply of science educators. Fewer schools are offering these subjects and even those that are offering these subjects are not well equipped with facilities and equipment to promote teaching and learning. In these schools teaching of Physical Science is theoretical rather than practical.

1.4 Intervention in science education in South Africa and the Eastern Cape Province

To address the problem of underperformance in Mathematics and Science, the Department of Basic Education (DBE) in conjunction with the Department of Higher Education and Training (DHET) and the Department of Science and Technology (DST) collaborated to improve the outcomes of the learners in the country. The Eastern Cape Department of Education came up with a strategy called Learner Attainment Improvement Strategy (LAIS). LAIS has a three-year implementation period which has its own objectives that are as follows:

- To roll out a programme of action for LAIS over a period of three years.
- To deal decisively with the factors that cause the education system in the Eastern Cape to have poor learner outcomes.
- To delineate the roles and responsibilities of the various levels of education management from school to provincial levels.
- To promote collaboration particularly at district level.

- To profile the multi-disciplinary team concept.
- To promote the sustainability of the gains of LAIS by assisting the underperforming schools while motivating the good performers for science.

The Eastern Cape Department of Education undertook the following strategies to address the challenges for science:

1. Incubation classes which took a few learners from a large pool of learners but catered only for bright sparks whereas most learners were struggling with Physical Science.
2. Winter and spring schools which were marked by overcrowded classes and did not cater for individual attention of learners.
3. Dinaledi programmes which supported and developed the schools that were already performing better. In the Eastern Cape Province only 60 schools were selected.
4. Science festivals which were held in Grahamstown. Not all learners were able to attend the festival as it was far from many schools in the province.
5. Nelson Mandela Metropolitan University programme for FET Physical Science educators which aimed at developing educators in Physical Sciences.
6. 1+4 programme which was aimed at developing Foundation Phase educators in numeracy. Their learners would provide the base for Physical Sciences.
7. Science Olympiad, South African Agency for Science and Technology Advancement science school's debates and science weeks targeted only a few learners while many schools did not bother participating.
8. Mathematics, Science and Technology grant which was aimed at supporting schools that were struggling with Physical Science.
9. University of the Western Cape Programmes which were run by the Science Learning Center of Africa in the Eastern Cape Province from 2010 to date.
10. Advanced Certificate in Education (ACE) in FET physical science which was a course that was offered to FET physical science educators and

- equipped them with overcoming the content gap, development of science clubs and understanding of the nature of science and scientific knowledge.
11. The programme took the educators with ACE to B.Ed. (Bachelor of education) Honours level where they studied and gained in-depth understanding of science and science education through teaching and learning. The ACE was followed by the B.Ed Honours degree which also encompassed curriculum and pedagogy, Information & Communication Technology learning, science education and indigenous knowledge systems.
 12. The honours graduates proceeded to masters' degrees in science education where research theses addressing challenges faced by the Eastern Cape Province in science were undertaken.
 13. Short course certificate for natural science educators which gave them the foundation for matter and material needed in Grade 12.

1.5 Context of the study

This research will be conducted at a school in the Karoo region in an education district in Eastern Cape where I teach. This town consists of agricultural/pasteurized farming where most of the people are domestic workers and gardeners with meagre salaries. Some depend on pensions and social grants. The most worrying factor about this town is lack of employment which negatively affect youth as there are no factories or any other activities that will ensure youth development.

The school where this research will be conducted was established in 1993. It is a no-fee school and placed at a Quintile 3 level i.e. schools in each province were classified into five groups from the poorest to the least poor. For example, Quintile 1 is a group of schools in each province catering for the poorest 20% of schools. Quintile 2 caters for the next poorest 20% of schools while Quintile 5 schools represent the least poor. Schools receive money from the government according to quintiles. Quintile 1 schools receive the highest allocation per learner, while Quintile 5 receive the lowest. We depend on fundraising to enhance the school. The school has a library and a computer lab that are non-functional because they have no equipment and trained personnel for them. The school has established a garden with

indigenous trees and it is now busy with the establishment of a sport field for rugby and soccer. It has an enrolment of 1200 learners and 28 staff members. Most learners are Xhosa speakers and a few are coloured. We also have a multiracial staff component even though the majority of learners are Xhosa speakers. The school has a principal, a deputy principal and four heads of department. Lessons in this school are offered in English which is the language of teaching and learning. I have been an educator in this school for five years teaching Mathematics and Mathematical Literacy. One of my major subjects is Physical Science which led me to become a substitute for teaching Physical Science. During that period, I taught grade 10's and I realized that the learners were having difficulties understanding chemistry. One of the reasons could be that the educator that was teaching Natural Science in grade 9 the previous year has no Chemistry background.

1.6 Research problem

Given the challenge that South Africa faces with learners not doing well in Physical Science, and the low attainment of learners in this subject in the Eastern Cape, the education district and the school where I am teaching, it is important that new teaching strategies be used to present challenging areas in the curriculum to learners. One such teaching strategy is the conceptual change approach to teaching. In a recent audit of the examination questions that learners have difficulty answering, chemical change and chemical equilibrium were identified as areas that needed support. In particular, the area of ions in aqueous solutions was considered very daunting to learners at Grades 10 and 12 levels. This study was therefore developed to address this particular area of the curriculum using a conceptual change teaching strategy.

1.7 Purpose of the study

The purpose of the study is to investigate how the use of the conceptual change method could contribute to enhance the teaching and learning of ions in aqueous solutions in a grade 10 science class.

1.8 Research question

The study aims to answer the following question:

How can the conceptual change approach be used to teach ions in aqueous solutions in Physical Sciences?

In order to answer the main research question, the following sub-questions were addressed:

- (i) What was learners' initial understanding of the concept of ions in aqueous solutions?
- (ii) How were the lessons for the conceptual change approach implemented?
- (iii) What was learners' understanding of the concept of ions in aqueous solutions after implementation of the conceptual change lessons?
- (iv) What were the learners' perceptions of the conceptual change lessons?

1.9 Significance of the study

Chemistry educators could benefit from research findings and recommendations for teaching ions in aqueous solution as the problems and prospects are documented. Educators could use these as a guide during lesson preparation and lesson delivery. When reference is made to documented problems and the prospects as well as implementing the recommendations, educator effectiveness could be improved.

The outcomes of the study could prove useful to educators new in the field and the 'less successful' educators could benefit more since ions in aqueous solution is an area where many learners present several alternative conceptions. New educators will be able to know what to expect when they start teaching the topic and the 'less successful' educators will be able to improve their teaching by trying what other educators are doing to reduce learners' formation of alternative conceptions.

The conceptual change approach helps learners to form links between existing knowledge and new knowledge resulting in meaningful learning. In this method, concepts are learned from simple to complex which help better acquisition of new knowledge. Therefore, the conceptual change approach helps teachers to arrange

the learning environment in a way that learners express their ideas, construct their knowledge and realize their misconceptions.

The research will add to the limited baseline data available on teaching science concepts using a conceptual change approach. The research is particularly important in the rural schools of the Eastern Cape.

The results of the study will enable subject specialists and the Department of Education (DoE) to be aware of educators' problems and prospects regarding the teaching of ions in aqueous solution. Professional development activities are planned on needs analysis of the target group. With chemistry educators as subjects of the study, the research findings and recommendations will guide subject specialists in coming up with intervention strategies especially for professional development.

Resource materials used by both educators and learners should enhance the teaching and learning of particular concepts or topics to achieve the intended objectives. When resource material developers are made aware of the problems and prospects of teaching the topic, they develop the materials in line with new and better teaching strategies and content presentation. There should be a strong relationship between new teaching strategies and resource materials used.

Textbook authors should realize that textbooks are one of the sources of misconceptions. Therefore, this study could assist writers of textbooks. Moreover, they would realize the effectiveness of conceptual change strategies in remediation of misconception and then give special attention to the conceptual change approach in their writings.

1.10 Limitations of the study

Being a case study design, the study draws conclusions from a limited number of sites which in this case is one class of one school in grade 10 of one district. Case study research designs have been attacked for lacking the aspect of generalizability. The recommendations and implications of the study therefore have a limited reach.

1.11 Structure of the thesis

This thesis consists of five chapters and it is sequenced as follows:

Chapter one introduces the study. It highlights the rationale of the research by means of the background and context. A description of the study as well as the scope and limitations of the study are included. The first chapter serves as an introductory explanation of the main research question, the background and context where this study was conducted.

Chapter two provides a theoretical framework for the study by reviewing the literature on the subject of the conceptual change method of teaching. It also contextualizes the subject by giving a brief overview of the context in which conceptual change usually occurs.

Chapter three outlines the research design and methodology that was employed in the research. It describes the research approach in detail and gives a justification for the use of the mixed methods approach (both quantitative and qualitative) and relevant data collection methods. It also features descriptions of the participants, the instrument(s) or data gathering methods used and an explanation of how the data were analysed and verified. Lastly, it explains how the researcher acted in an ethical manner.

Chapter four presents the collected data and provides a discussion of the findings.

Chapter five addresses the conclusions of the study and gives a summary of the key findings and the implications of the study. Finally, it makes recommendations for further research.

1.12 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 are presented together with the significance of the study. The following chapter concentrates on the literature review and the theoretical underpinnings of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is presented under six sub-headings: conceptual framework; studies in constructivism, concept, conception and misconception; concept change theory; research on chemistry education; and studies related to the topic.

2.2 Conceptual framework

This study is underpinned by the theories of constructivism and conceptual change. Suping (2003) argues that constructivism is a concept to do with the influence of a learner's culture and biography whereas science knowledge is less socially constructed. He further states that according to Piaget assimilation is directly linked to constructivism because learners are hesitant to obtain new concepts and replace older concepts. The concept of effective teaching practice is based on approaches that promote conceptual change and provide learners with skills on learning how to learn and making meaning out of their learning which is part of the constructivist view of learning and which produces scientific literate citizens (Ashcraft, Treadwell, & Kumar, 2008).

A variety of conceptual change strategies have been discussed in the literature with the majority of them focusing on process-oriented instruction as an active teaching and learning strategy (Duit & Treagust, 2003). Marumure (2012) reported that it is effective teaching practice where learners are engaged actively in the learning process that promotes the achievement of the intended objectives of producing scientific literate citizens with minimum misconceptions about chemistry concepts, especially on chemical equilibrium. Robottom (2004) defines knowledge as concepts that are constructed in the mind of the learner and that each learner has to construct his/her own knowledge. This view is, therefore, a more individual construction, thus highlighting the theory of constructivism. Constructivism combines very well with conceptual change, because learners construct their own understanding of certain concepts (Trowbridge & Wandersee, 1994).

2.3 Studies in constructivism

Constructivism is based on a theory that learners come to class with their pre-knowledge which may or may not be compatible with the scientific conceptions. This knowledge should be taken into consideration as it gives guidance to individual understanding of concepts. This knowledge is attained through their experiences and their learning exposure and may be modified throughout the process of learning as they interact with the learning materials and with the educator. Constructivism views the learner as playing an active role in building understanding and making sense of the given information (Ormord, 2011).

Constructivists view learning as taking place more positively when both the educator and the learner cooperatively participate and do their roles as required by the learning process. The role of the learner is “constructing the new knowledge”. Constructing new knowledge is of importance during the learning process and it needs to be done by the relevant participant, the learner. At the same time, the educator needs to create a positive learning environment as well as being a facilitator. Woolfolk (2010) identified three groups of thought that play a role regarding the construction of knowledge. (1) The information-processing theory which claims that knowledge construction is a representation of the outside world. (2) The Piaget chain of thought which views the construction of knowledge as transforming, organising and reorganising prior knowledge. (3) Vygotsky (1986) claimed that knowledge is constructed by social interactions and experiences. This knowledge is obtained through their experiences and their learning exposure and may be modified throughout the process of learning as they interact with the learning materials.

At times no prior idea exists and the new one is developed or acquired, namely “emergent”. Where both thought systems exert equal force is what is called “equipollent” (Ogunniyi, 2005). Even so, in a situation where a new idea is favoured over an old one, it is called “assimilatory”. However, awareness of the struggle that learners undergo in learning any science topic should help educators to appreciate the relevance of these socio-cultural constructivist theories.

Piaget (1970) & Vygotsky (1986) put emphasis on prior knowledge as the basis for individual understanding and further learning. Vygotsky (1986) singles out the learner as the constructor of new knowledge and as the active participant throughout the learning process. He views educators as facilitators as well as the creators of a conducive learning environment. Fosnot (1996) highlighted that constructivism is a learning theory and therefore there is no step-by-step description of how to teach nor of learning styles. Fosnot indicated the general principles of constructivism as follows:

- Learning is developed; it is not the result of development. Thus educators need to actively involve learners during the learning event and make the learning environment conducive;
- Contradictions resulting from the learning process need to be explained, explored and discussed in order to moderate learners' conceptions;
- Learning should be encouraged through reflective thoughts and reflective thoughts are facilitated by allowing reflective time through discussions and connections of ideas across learners' experiences.
- Allow learners rather than the educator to justify and communicate their ideas to the classroom community;
- Learning proceeds towards the construction of big ideas and can form principles which can be generalised across various experiences.

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

Selley (1999) also stresses that construction is an internal, personal and often unconscious process and construction consists largely of reinterpreting a piece of knowledge that one obtained from one's experiences and interaction with other

people to build a satisfactory and coherent picture of the world. Moreover, constructivism is a meaning-making theory where individuals create their own new understandings based on the interaction between what they already know and what they don't know (Richardson, 1997).

Rasmussen (1998) claims that every individual constructs his or her own realities based on existing knowledge and so it is not meaningful to talk of the objective truth. For example, when teachers believe they have been understood by their learners they should not put themselves into believing that they share the same opinions as their pupils. No one can ever be sure of this, because understanding is also a personal construction of things. What you understand in one way may be understood quite differently by someone else.

Constructivism states that knowledge is present in the individual and that knowledge cannot be transferred completely without any change from the teacher's head to that of learners (Tobin, 1992). The constructivist approach is learner centred. Learners should be active participants in the learning process since every learner will construct his or her individual meaning. Therefore, the instructional activities must attract the learner and encourage active participation. Active participation in a constructivist manner means that the learner is actively testing the new concepts so that they can realize whether the new concepts can be explained by existing or prior knowledge so they can evaluate how well a new concept is explained by existing schema and can choose whether to modify or change current schema. Therefore, constructivism is a theory of learning that rejects the idea that it is possible to transfer the content of teaching to pupils (Rasmussen, 1998).

Constructivist teaching requires the teacher to act as a facilitator and create constructivist learning experiences. That is, the teacher no longer teaches by imposition, but by negotiation. It involves more learner-centred, active learning experiences, more learner-learner and learner-teacher interaction, and more work with concrete materials and in solving realistic problems (Shuell, 1996). The constructivist classroom supports inquiry and learners can express their ideas and feelings freely. The constructivist approach on the other hand "places emphasis on the meaning and significance of what the child learns, and the child's active

participation in constructing this meaning” (Selley, 1999). Moreover, constructivist learning environments are designed to satisfy seven pedagogical goals (Honebein, 1996):

1. Provide experience with the knowledge construction process: learners take primary responsibility in selecting topics and methods of how to learn.
2. Provide experience in and appreciation for multiple perspectives: learners must engage in activities which enable them to think about several solutions since real life problems rarely have one correct solution.
3. Embed learning in realistic and relevant context: learning activities are designed so that they reflect all the complexity that surrounds them outside the classroom.
4. Encourage ownership and voice in the learning process: illustrates the learner centredness of constructivist learning.
5. Embed learning in social experience: learning should reflect collaboration between learner and teacher and learner and learner.
6. Encourage the use of multiple modes of representation: a variety of activities and instructional strategies coupled with a variety of media provides richer experiences.
7. Encourage self-awareness of the knowledge construction process: it is important for learners to know how they know.

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

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

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

The Outcome Based Education (OBE) Curriculum 2005 which is the curriculum that was developed during the post-apartheid era is based on constructivism in that the teacher is expected to guide the learners in such a way that they are able to construct their own knowledge based on their direct experiences within and outside the school environment. In this regard, the knowledge they eventually construct would be the result of a variety of interactions, e.g. peers, classmates, teachers, parents, etc.

2.4 Concepts, conception and misconception

Before conceptual change is discussed, one should understand what concept, conception and misconception are, since conceptual change requires reconstruction of preconceptions in order to remediate misconceptions. Numerous studies show that science learning is characterised by misconceptions, which learners develop as they try to understand the world around them (Vosniadou, 2001; Stepan, 1994).

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

The major objective of instruction should be teaching for understanding which occurs when concepts become a real part of mental structure. Therefore, one should not expect understanding to occur on occasions where a subject is learned as isolated skills and processes (Önder, 2006). Understanding develops through interaction with the environment and other individuals and when individuals have an opportunity to construct their own interpretation when they first meet a new topic (Lind, 2000). Learners construct new concepts through assimilation and accommodation of new information while they are exploring the world and store those concepts in correct mental categories in their minds.

When a learner comes to the science class, he/she comes with knowledge gained from home, peers and previous grades. In the science class, the learner is torn between two worlds, the scientific and the everyday world. The learner will attempt to reconcile the two domains, but his or her theories are frequently contrary to those of scientists (Osborne & Wittrock, 1985). Learners' self-constructed conceptions have been referred to in the literature as misconceptions, alternative conceptions, preconceptions, naive conceptions, etc. (Driver & Easley, 1978; Krishnan & Howe, 1994, Griffiths & Preston, 1992).

Balci (2006) classifies misconceptions into five types: preconceived notions, non-scientific beliefs, conceptual misunderstandings, vernacular misconceptions and factual misconceptions. These types of misconceptions are described as follows:

Preconceived notions are popular conceptions rooted in everyday experiences. For example, the thought that underground water must flow in streams may come from our daily expectations since people see the water flowing in streams in everyday life.

Non-scientific beliefs include views learned by students from sources other than scientific education, such as religious or mythical teachings.

Conceptual misunderstandings arise when scientific information is taught in a way that does not challenge students' prior knowledge and results in conflicting situations. As an example for this type of misconception, students may know the definition of matter but do not accept air as matter. Another example is that, although students are taught the water cycle, they may not believe evaporated water exists in air; rather than they think that evaporated water moves upwards to the clouds since their mental model was never challenged.

Vernacular misconceptions arise from the use of words that mean one thing in everyday life and another in a scientific context. For example, the meaning of the term 'work' in science classes is different from its meaning in everyday life.

Factual misconceptions are falsities often learned at an early age and retained unchallenged into adulthood. For example, "lightning never strikes twice in the same place" is an idea which is embedded in one's mind at an early age, but is not correct.

Misconceptions sometimes occur in chemistry due to terminology and wording used, especially when topics such as concepts of substances, the particles of which they consist and chemical symbols used for their representation are introduced. Misconceptions may also arise as a result of a variety of contacts learners make with the physical and social world or as a result of personal experiences; interactions with teachers, other people, or through the media; traditional instructional language; mismatches between teacher and learner knowledge of science; the abstract nature of science concepts and textbook portrayals (Griffiths & Preston, 1992; Soyibo, 1995). The fact that some learners cannot distinguish between macroscopic and sub-microscopic explanations can also lead to misconceptions.

Stojanovska, Petruševski & Šoptrajanov (2014) suggest two possible reasons for the misconceptions when dealing with the three mentioned levels of representation. The first is the risk of "overloading the working memory space" when learners are introduced to all three levels simultaneously. Secondly, neglecting the sub-microscopic level during teaching may also lead to the appearance of certain misconceptions. Language used on a daily basis is also regarded as another common source of misconceptions. Even the use of some scientific terms differently in our everyday language than its scientific meaning also plays a big role in creating misconceptions. Gill-Perez and Carrauca (1990) state that the resemblance between learners' intuitive ideas and pre-classical conceptions cannot be accidental, but must be the consequence of the same way of approaching problems. Absence of learners' doubts may lead to alternative frameworks, and trying to find possible alternative solutions to the problems also may lead to these intuitive ideas (Seker, 2006). A review of the research relating to learners' misconceptions of science concepts reveals that misconceptions have many common features. They are often strongly resistant to traditional teaching methods and learners are generally reluctant to transform these misconceptions (Driver & Easley, 1978; Sungur, Tekkay, & Geban, 2001).

2.5 Conceptual change theory

According to the constructivist view of learning, learners' prior knowledge is important to make sense of new experiences and new information (Wittrock, 1974;

Hand & Treagust, 1991; Duffy & Jonassen 1991). In this model, it is recommended that learners construct their knowledge and concepts in the direction of their abilities and experiences (Osborne, Bell & Gilbert, 1983). This shows the uniqueness of each individual's learning style. It is due to these different learning styles that various teaching models have been developed to change learners' misconceptions into scientific conceptions. This type of study has been described as a conceptual change model (Posner, Strike, Hewson, & Gertzog, 1982). In general, conceptual change has been described as part of a learning mechanism that requires the learners to change their conceptions about a phenomenon or principle either through restructuring or integrating new information into their existing schemata (Hewson, Laurent, & Vogel, 1996). The best-known conceptual change model has been that of Posner *et al.* (1982), which describes the conditions of conceptual change. In this model, there are four steps: (1) learners must become dissatisfied with their existing conceptions; (2) the new conception must be intelligible; (3) the new conception must be plausible; and (4) the new conception must be fruitful. After these conditions have been met, learners can experience conceptual change. The four steps are indicated in figure 1 below.

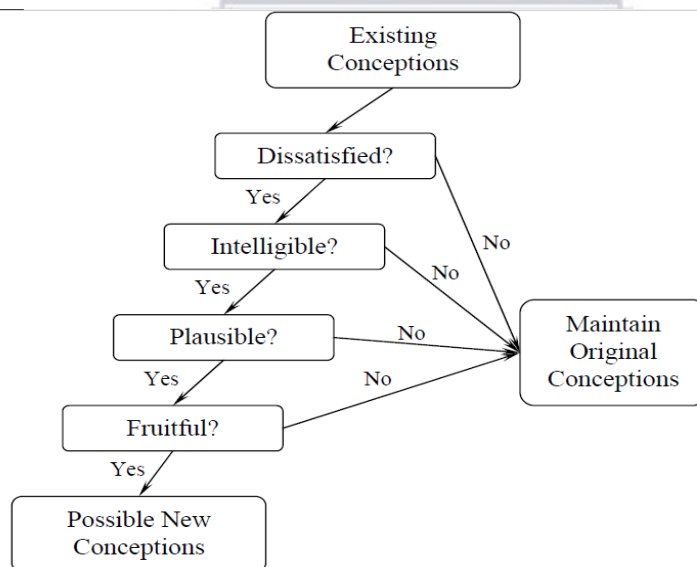


Figure 1: Posner *et al.*'s (1982) conceptual change model

Firstly, the learner must be aware that the old concept he knows is inadequate (dissatisfaction). When the discrepant event is presented, there must be

dissatisfaction with the existing conception. Secondly, the new concept must be understandable (intelligibility). Learners must attain a minimal initial understanding of the new scientific conceptions. Learners are not going to adopt a new conception unless they can first represent it to themselves. In other words, they must find it intelligible. Thirdly, the new concept must make sense to the learner (plausibility) and s/he should be able to easily picture it in her/his mind. A new conception must appear initially plausible. It must be connected with the current cognitive framework of the concept and related ideas and must be believable and, finally, the new concept must be beneficial to learners (fruitfulness); that is, they should be able to solve similar problems with the new concept in the future. Learners must see that the scientific conception is useful in understanding other examples of phenomena.

Chi, Slotta, & De Leeuw (1994) defined conceptual change as learning when certain existing concepts change. Learners have to be actively involved in a learning process. They construct their own knowledge through their existing ideas, knowledge or experiences. Meanwhile, they create their own personal meanings by using their ideas. Hence, it is likely for them to misinterpret the new concepts and to construct misconceptions by using their existing knowledge and experiences. In order to minimise if not to eliminate these misconceptions, educators need to consider conceptual change approach activities. Ausubel (1968) stresses the importance of existing knowledge in the process of accepting new concepts, but according to Chiu, Chou & Liu (2002) learners struggle to do this in chemical reactions.

Conceptual change theory has been put forth by Posner, Strike, Hewson & Gertzog (1982). This approach represents a perspective that is based on Piaget and Zeitgeist's views, yet it has been improved by Posner and his colleagues. The aim of this approach, which is based on Piaget's principles of assimilation, regulation and counterbalancing, is to encourage learners to remove misconceptions and instead learn scientific knowledge (Chambers & Andre, 1997). Most chemistry concepts are difficult to teach because the definitions of these concepts given in textbooks are either vague, or promote ideas that are sometimes not scientifically correct. Conceptual knowledge about ions in solutions implies awareness of the three levels of representation. Learners have to be able to go from the macroscopic level to the

sub-microscopic level in order to understand the concept and then learn to present the acquired knowledge in a symbolic way.

Conceptual change can be placed into different sub-categories – epistemological, ontological and affective orientation (Treagust & Duit, 2008). Epistemological main focus of the study is learning of science concepts. The epistemological perspective is the classic way conceptual change was seen for many years. Appropriate analogies help learners make connections between familiar knowledge and new science concepts (Treagust & Duit, 2009). Research has shown that analogical teaching approaches can enhance learner learning although analogies for teaching and learning can be a friend or a foe depending on the approach taken by the teacher (Harrison & Treagust, 2006). Treagust & Duit (2008) state that the teacher makes the learners aware of the unacceptable alternative framework by creating dissatisfaction. The teacher then introduces a new acceptable framework. Introducing the new framework can limit the learners' use of the newly obtained concepts to only a small part of the context. The best learners can come up with are a synthetic concept, where they combine only a small part of the new one with the existing one.

Dolo (2013) suggested the following as factors that influence conceptual change. Prior knowledge is one of the crucial factors that influences the learners' ability to plan and how an individual responds to specific situations is determined by his or her prior experience. Another important factor that influences the restructuring of ideas is practice as it provides opportunities for learners to involve all their senses.

Kurt and Ayas (2012) when researching with the aim to investigate the effects of activities developed based on a four-step constructivist approach on learners' understanding and explaining real-life problems about reaction rate concepts in chemistry. The study was carried out with 41 eleventh grade learners from two different classes attending a secondary school in Turkey. Two classes were randomly designated as experimental and control groups. While teaching the subject, a four-step constructivist approach was used for the experimental group whereas in the control group learners were taught by the traditional method. Teaching activities in both groups were observed by one of the researchers. In both

groups, the Real-life Relating Test (RRT), including the phenomena that learners observe in their daily life about reaction rate concepts, was implemented before and after the intervention. Also semi-structured interviews were conducted with 13 learners chosen from both groups. At the end of the study, it was determined that the intervention which was carried out based on a four-step constructivist approach helped the learners more in explaining real-life problems in a scientific way and provided more lasting learning than the traditional approach. It is suggested that such activities should be used for other abstract or problematic concepts in chemistry.

Kingir and Geban (2012) with the purpose of investigating the effect of conceptual change text oriented instruction compared to traditional instruction on 10th grade learners' understanding of reaction rate concepts. Forty-five learners from two classes of the same teacher in a public high school participated in this study. Learners in the experimental group were instructed by conceptual change text oriented instruction which is a model of instruction where students learn by actively identifying and challenging their existing conceptions and skills while learners in the control group were instructed by traditional instruction. The results indicated that conceptual change text oriented instruction was more effective than traditional instruction on learners' understanding of reaction rate concepts. It was also found that some of the misconceptions were still held by the learners in both groups. In the control group, the proportion of these misconceptions was higher than that in the experimental group. Moreover, previous learning in chemistry contributed to learners' understanding of reaction rate concepts significantly.

2.6 Studies in chemistry education using a conceptual change approach

There are 29 subjects in total in the NCS curriculum. Physical Sciences is one of them and it is grouped into learning fields forming a core curriculum for Grades 10-12 (general). It is generally referred to as Natural Sciences in General Education and Training (GET) and it includes the knowledge areas called Life and Living; Energy and Change; Planet, Earth and Beyond; and Matter and Material (DoE, 2003). On the other hand, in Further Education and Training (Grades 10-12), it is referred to as Physical Sciences and Life Sciences. A successful teaching and learning of science

requires educators to teach towards conceptual understanding. To accomplish this, the way educators teach in the science classroom is precisely of great significance, as this should assist learners to have the required understanding of basic science conceptions as alluded to by first year science lecturers (Potgieter, Rogan & Howie, 2005; Mumba, White & Rolnick, 2002).

The conceptual knowledge in chemistry is often presented in an abstract symbolic form. The symbols have precise meanings and are combined with rules that must be used correctly. In contrast, the human mind relates best to picture like representations that emphasise quality features but not detailed precise information. There have now been numerous studies of chemistry learning indicating that learners taught with an emphasis on using primarily mathematics to develop and apply concepts fail tests with seemingly simple conceptual questions that measure understanding. If educators want learners to understand and learn to use the symbolic representations that are part of the practice of science, educators have to link these abstract ways of describing the worlds to more concrete descriptions.

One more reason why many learners find chemistry difficult to understand is the multiple-levels of representation used in chemistry instruction (Johnstone, 1993; Gilbert & Treagust, 2009; Talanquer, 2011). These levels are the macroscopic, particulate and symbolic representations. When we use our five senses to perceive chemical phenomena that include colour changes, precipitation and heat, it is referred to as the macroscopic representation. Beyond a certain macroscopic level, however, our senses become inadequate at distinguishing chemical phenomena. These phenomena include the interactions of atoms, ions, electrons, and molecules and that level is referred to as the particulate representation. To express and describe the properties of the macroscopic and the particulate levels, chemists often use symbolic representations that include chemical symbols, chemical equations, and animations, graphed and tabulated data, etc. The capability of learners and chemists to transform and interpret from one representation to another is referred as the 'representational competence' (Kozma & Russell, 1997). When learners are taught chemistry using the three levels, instructions seamlessly move from one level of representation to another while novice learners often view the movement as confusing and can at the same time develop misconceptions during the instruction.

Numerous researchers have described learners' difficulties in moving from the macroscopic to the particulate level (Osborne & Cosgrove, 1983; Gabel, 1993) and from the symbolic to the particulate level (Yarroch, 1985; Nurrenbern & Pickering, 1987; Nakhleh, 1993).

Marumure (2012) studied the problems and prospects of teaching chemical equilibrium in the further education and training (FET) band. In this study the aim was to investigate the problems and the prospects of teaching the concepts of chemical equilibrium in the FET band. A mixed method of qualitative and quantitative approaches was used which involved the application of varied questions like multiple choice, closed questions and open ended questions to collect data. Also an interview schedule was used to collect further data. The study was comprised of one hundred and twelve (112) Chemistry (Physical Sciences) educators in the FET band in the Thohoyandou cluster of circuits in the Vhembe District of Limpopo Province and two Physical Science subject advisors in the cluster. Results of the study showed that the major problems of teaching the concepts of chemical equilibrium lie in the understanding, explaining and demonstrating of the basic concept of chemical equilibrium. Also there are several alternative conceptions in educators on key terms which are used to explain the basic concepts of chemical equilibrium. Instead of key terms like 'system', 'open and closed system', 'shift', 'equilibrium', 'constant' and 'state of balance' being applied after developing the concepts, these are applied as raw English words without scientific meaning just as the textbooks used by both educators and learners fail to explain the key terms. This contributes significantly to alternative concept formation in learners.

Kriek & Grayson (2009) in their study called "A Holistic Professional Development (HPD) model for South African physical science teachers" aimed to design and evaluate a holistic professional development model for FET (Further Education and Training) Physical Science teachers in South Africa. In this study a model that explicitly integrates the development of teachers along the three dimensions, namely: content knowledge, teaching approaches, and professional attitudes was created. In addition to looking at South African models, existing programmes and models from several different countries were studied. These programmes are PEEL (Australia), Discovery (USA), Cognitively Guided Instruction (USA) and the Japanese

approach to professional development. These programmes were selected because they have been sustainable over a long period. Two models for professional development were also studied, namely, the models of Bell and Gilbert (New Zealand) and Loucks-Horsley, and Hewson, Love and Stiles (USA).

Results of the study showed that the application of the HPD model has the potential to extricate teachers from a vicious cycle where poor content knowledge leads to lack of confidence and enjoyment of teaching, resulting in an unwillingness to spend time on task and use innovative teaching approaches. Instead, teachers can become part of a virtuous circle where improved content knowledge leads to increased confidence, enjoyment and a willingness to spend more time on task and use more learner-centred teaching approaches. Moreover, the HPD is sound when judged according to external standards for professional development and is aligned with the South African government's intentions for MST teacher development.

Hewson & Hewson (1983) employed a conceptual change approach to promote conceptual change in learners regarding density, mass and volume concepts. That study showed that the use of instructional strategies taking learners' misconceptions into account results in better acquisition of scientific concepts. Suits (2000) studied conceptual change and chemistry achievement. In this study, three qualitatively distinct achievement groups were formed according to the results of a chemistry achievement test: rote learners, algorithm memorizers, and conceptualizers. In addition, a two-dimensional achievement model was formed based on the chemistry achievement test. In the first stage, the memorize line, learners only accumulate knowledge. In the second stage, the conceptual line is the stage where learners were able to see connections between knowledge fragments and restructure their knowledge. Results of this study indicated that the rote learners were stuck in stage one. Algorithm memorizers showed a form of weak restructuring or tuning while conceptualisers tended to possess a coherent set of attributes that allowed them to create new knowledge structures. This indicated the influence of conceptual change on achievement.

Eryilmaz (2002) investigated the effect of conceptual assignments and conceptual change discussions on learners' achievement and misconceptions about force and

motion. A test was administered to 396 high school physics learners. It was administered as Force Misconceptions and Force Achievement Test to the learners as a pre-test. Five conceptual assignments about force and 23 motions were given to learners. In addition, learners participated in the conceptual change discussions. After the intervention period, the same test was administered to the learners. The results of the study showed that the conceptual change discussion was an effective means of reducing the number of misconceptions that learners held.

Pekmez (2002) discussed the issue of changing learners' ideas and presented several misconceptions learners have related to chemical equilibrium. She also mentioned that learners have many misconceptions about acid-base and solubility equilibrium. Therefore, she discussed ways of changing learners' misconceptions. She presented several misconceptions about chemical equilibrium and presented a brief explanation about each misconception. Moreover, she also presented some reasons for the misconceptions. Everyday language, multiple definitions, rote application of concepts and overlapping similar concepts were presented as causes of misconceptions.

Ayhan (2004) investigated the effect of conceptual change oriented instruction accompanied by cooperative group work on 10th grade learners' understanding of acid-base concepts. The results of the study showed that conceptual change oriented instruction accompanied by cooperative group work were effective to correct the learners' misconceptions of acids and bases.

Ceylan (2004) conducted a research study in order to compare the effectiveness of the conceptual change oriented instruction through demonstration and traditionally designed chemistry instruction on 10th grade learners' understanding of chemical reactions and energy concepts. His findings indicated that demonstrations based on the conceptual change approach were effective in decreasing learners' misconceptions regarding the chemical reactions and energy concepts. Sanger & Greenbowe (2000) also found that conceptual change instruction based on demonstrations was effective at ousting learner misconceptions regarding the electrochemistry topic.

Piquette & Heikkinen (2005) explored the general-chemistry instructors' awareness of and ability to identify and address common learner learning obstacles in chemical equilibrium. Fifty-two volunteer general chemistry instructors completed an interactive web-based instrument consisting of open-ended questions, a rating scale, classroom scenarios, and a demographic form. Then respondents were interviewed by phone to clarify their responses. All the chemistry instructors were able to report and identify common difficulties learners face in chemical equilibrium. Chemistry instructors suggested several strategies to address and attempt to remediate learners' alternative conceptions. However, these strategies rarely included all four necessary conditions specified by Posner, Strike, Hewson, & Gertzog (1982) to stimulate conceptual change.

Beeth (1993), in his study, described research conducted in a classroom devoted to conceptual change instruction. By taking learners' comments about conceptions, the teacher was able to assess his learners' scientific knowledge and plan instructional activities with respect to the conceptual change model. The learning environment in his classroom, created by the interaction between learners' responses and planned instructional activities, facilitated the development of learners' conceptions.

The study of Niaz, Maza & Liendo (2002) also indicated the effectiveness of the conceptual change approach on freshmen learners' understanding of electrochemistry. Learners in the experimental group were instructed by teaching experiments based on the conceptual change approach whereas learners in the control group were given traditional instruction. As a result, it was found that teaching experiments based on teaching experiments enhanced freshman learners' understanding of electrochemistry.

Chemical equilibrium is one of the most difficult topics in the science classroom (Bergquist & Heikkinen, 1990); it doesn't matter in which grade and therefore this topic gives rise to more alternative ideas than other topics. It is thus very important to eliminate these alternative ideas within this topic because they act as a base topic for others, for example, acids and bases.

This study examined whether conceptual change text oriented instruction produces positive attitudes toward science compared to traditional instructional methods since positive attitudes toward science increases learners' achievement. Moreover, the attitudes of learners toward conceptual change texts were also determined in order to investigate whether they increase learners' interest and achievement.

2.6.1 Challenges of teaching chemistry

Chemistry is an abstract and difficult subject to learn so teachers make use of tangible and visual teaching tools such as diagrammatic representations, verbal and oral descriptions, symbolic representations and physical models to help convey the meaning of new terms and new concepts (Gabel, 1998). Chemical concepts are commonly portrayed at three different levels as described by Johnstone (1982), figure 2 below.

Macroscopic level – the real observable chemical phenomena including references to learners' everyday experiences;

Symbolic level – the representation of chemical phenomenon using a variety of media including models, pictures, algebra, and computational forms; and

Sub-microscopic level – the real sub-microscopic particles, which cannot be seen directly, such as electrons, molecules, and atoms.

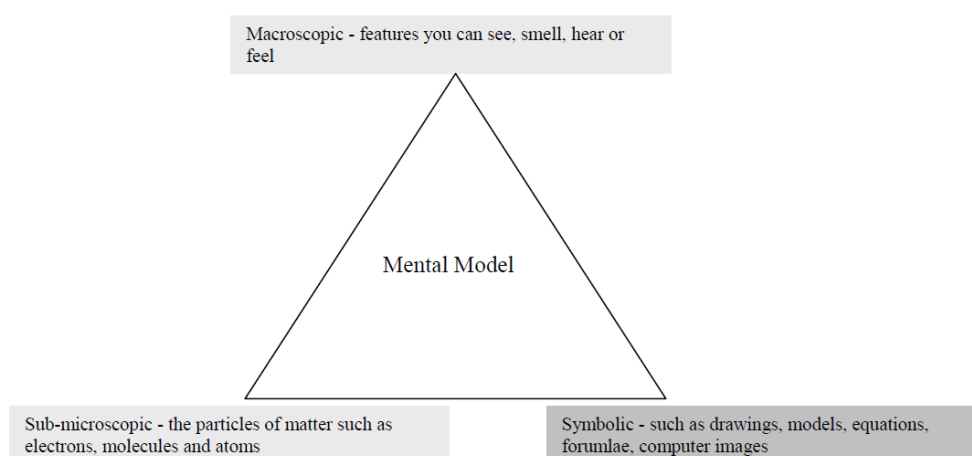


Figure 2: Chemical description and depiction

Except for experts in the subject, it is difficult to quickly move from one level to the other, therefore it should be done in stages for easy comprehension of the three levels. Many subjects exist on two levels, the macroscopic and the symbolic levels. These two levels are easy to learn and understand as there will be no overloading the memory working space (Johnstone, 2000). The three chemistry levels are linked and all three contribute to the learners' construction of meaning and understanding, which is reflected in their personal mental model of the phenomena.

According to Mayer & Moreno (2001), when constructing meaningful knowledge we should follow the multiple representation principle. This means that it is better to present an explanation in words and pictures than only in words. From this perspective, learning science is also strongly connected with building knowledge through understanding and concepts linking in learners' long-term memory by interpreting multi-modal representations of science phenomena (Ainsworth, 1999; Dolin, 2001; Russell & McGuigan, 2001; Lemke, 2004). Learners who recognized relationships between different representations demonstrated better conceptual understanding than learners who lacked this knowledge (Prain & Waldrip, 2006). In order to achieve better understanding of science concepts learners should be able to translate one representation into another one and co-ordinate their use in representing scientific knowledge (Ainsworth, 1999).

Russell & McGuigan (2001) argue that learners need opportunities to generate various representations of a concept, and to recode these representations in different modes, as they refine and make more explicit their understanding. In the process of science learning teachers should, therefore, incorporate learners' "rich pool of representational competence" in creating lessons that are motivating for learners (diSessa, 2004, p. 298), but diSessa also points out that the quality of the representation ought to be evaluated according to its purpose. Waldrip *et al.* (2006) argue that in order to maximize the effectiveness of design representational environments, it is necessary to take into account the diversity of learner background knowledge, expectations, preferences, and interpretive skills.

There is thus convincing evidence that most learners' difficulties and misconceptions in chemistry stem from inadequate or inaccurate models of the molecular world

(Lijnse *et al.*, 1990). An important aspect of successful problem solving in chemistry involves "representational competence", *i.e.* the ability to use multiple representations and to transform representations in one form to equivalent representations in another (Kozma & Russell, 1997).

A number of study projects have been conducted in Southern Africa on the teaching and learning of science. There were some patterns in their findings which were expressed by Van der Laan in Vonk De Feiter, and Van den Akker (1995) as follows:

- "Insufficient confidence and mastery by many educators of both subject content and basic teaching skills (like questioning);
- Language problems for both educators and learners, English being their second or third language;
- The disjuncture between school science along often Western-based curricula and textbooks (if available) and African life outside the school environment;
- Tension between African culture (for example values about the relation between adults and children) and the spirit of inquiry and critical questioning required in school science;
- Poor material facilities (for example, equipment) in schools and classrooms;
- Weak alignment of 'innovative' curricular aims and typical assessment and examination practices."

Van den Laan in Vonk, De Feiter, & Van Der Akker, (1995, p. 45) concluded that "there is a gap between improvement ideals in the various educator development projects and the current classroom practices."

2.6.2 Reports on previous researches on ways to improve science teaching

There are a variety of teaching methods and strategies that are used in the teaching of chemistry; it is therefore advisable that educators should combine these methods depending on the objective to be achieved as no method can be used in isolation. In other words, there is no one method which is said to be the correct one when developing a concept but it depends on how one employs the method taking into consideration the weakness of the method and the available conditions. Due to the nature of chemistry not all methods can be used and achieve the same level of

outcomes. Key elements of different teaching methods are looked at including their strengths and weaknesses.

Since chemistry is believed to exist on three levels - the macro, sub-micro and the symbol level - it is advisable that a lesson should not be introduced at different levels because covering all these different levels and introducing them simultaneously will lead to overloading. This is proposed in accordance with the theoretical framework that holds the notion that learning always builds upon the knowledge a learner already has and that learning is filtered through pre-existing knowledge and that more effective learning takes place when learners are actively engaged. One primary goal of using the constructivist teaching method is that learners learn how to learn by giving them the training to take the initiative for their own learning experiences". (Eybe & Schmidt, 2001).

Devetak *et al.* (2004) suggest that before the introduction of new concepts, the teacher should first establish what the learners already know. In case of misconceptions, the teacher must first clarify these and only then add new concepts and their connections to the conceptual structure of the individual. Chemical thinking requires knowledge about how to connect macroscopic findings with the explanations at the sub-microscopic level and their recordings at a symbolic level. Unless this is achieved, chemical education results only in fragmentary knowledge, which is quickly forgotten. This is accompanied by a feeling that chemistry is difficult to understand, which does not improve learners' motivation. Seemingly, it would be better if chemistry concepts were taught progressively, starting with macroscopic observation, through to the sub-microscopic interpretations and only then work with the symbolic representations.

According to Gray, (1997), the characteristics of a constructivist classroom are as follows:

- the learners are actively involved
- the environment is democratic
- the activities are interactive and learner-centred

Marumure (2012) lists the following as some activities encouraged in constructivist classrooms:

- 'Experimentation: learners individually perform an experiment and then come together as a class to discuss the results.
- Research projects: learners research a topic and can present their findings to the class.
- Field trips: these allow learners to put the concepts and ideas discussed in class in a real-world context. Field trips would often be followed by class discussions.
- Films: these provide visual context and thus bring another sense into the learning experience.
- Class discussions: this technique is used in all of the methods described above. It is one of the most important distinctions of constructivist teaching methods.

2.7 Studies related to conceptions in chemistry

Devetak *et al.* (2004) in the study entitled "Submicroscopic representation as a tool for evaluating learners' chemical conceptions" explored a group of 350 secondary learners (average age of 18), who chose chemistry as part of their exam at the end of secondary school, and 339 first year university learners (average age of 18) enrolled in the university programme: Primary school teacher and teachers of Mathematics, Biology, Physics, Technical Studies and Home Economics. Both groups of learners who participated in the study were the same average age, because the exam was conducted at the end of secondary school, in the same year that the learners went to university. University learners were tested at the beginning of their first semester, so that university studies could not have influenced their results.

The learners had to solve four tasks: (1) to present different concentrations of aqueous solutions by drawing the number of solvent particles; (2) to determine the base strength of anions from three sub-micro representations regarding aqueous solutions of different sodium salts; (3) to present reaction equilibrium changes when reaction conditions were altered, and (4) to determine the equilibrium equation from

the drawing and determine the type of energetic change during the reaction. The results showed that secondary school learners were more successful in solving these type of tasks than university learners are. This may be explained by the fact that the tested secondary school learners chose chemistry to be their entry exam at the end of secondary school and thus had more practice in relevant fields.

Tlala (2011) investigated Grade 10 Science learners' conceptual understanding of dissolved salts and explored the use of the predict-observe-explain (POE) strategy in order to reduce learners' misconceptions about the dissolved salts. The study also, explored learners' prior knowledge of concepts related to the dissolved salts. A quasi-experimental design was used where the experimental group (EG) used the POE strategy during treatment and where the control group (CG) used the traditional teaching using lecturing and demonstrations. Before the start of the study both groups wrote a pre-test using the Achievement Test (AT) to determine science baseline knowledge. Thereafter the intervention for EG and lecturing for CG followed and lasted for five weeks. After the intervention, both groups wrote the post-test to determine learners' achievements. The post-test was followed by interviews to discover issues that were not identified during the AT. From the study it was concluded that EG performed better in the post-test than the CG. More importantly, the study identified two new misconceptions that have not been reported in the literature: salts dissolve in water when it is in 'fine' grains; and solid sodium chloride is not an ionic compound. Furthermore, findings from AT revealed that learners' conceptual understanding of how salts are formed, how salts dissolve in water and how salts ionize improved dramatically, especially for the EG, but not for the CG.

2.8 Conclusion

This chapter provided literature on variety of misconceptions in chemistry and various teaching methods. The use of literature on related topics in chemistry was used in this chapter due to the scarcity of researches conducted within the topic of ions in aqueous solutions. The following chapter will provide a detailed explanation of and justification for various data collection methods.



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CHAPTER 3

METHODOLOGY

3.1 Introduction

The aim of this chapter is to outline the research design using a mixed method approach. It also provides a detailed explanation of and justification for various data collection methods. To address the main research question “***How can the conceptual change approach be used to teach ions in aqueous solutions in physical science?***” the following aspects will be covered: research design, sample, data collection method, data analysis, validation and reliability, ethical considerations and summary.

3.2 Research design

This study is a case study which employed a mixed method approach by using both qualitative and quantitative methods. A mixed method is a type of research in which quantitative and qualitative methods or techniques are mixed in one study (Johnson & Onwuegbuzie, 2004).

Johnson & Turner (2003) outlined the following advantages and disadvantages of using a mixed method:

- It helps you to collect multiple sets of data; by so doing it will be less likely that you will miss something important or make a mistake.
- Can answer a broader and more complete range of research questions because the research is not confined to a single method or research approach.
- Can strategically combine quantitative and qualitative research strength in a single study to cover a single purpose better than to cover multiple purposes
- A researcher can use the strengths of an additional method to overcome the weaknesses in another method by using both in a research study.
- Combining qualitative and quantitative research produces integrated knowledge that best informs theory and practice.

- It can be difficult for a single researcher to carry out both qualitative and quantitative research especially if two or more approaches are expected.
- It is more time consuming and expensive.
- The researcher has to learn about multiple methods and approaches and understand how to mix them appropriately.

The study is based on three phases. The first phase is the pre-test, the second phase is the intervention lesson and third phase is the post-test, involving quantitative methods to determine learning gain during the intervention. In quantitative research, the focus is on the control of all the variables. In qualitative research, the variables are not controlled, but the focus is on understanding and explaining the variables using data collected by various methods (Freebody, 2003). Qualitative data were collected only during the intervention phase (phase 2). The essential purpose of qualitative research is to document in detail the conduct of everyday events and to identify the meaning that those events have for those who participate in them (Erickson, 2012).

The research is done as a case study as it involves a sample of learners in a single school. Swanborn (2010) defines a case study as an intensive approach that provides a focus on one specific instance to be analysed in-depth. There are advantages and disadvantages of choosing to do a singular case study. Rule and John (2011) provide an indication of the advantages: (i) The case is a good example of its kind; (ii) it can be studied in great depth; (iii) the researcher has easy access to the case; and (iv) the researcher has experience of the case and 'insider knowledge'. The disadvantages of selecting a singular case study are: (i) The findings cannot be generalised to other cases with coherent academic conviction; (ii) there is no comparative dimension in the study; and (iii) the bias of the researcher might restrict or distort the findings.

3.3 Sample

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. The

sample for this research consisted of a single class in a school where the researcher taught and the class had 26 learners of mixed gender. The school was located in the Cradock district in the Karoo region in the Eastern Cape. All learners in this class took part in the study and they all participated in the focus group interviews. The sample is summarised in the table 2 below.

Table 2: Sample table

Participants	Population	Techniques	Criteria
Learners	26 out of 26	Total population	Purposive
Learners	For the purpose of focus group interviews 5 groups which consisted of 5-6 learners each were interviewed.	Total population	Random selection of the focus group

3.4 Data collection method

Data collection is the act of gathering necessary information that is related to a particular study through various methods and sources. There are many categories of data collection, including observation, document study and interviews (Henning and Wilhem, 2004). In line with this, the data collection was based on two sections. The first section included the full sample and was a pre-test that consisted of multiple choice questions. The test (Appendix D) was used as a baseline to check the learners' pre- knowledge and misconceptions based on the work that was done in the previous year in Grade 9 Natural Sciences. From the information gathered in the pre-test developmental lessons were used to help the learners to better understand the concept of ions in an aqueous solution (Appendix E). The lessons were drawn up to address the four conceptual change stages, namely dissatisfaction, intelligibility, plausibility and fruitfulness. Table 3 below is a reflection of the data collection plan.

Table 3: Methodological framework

Research question	Method	Instruments	Respondent	Analysis
How can teaching reactions in aqueous solutions through conceptual change impact learners' understanding?				
Step 1 (i) What were learners' initial understanding of the concept of ions in aqueous solutions?	Pre-test	Test	Gr 10 learners	Marking memorandum
Step 2 (ii) How were the lessons for the conceptual change approach implemented?	Lessons will be observed and video-taped	Lesson plan to address the four phases of conceptual change 1. Dissatisfaction 2. Intellegibility 3. Plausibility 4. Fruitfulness and observation schedule	Gr 10 learners	Evaluation sheet Thematic analysis Coding
Step 3 What were learners' understanding of the concept of ions in aqueous solutions after implementation of the conceptual change lessons?	Post test	Test	Gr 10 learners	Marking memorandum

Step 4 What were the learners' perception of the conceptual change lessons?	Focus group interviews	Interview schedule	Gr 10 learners	Coding / thematic analysis
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For the second section developmental lessons consisted of a number of activities such as demonstrations, group presentations and experiments which were implemented to address the four phases of conceptual change. For analysis purposes the researcher organised that the developmental lessons be video-taped for later observation. After the developmental lessons, learners were given a post test that also covered the same fundamentals as in the pre-test. Instruments for this research consisted of semi-structured interviews using an interview schedule (Appendix F) and an observation checklist (Appendix G) for the observations during the practical lesson. The researcher decided to use more than one method of data collection for the sake of credibility, referred to as triangulation.

To get the insider perspective the researcher made use of focus group interviews. Group interviews had the added advantage that they enabled the researcher to observe interaction between the learners on the topic of discipline. Through observing the participants, the researcher noted aspects that the learners were reluctant to reveal verbally. In this research, data was obtained through observations of the behaviour of the learners, including their body language, the verbal language and the duration of any of these actions.

3.4.1 Interviews

An interview is a dialogue between the researcher and the participant, aimed at collecting information about the topic under study (Rossouw, 2005). Rossouw also points out a number of advantages and disadvantages of interviews. A major advantage of an interview is that the researcher can obtain a large amount of data in a short space of time and the disadvantages thereof include:

- Unwillingness of the participants to share information, and the researcher asking questions which do not provide the required answers.

- Researcher's poor interviewing skills, an inability to phrase questions properly, or lack of understanding of the interviewee's culture or frame of reference, which may result in inadequate collection of data.

In this research the total population of learners participated for focus group interviews to obtain their level of knowledge, misconceptions about the concept of ions in aqueous solution and the stages of conceptual change. Learners were grouped into four groups with the first two groups consisting of six learners and seven learners in the last two.

Focus groups have been defined by Richardson & Rabiee (2001) as a technique that involves the use of in-depth group interviews, in which participants are selected because they are focused on a given topic and, more importantly, because they have something to say on the topic. The advantage of using focus group discussions is that they generate data and insights which would be less accessible without the interaction found in a group setting (Babbie & Mouton, 2001; Maree, 2007). In addition, they are inexpensive, provide immediate responses to questions raised, and are cumulative and elaborative (Maree, 2007). The disadvantages of such discussions are that the researcher has less control over a group and that time can be spent on issues which are irrelevant to the topic discussed (Patton, 2002). A further disadvantage of a focus group is that it can be dominated by outspoken individuals who make it difficult for the less outspoken members to participate.

The interviews were conducted after the post test was written using an interview schedule (Appendix F). The first four questions of the interview schedule comprised of science content whereas the last four questions were based on how conceptual change contributed to their understanding of the concepts. The duration of each interview was not fixed to allow participants to express themselves freely and the interviews were scheduled for the last period of the day so that it could continue for a few minutes afterwards. The participants felt free to engage because the interview questions were semi-structured, and included open-ended questions that allowed them to clarify or to question things pertaining to the topic. Interviews were transcribed and translated.

All the participants in the interviews were made aware of the procedures and purpose of the interviews. The participants had already agreed to take part in the study and had given their go-ahead for the information obtained to be used for research purposes. The researcher informed the participants of their right to withdraw from the interview at any stage, and their right not to answer any question that makes them feel uncomfortable. The participants were also assured of the fact that the content of the interview would remain confidential and the researcher emphasised their right to see the transcript and the researcher's interpretation of the research.

3.4.2 Observations

Observation is very important in research as the researcher takes notes of the behaviour and activities of the researched. It refers to methods of data generation which involves the researcher immersing him/herself in a research setting and observing the different dimensions of that setting (Creswell, 2003). Simpson and Tuson (2003) see observation as the act of looking analytically and constantly, and thoroughly noting people, setting, events, artefacts, and behaviours in naturally occurring situations.

This system of data collection is very important as it gives the researcher the opportunity to study the occurrence at a close range with many of the contextual variables present. Although the above are some of the important advantages of observation which makes it suitable for this research, at the same time it can be disadvantageous in that the results do not reflect the actual behaviour of the learners. With the researcher being both close to and part of the research alters the way in which learners behave and may also result in biases which may later affect the researcher's objectivity in the analysis of the data. According to Best (1959), the observer must be able to distinguish between the significant aspects of the situation and factors that have little or no importance to the investigation.

3.5 Data analysis

Data analysis refers to interpretation and understanding of the raw data to respond to the aims of the study and the research questions (Henning, van Rensburg & Smit, 2004). A variety of methods, including interviews, assessment tests and focus group

interviews were used to collect data. In this study, for ethical purposes, the names of the participants and institutions were not used; instead, they were given codes. During this phase the results of the assessment tests provided a measure that was used to gauge the learners' improvement in understanding the concept. The researcher compared the performance of the learners in the two assessment tests, that is the pre-test and the post-test. During the intervention lesson the researcher then addressed the four steps of conceptual change. The intervention lesson was transcribed from the video-recordings and described in detail.

All interviews were recorded using an audio tape-recorder. An interview schedule was used to guide the semi-structured interviews. After the interviews with the learners the recordings were transcribed and also translated word for word that even emotions were noted. The data was scanned and cleaned with the outliers highlighted. The researcher looked for similarities and differences in the answers and then looked for patterns that emerged, by so doing creating themes. For the data that didn't fit the themes the researcher used different highlighters for later use. The data collected by the focus groups interviews were qualitatively analysed. Data gathered from interviews were transcribed verbatim. A response from some of the learners that was captured in isiXhosa was translated into English. The process of analysis started with reading to scan data and rereading of the transcripts from the audiotaped recordings of the interviews to clean the data. Learner names and focus groups were coded. L was the code used for learner and FG for the focus groups. For the twenty-six learners L₁ was the code for the learner 1 in each focus group and L₂ was the code for learner 2, etc. For the focus group to which the learners belonged, FG was used as a code. A focus group code for the learner in focus group 1 was FG₁. The above codes are presented in table 4 below: Thereafter, data from interviews were colour coded for themes that emanated.

Table 4: Data coding for interviews

Coding of learner's name	Focus group	Example of final code
Learner 1 – L ₁	Focus Group 1 - FG ₁	FG ₁ L ₁
Learner 2 - L ₂		
Learner 3 – L ₃		
Learner 4 – L ₄		
Learner 5 – L ₅		
Learner 6 – L ₆		
Learner 1 – L ₁	Focus Group 2 – FG ₂	FG ₂ L ₂
Learner 2 – L ₂		
Learner 3 – L ₃		
Learner 4 – L ₄		
Learner 5– L ₅		
Learner 6- L ₆		
Learner 1 – L ₁	Focus Group 3 – FG ₃	FG ₃ L ₃
Learner 2 – L ₂		
Learner 3 – L ₃		
Learner 4 – L ₄		
Learner 5 – L ₅		
Learner 6 – L ₆		
Learner 1 – L ₁	Focus Group 4 – FG ₄	FG ₄ L ₄
Learner 2 – L ₂		
Learner3 – L ₃		
Learner4 – L ₄		
Learner5 – L ₅		
Learner6 – L ₆		
Learner1 – L ₁	Focus Group 5 – FG ₅	FG ₅ L ₅
Learner2 – L ₂		
Learner3 – L ₃		
Learner4 – L ₄		
Learner5 – L ₅		
Learner 6 – L ₆		

3.6 Validity and reliability

According to Leedy (1993) to ensure validity the researcher should be able to answer certain questions like: (1) Do the instruments measure what they are supposed to measure? and (2) Is the sample adequately representative of the behaviour measured? The qualitative observational researcher must attempt to maintain a non-judgmental bias throughout the study. In addition, preconceived expectations inhibit the researcher from observing character and speech that may be important to understand group behaviours or interactions. Although it is impossible to be a hundred percent objective, it is important that researchers enter the field or study group with an open mind, an awareness of their own biases, and a commitment to detach from those biases as much as possible while observing and representing the group. For this study the researcher ensured validity by audio recording the interviews, sending the interview schedule to non-participants for member check, and using focused clear and aligned questions and also triangulation of instruments.

Reliability is generally understood to concern the replicability of the research and obtaining of similar findings if another study using the same methods was undertaken (Lewis & Ritchie, 2003). In this study reliability is achieved by drawing up interview and observation schedules to ensure consistency. All instruments were sent to other science educators for trial-testing, including grammar, level of the questions and alignment with the research question.

3.7 Ethical consideration

According to Oppenheim (1996), “the basic ethical principle is that no harm should come to the respondents as a result of their participation in the research.”

The research proposal along with all data collection tools were presented to and approved by the University of the Western Cape’s Senate Research Committee before data collection. The process of data collection commenced immediately upon approval of the research proposal and instruments. Secondly, approval and informed consent were sought from the participants and relevant institutions. This was to ensure that no harm was done to the study participants (Babbie & Mouton, 2001).

The respondents were presented with a consent form and a brief introduction to the study. They were also informed that they had the option to withdraw their participation at any time. This enabled them to make informed decisions when consenting to the study. All participants remained anonymous throughout the analysis of the data (Creswell, 2009). Confidentiality and anonymity were maintained throughout and all participants were advised of this. The researcher removed any details that might be harmful to the participants. The participants were, however, cautioned that their words could be quoted in the final report, but that their names would not be used in conjunction with the quotation.

In the case of interviews, caution was taken by refraining from asking questions that could cause discomfort to the interviewees. The use of an electronic recording device was divulged to the participants before the interviews. The interview transcripts along with the questionnaire data were securely stored in a password-protected computer file and will be destroyed after a period of five years from the time the study is complete.

3.8 Conclusion

This chapter looked at the research design and methodology applied, and gave a description of how the data was analysed in the study. The data collection methods and ethical considerations were also described. The research analysis, results and the summary of findings will be discussed in the next chapter.

CHAPTER 4

FINDINGS AND DISCUSSION

4.1 Introduction

The previous chapter gave a description of the research methodology and focused on how the research was approached and coordinated. This chapter summarizes the findings and will report on the analysis of data using both qualitative and quantitative instruments. The chapter is arranged to answer the following main research question and sub-questions:

How can the conceptual change approach be used to teach ions in aqueous solutions in physical science?

- (i) What was learners' initial understanding of the concept of ions in aqueous solutions?
- (ii) How were the lessons for the conceptual change approach implemented?
- (iii) What was learners' understanding of the concept of ions in aqueous solutions after implementation of the conceptual change lessons?
- (iv) What were the learners' perceptions of the conceptual change lessons?

4.2 What was learners' initial understanding of the concept of ions in aqueous solutions?

In order to establish learners' initial understanding of the concept of ions in aqueous solutions, a pre-test was administered. The performance of the learners was measured by means of the coding scale that ranged between 0 and 3, where the description of the code allocated to each item was measured to represent the following:

- 0 Did not write at all
- 1 No attempt/no response to a particular question
- 2 Wrong answer due to misconceptions or lack of content knowledge
- 3 Correct answer

As mentioned in the sub-section on instrumentation in the previous chapter, there were ten items in the instrument that learners were tested on and the meaning attached to the codes for each answer provided by the learners per item was

characterized and analysed. The results of the pre-test are indicated below. Table 5 and figure 3 reflect how learners performed in the pre-test.

The entries in each column below the sub-heading - labelled levels of learners' understanding of the concept - represent the percentage of learners who subscribe to certain characteristics of a given score per question item(s). These entries are useful in giving a sense of how many learners have acquired each score per question item(s). Furthermore, the first column in the table denotes different categories of process skills required to categorize the learners' concept of ions in aqueous solutions such as: recall; concept understanding; and application of knowledge. The second column shows a summary of items starting from solutions (question 1-3) to acids and bases (question 4-7) and to ions in solution (8-10).

Table 5: Learners' pre-test percentages

Process skills	Ions in aqueous solutions	Levels of learners' understanding				
	Summary of question items	% (number of learners = 25)				Overall pass percentage
		0	1	2	3	
Recall	1. Solution of sugar in water	1	0	12	13	52%
	2. Universal solvent	1	1	8	16	64%
	3. Solvent in aqueous solution	1	1	8	16	64%
Sub-section average		100	1	9	15	60%
Concept understanding	4. Reaction of acid with a metal	1	1	19	5	20%

	5. Reaction of acid and a base	1	1	18	6	24%
	6. Chemical reaction	1	0	14	11	44%
	7. Hydration process	1	0	19	6	24%
Sub-section average		100	0	18	07	28
Application	8. Electrolyte	1	0	10	15	60%
	9. Precipitate	1	0	18	7	28%
	10. Dissociation process	1	0	9	16	64%
Sub-section average		100	0	12	13	51

The results of the pre-test in Table 5 above range from 10% to 80%. The table also shows that out of the 25 learners who wrote the test, instead of 26 who were supposed to write the test, two of them obtained less than 30% on the test, seven learners obtained 30%, five learners obtained 40%, four obtained 50%, two obtained 60%, four obtained 70% and one obtained 80%. There was one learner absent who did not write the test.

Question by question analysis of the test is illustrated in diagram 3 below. The graph below shows that learners had difficulty answering questions 4, 5, 7 and 9 as they obtained less than 30% on them. Questions 4, 5 and 7 are part of the work they did the previous term on chemical reactions and, as for question 9, it is part of the new work that they would be doing. In question 6 learners obtained less than 50% and they then performed better in questions 1, 2, 3, 8 and 10 as they obtained more than 50%.

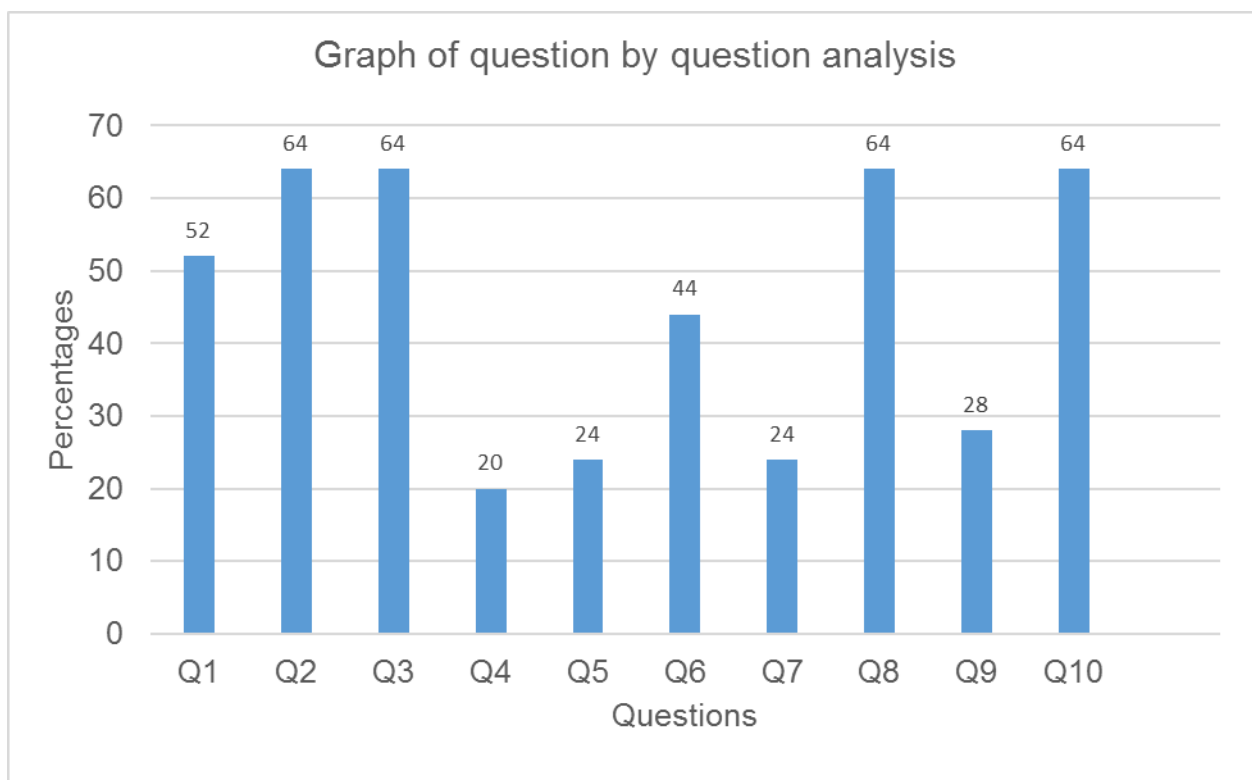


Figure 3: Graph representing question by question analysis of the pre-test

According to the results in the pre-test very few of the learners could answer the questions properly and have the required understanding of what the concept is all about. In order to address the misconceptions of the learners a conceptual change teaching approach was used as indicated below.

4.3 Application of the conceptual change approach

In order to improve the conceptual understanding of the concepts of ions in aqueous solutions, a series of lessons were implemented using the conceptual change approach. According to Posner *et al.* (1982) the conceptual change approach consists of the following steps:

4.3.1 Dissatisfaction

Dissatisfaction is the mental state of the learner when he/she appreciates that his/her current solution to a problem is not adequate. Dissatisfaction causes the learner to query his/her existing conception. Without dissatisfaction, the learner will

not appreciate the benefit of restructuring his/her beliefs. In order to satisfy this step of the conceptual change framework, the following lesson was implemented.

To make sure that the learners were dissatisfied with their pre knowledge, the topic of the lesson was first unpacked. The educator wrote the topic “Ions in aqueous solutions” on the board and took out the key words ‘ions’, ‘aqueous’ and ‘solution’ and then asked learners to define them.

The first key word that the learners were asked to define was ions but the learners kept quiet for a while not answering until the educator moved to another question and asked them to at least give examples of ions that they know if they cannot come up with the definition. The following learner responses to the above questions were obtained in the class:

Steel iron. [Learner 1]

Iron that is used on laundry. [Learner2]

We know about anions and cations. [Learner 3]

Ions that lost or gained electrons. [Learner 4]

Some ions are positive and others are negative. [Learner 5]

The educator then wrote the responses on the board and asked the learners to discuss and choose among the responses on the board which one was correct. Through the discussion among them it emerged that the last three were correct. The educator then continued and asked what the difference was between ‘anions’ and ‘cations’. The learners indicated that:

Anions have a negative charge while cations have a positive charge. [Learner 3]

Anions gained electrons while cations lost electrons. [Learner 6]

The educator then wrote an example of the cation as Na^+ and anion as Cl^- and asked the learners to look at their similarity which would help them in answering the first question of defining ions. It was at this stage that one learner defined ions as the charged atom. The educator then asked learners to give other examples of ions and wrote the list of all the named ions on the board. Out of the list that was given most

of the atoms were not ions so the educator wrote them aside of the correct ones and asked the learners to identify the difference and the following responses were given:

The atoms were stable. [Learner 3]

Atoms did not lose or gain electrons. [Learner 7]

Atoms had no sign on top. [Learner 8]

Atoms were balanced. [Learner 9]

Atoms had the same number of electrons and protons. [Learner 3]

Atoms lost electrons therefore their charge is zero. [Learner 10]

There was again a discussion on all the responses that were given until all the ones that did not fit were omitted.

The educator then asked learners to define the term 'solution' and these were the responses of the learners:

A solution is when you mix something like water and sugar. [Learner 7]

It is when a solid is mixed with a liquid. [Learner 11]

When you mix two or more substances. [Learner 12]

It is when you mix two things it can both be liquids or both solids. [Learner 13]

Coffee is also a solution. [Learner 1]

Drink. [Learner 14]

The educator then took out two beakers and mixed sugar and water in one beaker and in another water and oil and asked the learners to tell whether those two could be defined as solutions.

Not both of them are solutions because they are not the same. [Learner 15]

Only sugar water is a solution because it dissolved in water the other one did not dissolve in water therefore it is not a solution. [Learner 16]

They are both solutions because they are both mixed with water. [Learner 17]

The first one is a solution because there is a liquid and solid mixed together.

[Learner 2]

They are both solutions as long as there is a solute and a solvent. [Learner 18]

The last one is not a solution because it has a layer. [Learner 19]

The educator then gave them another opportunity for discussion as there were many different responses but they still could not decide exactly which one was correct. The educator then summarised the topic by telling them that both the beakers had solutions and that for the solution there must be a solvent and a solute and that a solute does not have to be in a solid form - sometimes it can be in a liquid form just like the oil in this case. The educator also indicated that in both beakers the solvent is water and that is where the aqueous term fits in. All solutions that had something dissolved in water were said to be aqueous solutions. During the introduction of the lesson learners gave a different answer in the definition of the solution as they did with question one and question three of the pre-test which were based on this definition. This demonstrates that there were real differences in their answers and how they were thinking about their answers. Ultimately it displays some form of dissatisfaction with their original understanding.

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4.3.2 *Intelligibility*

Intelligibility means that the new concept must be understandable and an individual must be able to grasp how knowledge can be structured by a new concept enough to explore the possibilities inherent in it. In order to address intelligibility, the following lesson was implemented. In this lesson learners were given various salt solutions prepared in de-ionised water to identify the anions in those various salt solutions.

EXPERIMENT

Learners were grouped into four groups and were given solutions of sodium chloride, sodium bromide, sodium iodide and silver nitrate prepared in de-ionised water, as well as concentrated nitric acid and ammonia solution. They were instructed to clean test tubes and fill three of them with the halide solutions and add a few drops of silver nitrate into each by using a medicine dropper. They were then told to note the colour of any precipitation that was formed. They were then told to add a few drops

of concentrated nitric acid, wait a few seconds and add a few drops of ammonia solution.

Learners were again given solutions of magnesium sulphate and sodium carbonate prepared in de-ionised water in separate test tubes. They were required to add a few drops of barium chloride to the solution in each test tube then add a few drops of concentrated nitric acid to each test tube. They were again told to write down their observations.

In those groups there was little discussion on why these salts were prepared in de-ionised water and not tap water, and also why they needed to clean the test tubes before using them and how to balance chemical equations of the reactions in each test tube. From these equations another discussion arose on when to use the coefficient and the subscript. There was also some argument on the colour of the precipitate, especially between the colour white, cream and silver and also what would have happened if they used sulphuric acid instead of nitric acid.

In this context, learners used methods and procedures of science to investigate phenomena, solve problems and pursue interests in order to develop an understanding of the scientific concepts, models and theories and acquire an understanding of the nature and methods of scientific inquiry. In this stage learners were guided into taking control of their own learning in a search for understanding. From the lesson it was clear that learners were involved in the lesson and thinking about what they were doing and using various options to come to a solution. This satisfied the intelligibility component of the conceptual change framework.

4.3.3 Plausibility

The new concept must make sense to the learner and he/s should be able to easily use the information to solve other related problems. In order to address plausibility, the following lessons were implemented.

A lesson was given to the learners making use of a video-clip. The reason for using a video-clip was to enhance the learners' understanding of why water was used to

dissolve most substances. This lesson dealt mostly with the polarity of water which was at the sub-microscopic level. Learners needed to imagine the movement of particles, but in the video clip the assimilations of particles were shown for them to better understand the concept.

The video-clip showed that water was seldom pure. Because of the structure of the water molecule, substances could dissolve easily in it. This was very important because if water was not able to do this, life would not be able to survive. Many of the substances that dissolve are *ionic* and when they dissolve they form ions in solution. It then showed how water is able to dissolve ionic compounds. The video-clip was divided into the following sub-headings

Polarity of water

A water molecule is made up of two hydrogen atoms and one oxygen atom, figure 4. Hydrogen and oxygen were both acting as non-metals under ordinary conditions, but oxygen was quite a bit more electronegative than hydrogen, so the two atoms formed a covalent chemical bond.

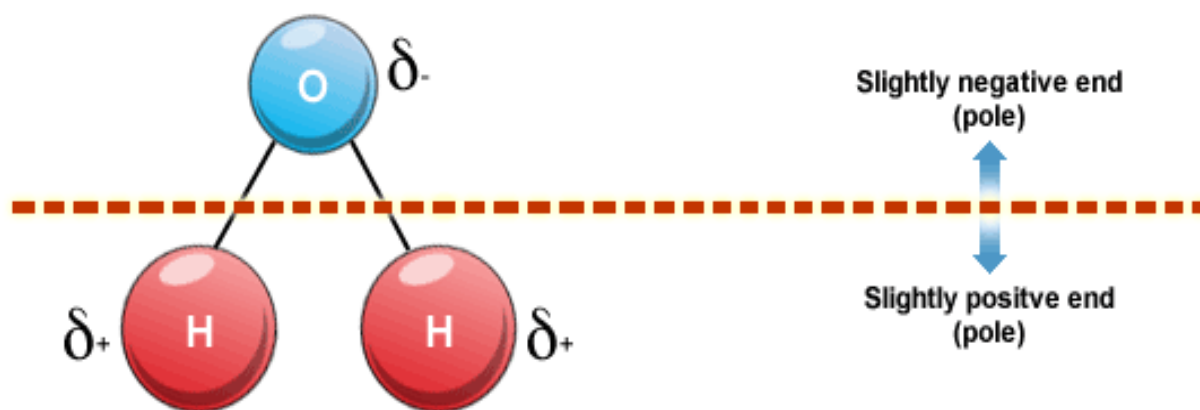


Figure 4: Polarity of water

The highly electronegative oxygen atom attracted electrons or a negative charge to it, making the region around the oxygen more negative than the areas around the two hydrogen atoms. The electrically positive portions of the molecule (the hydrogen

atoms) were flexed away from the two filled orbitals of the oxygen. Basically, both hydrogen atoms were attracted to the same side of the oxygen atom, but they were as far apart from each other as they could be because the hydrogen atoms both carried a positive charge. The bent conformation was a balance between attraction and repulsion.

Dissociation of water

It is the polar nature of water that allows ionic compounds to dissolve in it. In the case of sodium chloride (NaCl), for example, the positive sodium ions (Na⁺) would be attracted to the negative pole of the water molecule, while the negative chloride ions (Cl⁻) would be attracted to the positive pole of the water molecule. In the process, the ionic bonds between the sodium and chloride ions were weakened and the water molecules were able to work their way between the individual ions, surrounding them and slowly dissolving the compound. This process was called **dissociation**. A simplified representation of this is shown in the figure 5 below.

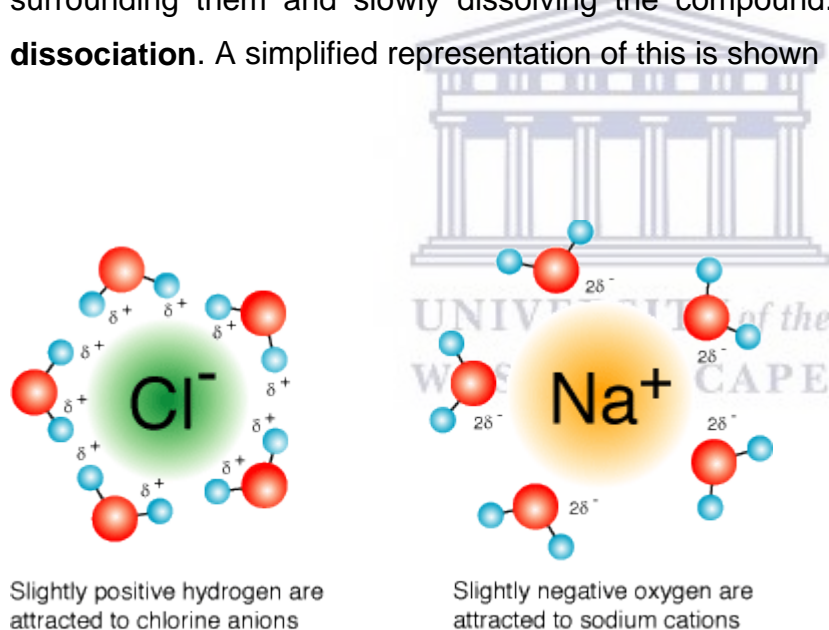
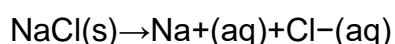


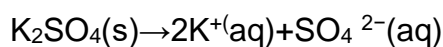
Figure 5: Dissolution of NaCl

The dissolution of sodium chloride could be represented by the following equation:

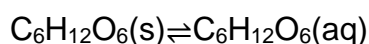


The symbols s (solid), l (liquid), g (gas) and aq (material is dissolved in water) were written after the chemical formula to show the state or phase of the material. The

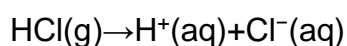
dissolution of potassium sulphate into potassium and sulphate ions was shown below as another example:



In the video it was also noted that molecular substances (e.g. covalent compounds) may also dissolve, but most will not form ions. One example highlighted in the video was sugar.



There were exceptions to this and some molecular substances would form ions when they dissolved. Hydrogen chloride, for example, could ionise to form hydrogen and chloride ions.



After the video-lesson learners were given an activity below where they were required to apply the information that they gained from the lesson to solve the following problems.



Activity 1

1.1 Give the names and formulae of four salts that you know

- (1) (2).....
(3) (4).....

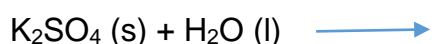
1.2 In what physical state (phase) are these salts mentioned in 1.1 found in the laboratory?

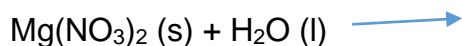
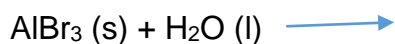
1.3 Out of what particles are these salts composed?

1.4 Which bonds or forces mentioned keep the particles named in 1.3 together in a crystal lattice?

1.5 Many salts such as BaSO_4 , FeCO_3 , AgCl are insoluble in water. Explain why some salts are insoluble in water.

1.6 Write a balanced equation for the dissolution process of the following:





Lesson 2

The educator introduced the lesson by a demonstration where she performed the following reactions and learners were asked to look at the differences in these reactions.

- Aqueous lead nitrate with aqueous potassium iodide
- Zn metal and sulphuric acid
- Copper with silver nitrate solution
- Sodium hydroxide with nitric acid

Learners indicated that with the first reaction there was a colour change. They even argued on the colour - some said it was white and others said it was cream. With the second reaction learners indicated the fact that there were bubbles that were released which meant that there was a gas being formed or released. With the third reaction the learners said the copper was turning brownish and when they had to explain what they saw in the fourth reaction they said there was no reaction.

The educator then introduced the topic of different reactions where learners were taught that there were four types of reactions, namely: acid base reaction, gas forming reaction, precipitation reaction and oxidation reduction reaction and their driving forces. The educator also taught learners how to write balanced chemical equations and net ionic equations. The learners were then given an exercise to do after the lesson.

Activity 2

Write a balanced chemical equation for the following reactions and identify in each case whether it is a precipitate reaction, gaseous reaction or acid-base reaction.

- (a) Aqueous lead nitrate is mixed with an aqueous potassium iodide.
- (b) Calcium hydroxide is mixed with hydrochloric acid.

- (c) Zinc metal + sulphuric acid
- (d) Hydrochloric acid and sodium hydrogen carbonate
- (e) A piece of sodium metal is added to water.
- (f) Barium carbonate is added to an aqueous solution of nitric acid.

Because learners used what they learned to solve other related problems the plausibility stage has been achieved.

4.3.4 Fruitfulness

The new concept must be useful to the learners and they must be able to use it in their real life situation. In order to address fruitfulness, the following practical investigation was implemented.

For a practical investigation learners were given a task under purification of water where they were requested to collect a sample of water from the river which was suspected by the community of causing stomach problems and skin problems. Learners were requested to test for ions found in the river water, acidity, conductivity and turbidity. They were required to report on the results of the test and say whether they found it to be the cause of the stomach and skin problems. Learners could apply what they learnt in the previous lessons to the real world situation; therefore, the step of fruitfulness was achieved.

4.4 What were learners' understanding of the concept of ions in aqueous solutions after implementation of the conceptual change lessons?

In order to determine learners' understanding of the concept of ions in solution after the conceptual change lessons a post-test was given to the learners and the results of the post- test are indicated below in table 6 and figure 6.

Table 6: Learners' post-test percentages

Process skills	Ions in aqueous solutions	Levels of learners' understanding				
	Summary of question items	% (number of learners = 20)				Overall pass percentage
		0	1	2	3	
Recall	1. Solution of sugar in water	6	1	12	7	35%
	2. Universal solvent	6	0	5	15	75%
	3. Solvent in aqueous solution	6	1	6	13	65%
Sub-section average		100	1	8	11	58%
Concept understanding	4. Reaction of acid with a metal	6	0	9	11	55%
	5. Reaction of acid and a base	6	0	13	8	35%
	6. Chemical reaction	6	0	9	11	55%
	7. Hydration process	6	0	12	8	40%
Sub-section average		100	0	18	07	48

Application	8. Electrolyte	6	0	10	10	50%
	9. Precipitate	6	0	15	5	25%
	10. Dissociation process	6	0	1	19	95%
Sub-section average		100	0	12	13	56

The results in the post-test in the table above range from 10% to 90%. The table also shows that out of the 20 learners who wrote the test - the other six were absent from school - one of them obtained 10% on the test, one obtained 30%, six learners obtained 40%, three learners obtained 50%, five learners obtained 60%, two learners obtained 70%, one obtained 80%, and one obtained 90%.

Question by question analysis of the above test is illustrated in diagram 4 below. The graph below shows that learners still had difficulty answering question 9 as they obtained less than 30% on that question. In questions 1, 5 and 7 they obtained below 50%. In questions 4 and 8 they obtained above 50%, in 3 and 6 they obtained above 60%, in question 2 they obtained above 80% and in question 10 they obtained more than 95%.

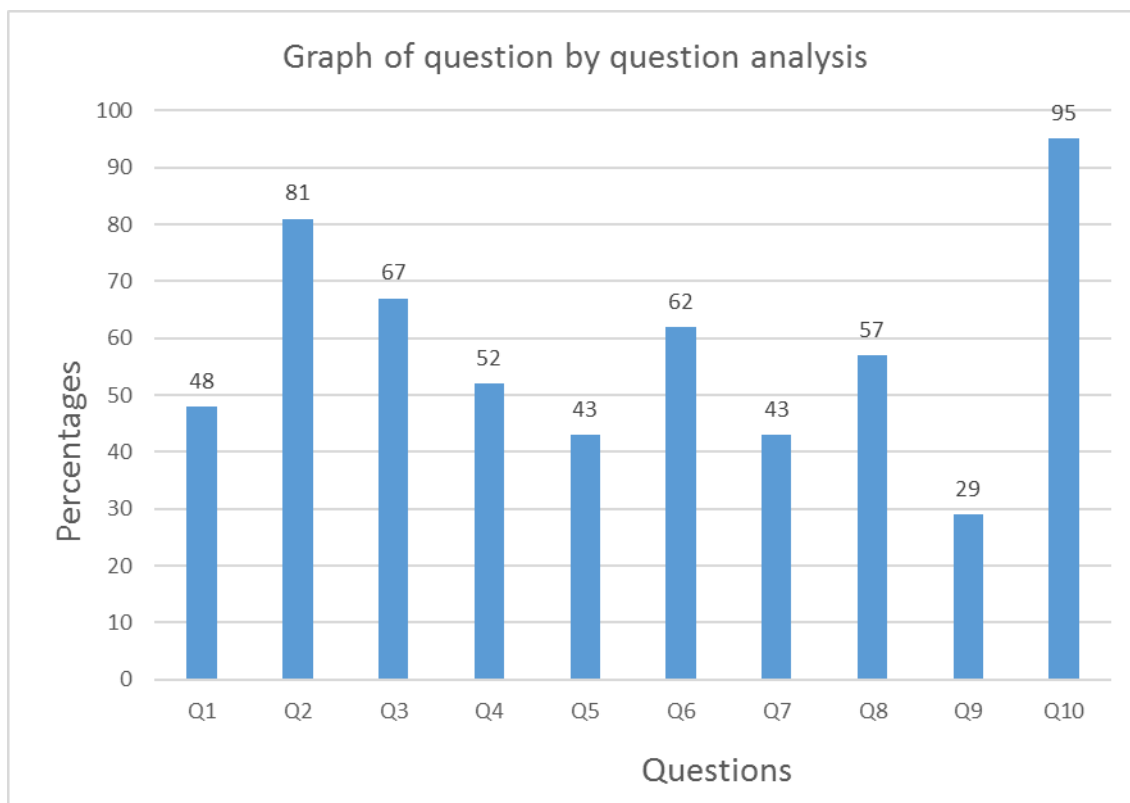


Figure 6: Diagram of question by question analysis

4.5 Learners' performance from pre- to post-test

Based on the results of the pre-test and the post-test it is evident that learners performed better in the post-test compared to the pre-test. The purpose of this study was not only to determine learners' achievements but also to check their improvement from pre- to post-test and to also check if the intervention lesson provides any change to the learner's conception of ions in solution. For comparison reasons the results of the pre-test were compared to those of the post-test, where the researcher determined learners' understanding before and after the conceptual change lesson. The findings are presented in table 7 below.

Table 7: Comparison between the pre- and post-test

Summary of question items	Results of pre-test	Results of post-test
1. Solution of sugar in water	52%	35%
2. Universal solvent	64%	75%
3. Solvent in aqueous solution	64%	65%
4. Reaction of acid with a metal	20%	55%
5. Reaction of acid and a base	24%	35%
6. Chemical reaction	44%	55%
7. Hydration process	24%	40%
8. Electrolyte	60%	50%
9. Precipitate	28%	25%
10. Dissociation process	64%	95%

According to the table above it is indicated that there has been an improvement from pre-test to post-test except for questions 1, 8 and 9.

In the pre-test question 1 which dealt with a solution of sugar in water, out of 25 learners who wrote the test 13 of them said that sugar was called a solute, 7 of them said sugar was called a solvent, 4 of them said that sugar and water were both called products and 1 said that water was called a reactant. With question 1 in the post-test 1, of the 20 learners who wrote the test 7 of the learners said that sugar was called a solute, 11 of them said sugar was called a solvent while 1 said that sugar and water were both called products and 1 said water was called a reactant. There was a decline from 52% in the pre-test to 35% in the post-test which was a decline of 17%. 9 out of 12 learners in the post-test who were wrong in this question claimed that in a solution of sugar in water, sugar was called a solvent. This might be because the term 'solvent' was used a lot while they were doing the experiment and while doing the project which was the application of a real life situation.

With question 2 which was asking which liquid was considered the universal solvent, 16 out of 25 learners in the pre-test said that water was a universal solvent, 5 said an acid is a universal solvent while 2 learners claimed that oil is a universal solvent. 1 learner said a base is a universal solvent and 1 learner left the question unanswered. Looking at the post-test, 15 out of 20 learners said that water is a universal solvent, 4 learners said that an acid is a universal solvent and 1 learner claimed that oil is a universal solvent. In this question there was an improvement from 64% in the pre-test to 75 % in the post-test. There was an increase of 11%. The increase might be because while they were doing the project most solutions were prepared by the learners and it was constantly mentioned that most chemical solutions are prepared in water and that water is the universal solvent.

Question 3 was about stating the solvent used in an aqueous solution. In the pre-test 16 out of 25 learners indicated that water was a solvent used in aqueous solution, 6 learners said an acid was a solvent used in aqueous solution, three said a base was a solvent in aqueous solution while 1 left the question unanswered. As for the post-test in this question, 13 out of 20 learners indicated water to be the solvent used in aqueous solution, 5 learners said an acid was a solvent in aqueous solution, 1 learner identified a base as a solvent in aqueous solution and 1 learner left the question unanswered. There was an improvement from 64% in the pre-test to 65% in the post-test, an increase of only 1%. Here the increase in percentage might be because in one of the lessons the educator told the learners that they must note that 'aqua' means water and that aqueous solutions are solutions prepared in water.

In question 4 that required a product formed when an acid reacts with a metal, 5 out of 25 learners in the pre-test indicated that a salt is formed from this reaction. 16 learners said an acid is formed from the reaction of an acid and a metal while 3 learners indicated water as one of the products and 1 learner left the question unanswered. In the post-test 11 out of 20 learners indicated that salt is one of the products formed when an acid reacts with a metal, 6 learners identified a base as one of the products, while 3 said water is one of the products. There was also an improvement in this question from 20% in the pre-test to 55% in the post-test, an increase of 35%. The chapter of reactions of acids and bases is part of the previous year's work but learners have a tendency of forgetting what has been taught the

previous year. The increase in the percentage might be because learners only realised after the intervention lesson that salt is produced when an acid reacts with a base.

Question 5 was a question about the term given to a reaction of an acid that reacts completely with a base to produce water and salt. In the pre-test out of 25 learners only 6 learners were correct to say it is the neutralization reaction, another 7 said it is the precipitation reaction, 7 learners indicated that it was the synthesis reaction while 4 learners said it is the decomposition reaction and 1 left the question unanswered. Looking at the post-test, out of the 20 learners who wrote the test 7 learners said it is the neutralisation reaction, 9 said it is the precipitation reaction while only 4 said it is the synthesis reaction. There has been an improvement from 24% in the pre-test to 35% in the post-test, meaning a percentage difference of 11%. The same reason for question 4 applies here. The increase in the percentage might be caused by the realization of the work that was done the previous year but has been forgotten during the pre-test and remembered during the intervention lesson.

Question 6 was about writing a chemical reaction. In the pre-test out of 25 learners who wrote the test 11 were correct to say the reactants are written on the left of the arrow, while 9 said reactants are written on the right of the arrow, 2 said reactants and products are always on the same side and 2 said reactants and products mean the same thing. One learner left the question unanswered. In the post-test out of the 20 learners who, 11 said reactants are written on the left of the arrow, 6 said reactants are written on the right of the arrow while 2 said reactants and products are always on the same side and 1 left the question unanswered. There was an improvement from 44% in the pre-test to 55% in the post test, a percentage difference of 11%. This is the difficult part of the lesson for learners in Grade 9. They struggle a lot with writing chemical reactions and I think in Grade 10 it is now starting to make sense because it is being taught for the second time. That could have caused the increase in the results.

Question 7 asked about the process involved when NaCl reacts with H₂O. In the pre-test out of 25 learners only 6 were correct and said the process was called dissolution, 12 said it was ionisation, 5 said it was polarisation and 2 said it was

neutralisation. In the post-test out of 20 learners 8 said the process was called dissolution while 10 learners said it was the ionisation process and 1 said it was the hydration process. There was an improvement from 24% in the pre-test to 40% in the post-test. A percentage increase of 16% was determined. This question was part of the new work that the learners had not done the previous year. It might be that even those who got it right might have been guessing.

Question 8 asked for the definition of an electrolyte. In the pre-test 16 out of 25 learners were correct and indicated that it is a solution that contains ions and can conduct electricity, 6 learners said it is a process where ions are surrounded with water molecules in a water solution, 2 learners said it is a process where solid ionic crystals are broken up into ions and 1 learner indicated that it is a process where an ion exchange occurs. In a post-test out of 20 learners, 10 indicated that it is a solution that contains ions and can conduct electricity, 6 learners said it is a process where ions are surrounded with a water molecule, 2 learners said it is a process where ion exchange occurs and another 2 learners indicated that it is a process where solid ionic crystal are broken up into ions. There has been a decline in percentages from 64% in the pre-test to 50% in the post test. The decline might have been caused by the confusion that learners had. This confusion might have happened during the plausibility stage in the intervention lesson when the polarity of water was discussed in the video clip.

Question 9 was the question that required learners to define a precipitate. In the pre-test out of 25 learners only 8 were correct and said it is a solid formed during a chemical reaction. 13 claimed that it is the change in colour of the solution during a chemical reaction while 2 indicated that it is the rock edge and another 2 said it is a substance dissolved in water. Then in the post-test out of 20 learners only 5 maintained that it is a solid formed from a chemical reaction, 13 said it is a change in colour of the solution during a chemical reaction while 2 said it is a substance dissolved in a liquid. There was a decline in percentages from 35% in the pre-test to 25% in the post-test. This decline could be from the fact that, while learners were doing the experiment of the formation of the precipitate, there was a lot of colour change. This means that this misconception by the learners needs more attention.

Question 10 was a question where learners were requested to identify the equation that represents the dissociation of NaCl. Out of 25 learners 16 were correct and said: $\text{NaCl (s)} = \text{Na}^+ (\text{aq}) + \text{Cl}^- (\text{aq})$, 6 of the learners said $\text{NaCl (s)} = \text{Na (aq)} + \text{Cl (aq)}$, 2 learners said $\text{NaCl (s)} = \text{Na}^- (\text{aq}) + \text{Cl}^- (\text{aq})$ while 1 learner said $\text{NaCl (s)} = \text{Na}^- (\text{aq}) + \text{Cl}^+ (\text{aq})$. Then in the post-test out of 20 who wrote the test 19 were correct and said: $\text{NaCl(s)} = \text{Na}^+ (\text{aq}) + \text{Cl}^- (\text{aq})$ but only one was incorrect and said $\text{NaCl (s)} = \text{Na (aq)} + \text{Cl (aq)}$. There was a percentage increase of 31% which might have been caused by the video lesson that learners watched. The video clip thoroughly explained dissociation and dissolution by means of animation.

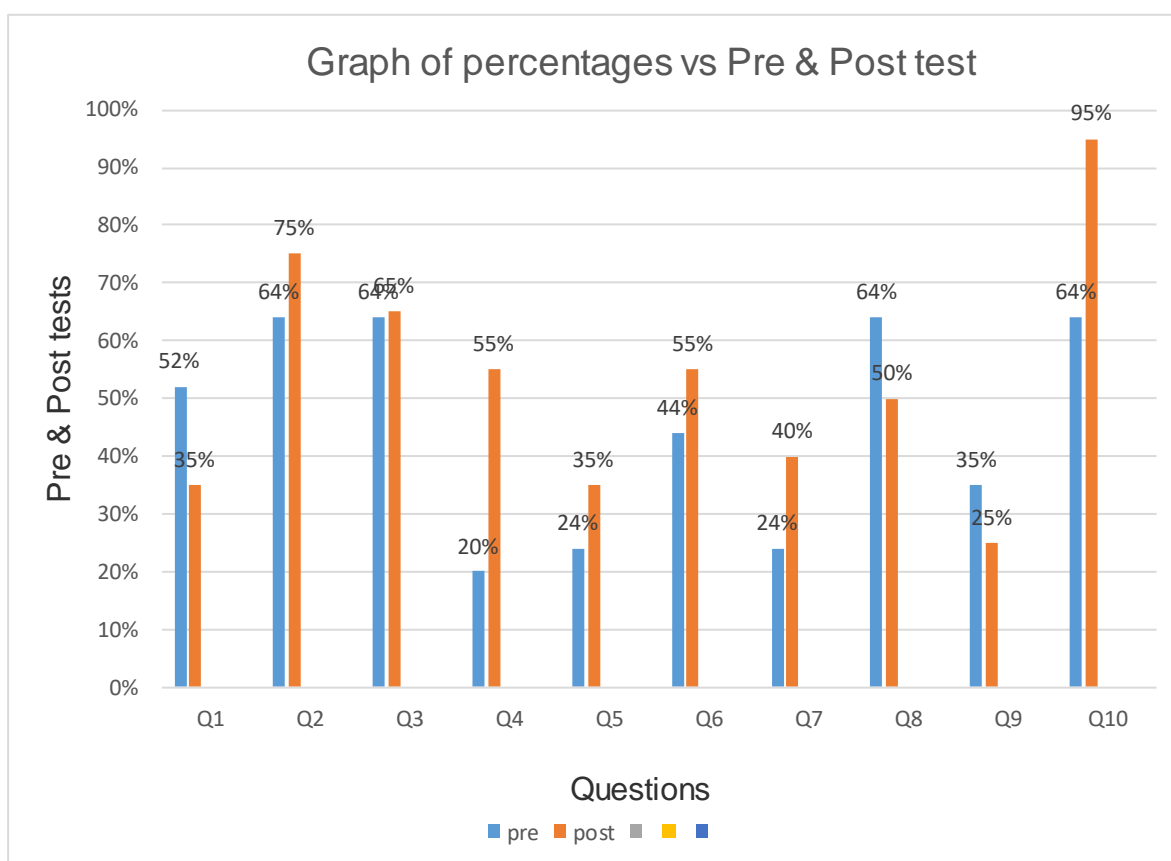


Figure 7: Diagram comparing the pre- and post-tests

Figure 7 above clearly shows that learners had a better understanding of the concept of ions in aqueous solution after the lessons than they did before the lessons. This improvement in their understanding is determined by the fact that out of 10 question on which learners were tested, there was an improvement in 7 questions, even

though there was a decline in 3 of the questions. This decline from the pre-test to the post-test showed that there were still misconceptions that the lesson did not address.

4.6 Conceptual change lessons

During the implementation learners had difficulties defining terms when the educator requested them. That was when the educator was introducing the lesson and the learners also struggled to give scientific explanations when defining. When the educator asked the learners to define an ion, learners did not respond and the educator had to proceed to the following question or probe more for the learners to finally give the definition. For example, learners responded by saying ions is when an element has a minus or a positive sign and another one said it is when an atom has lost or gained electrons.

The learners were also asked to define a solution and instead of giving a scientific definition they gave answers of what a solution is in the household context. For example, one learner said a solution is when you mix two things and the other one said it is like coffee where coffee powder is dissolved in hot water. This indicated that learners do have some knowledge of what a solution is but that their understanding is expressed in general terms and not necessarily in scientific terms.

When performing experiments learners were actively involved in the sense that they did the experiment on their own and were even discussing amongst themselves the outcomes of it. Since the experiment was based on precipitation and balancing of equations, more discussions amongst them were based on colour changes where there were arguments on the exact colour and also when they were to balance equations whether the number that is used to balance should be written as a coefficient or as a subscript. They would first argue amongst themselves and if they did not agree they would ask the educator to confirm the correct answer - like when they were not sure about the colour changes of the precipitates.

In the course of one of the intervention lessons where the educator gave a lesson in terms of a video clip that described the polarity of water and the hydration process,

most learners looked bored. This might be because there was so much abstract information. Even though the educator kept pausing the video and explaining the concept and the video also had animations to help the learners to respond to the lesson, the responses received were not what the educator expected; instead they looked bored. The lesson in video form would probably have been better served if the educator first explained the concept and then let the learners watch the video afterwards so as to give them a better understanding of the concept instead of playing the video and explaining in-between.

4.7 Focus group interviews

To determine learners' views on how conceptual change teaching has contributed to their understanding of the concept, focus group interviews were conducted. Table 8 below indicates themes that emerged during the focus group interviews that were conducted with four groups with six learners in the first two groups and seven in the last two.

Table 8: Summary of interview questions and themes

Questions	Key questions	Themes
1	Formation of salts	Reaction of acid and base
2	Naming of salts and identification of solubility	Chlorides, sulphates and iodides
3	Polarity of water	Dipole structure of the water molecule
4	How salts dissolve in water	Dissolution process
5	Change in response from pre- to post-test	Better understanding after the intervention lesson
6	Understanding of the concept	Improved understanding
7	Contribution of concept in everyday life	Acid rain and hard or soft water
8	Contribution of the experiment towards understanding of the concept	Better understanding

Question 1: Briefly explain how salts are formed.

In answering this question most learners indicated that salts were formed when acids react with a base even though they had different ways of putting it but they all said the same thing.

When acids react with . [FG₁ L₃]

Acids react with bases. [FG₂ L₄]

When the acid and the base reacts with each other. [FG₃ L₁]

Formed from the acid base reaction. [FG₄ L₄]

Question 2: Mention the few salts that you know and please tell which salts are soluble in water from what you have mentioned.

Most learners when answering this question mentioned sodium chloride, sodium sulphate and iodide as salts.

Question 3: Is water a polar substance or non-polar substance? Explain your choice.

In answering this question all learners indicated that water was a polar substance and in explaining why they said so they talked about the dipole structure of the water molecule. In focus group 1 none of the learners could explain why they said it was a polar molecule while in other groups they even went to the extent of explaining that the positive side of the water molecule attracts the negative side of another molecule and the negative side of the water molecule attracts the positive side of another molecule that reacts with it.

One side of water is partially + while the other side is partially negative. [FG₂ L₃]

One side is slightly + and the other side is slightly negative that makes Oxygen more electronegative. [FG₂ L₅]

It has a positive side which attracts a negative of another substance and a positive side which attracts the positive of another substance. [FG₃ L₄]

Water has 2 Hydrogens and 1 Oxygen. It is these 2 Hydrogens that represent the positive side and the 1 Oxygen represent the negative side. [FG₄ L₁]

Some of the learner knew that water was a polar substance but they had no clue of what this meant. Examples are the following responses:

It has an uneven distribution of charge. [FG₃ L₃]

It is because we have negative water and positive water. [FG₄ L₂]

Question 4: Explain how salts dissolve in water.

In an attempt to answer this question learners indicated that salts dissolve in water due to the dissolution process.

When the salt is dissolved in water it turns water salty and disappears in water. [FG₂ L₄]

When salt dissolve in water dissolution process takes place for an example when NaCl dissolve in water Na⁺ will be separated from Cl⁻, Cl which is negative will be pulled by the H atom and the Na which is positive will be pulled by the O atom of the water molecule. [FG₁ L₂]

Question 5: The response that you gave in the pre-test has changed to what you gave in the post-test. Why is that so?

Most learners indicated that the reason for them to have a difference response on the post-test compared to the pre-test is because they now have a better understanding of the concept after the conceptual change lesson.

Question 6: Do you now feel that your understanding of this concept has improved? If yes, how has it improved?

Learners pointed out that their understanding has improved and in different sections of the topic except for one learner who indicated that it has not improved because 'he still needs to understand the polarity of water'.

It has now improved because I now know that there are different types of salts other than the table salt. [F1 L5]

It has improved because I now understand that different types of water have different PH. [F4 L4]

It has improved because when I dissolve table salt in water, I now have an idea of what happens that I cannot see with the eye. [F4 L1]

Question 7: What benefits does learning ions in aqueous solution have in our everyday life?

In response to this question learners pointed out that the application of ions in their real life situation could be found in the explanation of acid rain which was caused by polluted gases such as carbon dioxide which dissolve in rain. Others specified the fact that it could also be used to distinguish between soft and hard water. Another learner responded by mentioning the fact that even the process of how nutrients dissolve in water and how they are absorbed by the roots of plants is also part of ions in aqueous solution.

Question 8: How did the practical experiment contribute to your understanding of the concept?

The response to this question was that the experiment makes them understand the abstract concepts more than just reading the book.

I had no idea of what a precipitate looks like but through experiments I understand precipitation more. [FG₄ L₇]

Studying something that you see makes you understand more than just memorising the textbook. [FG₃ L₆]

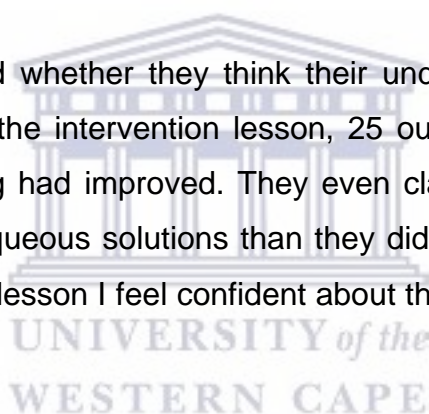
4.8 Learners perceptions of the conceptual change lessons

When learners were requested to do a practical investigation where they had to (i) test the quality of the river water that was suspected of causing stomach problems and (ii) report on their findings, they were all enthusiastic because they all wanted to find out if the suspicions were correct. The fact that they were the ones who were to

provide the results made them more excited. One learner even said “I now feel like a real scientist,” while another one said “I just wish I could also test some food products and see if they really do contain the ingredients that they claim to have.”

The educator had to make them aware of the fact that the project was only made for school purposes and that they should not go around proclaiming their findings to the community because they did not have proper equipment to do a full test of the water. Learners indicated that this was the best part of the lesson because they never knew that there were so many issues involved with water even though they use water so much in their daily lives. One learner said “I only thought that water was tested for micro particles that causes bacteria only. I never knew there was so much tested on water.” While a few indicated that they did not even know that water is tested by the municipality before it is used.

When learners were asked whether they think their understanding of the concept had improved or not after the intervention lesson, 25 out of 26 indicated that they thought their understanding had improved. They even claimed that now they knew more concerning ions in aqueous solutions than they did before the lesson. One of the learners said “After the lesson I feel confident about the topic that I trust that I did better in my second test”.



One learner claimed that his understanding did not improve because he still didn't understand the part of the polarity of water. The learner said “For me I feel my understanding has not improved because I am still confused about the polarity of water. I don't understand that part at all”. Looking at this learner's results there has been no change from the pre-test to the post-test. He obtained 40% in both tests, meaning he still has misconceptions even after the intervention lesson.

4.9 Conclusion

The results of this study support the view that conceptual change teaching is an effective means of reducing the number of learners holding misconceptions about ions in aqueous solutions. Therefore, conceptual change teaching can be used effectively in physical science classes to remedy learners' misconceptions and

increase their conceptual understanding. But as this method of instruction depends deeply on learners' prior knowledge, exploring and classifying learners' misconceptions plays a very important role in the successful implementation of this teaching method.

On the other hand, even if the conceptual change method of teaching caused mainly positive changes in learners' perceptions about ions in aqueous solutions, and was also effective in increasing their conceptual understanding and their scientific knowledge, some learners still maintained their misconceptions throughout the study. This clearly showed that there was no single cure for remedying all learners' misconceptions and if there truly is a need for an education that addresses the needs of all learners, a variety of teaching strategies must be used. The following chapter will discuss the conclusion and recommendations.



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 in chapters 4 and 5. In addition, the implications of the findings and the limitations pertaining to the study are discussed, and recommendations for further studies are presented.

The study also attempts to investigate how the use of the conceptual change method could contribute to enhance the teaching and learning of ions in aqueous solutions in a Grade 10 science class.

5.2 Overview of the study

5.2.1 Rationale of the study

Chapter 1 provided an introduction to the research into the application of a conceptual change approach to teach the concept of ions in aqueous solutions, an area in the Grade 10 Physical Sciences syllabus. The chapter introduced the background to the study and highlighted the context in which the study was conducted. It also described the research problem and the research question as well as the significance and limitations of the study. In this chapter it is stated that, although science is seen as a tool that can be used in answering questions of events in our everyday lives, it is also referred to as challenging to learners to understand and to use it to explain various areas of life. Researchers indicate that science is considered to be a difficult subject to learn by learners and this is believed to be due to its abstract nature.

5.2.2 Literature review

Chapter 2 provided the theoretical basis of the study. It indicated that the study was underpinned by the theories of constructivism and conceptual change. It also emphasised the fact that for effective teaching to be achieved it should be based on

approaches that promote conceptual change and to provide learners with skills on learning how to learn and making meaning out of their learning. This forms part of the constructivist view of learning to produce scientific, literate citizens. Constructivism as well as conceptual change views learners as constructors of their own understanding of certain concepts. Numerous researchers view the construction of knowledge as transforming, organising and reorganising prior knowledge and believe knowledge is constructed by social interactions and experiences. Constructivists view learning as taking place more positively when both the educator and the learner cooperatively participate and do their roles as required by the learning process. According to the constructivist view of learning, learners' prior knowledge is important to make sense of new experiences and new information. The constructivist view also recommends that learners construct their knowledge and concepts in the direction of their abilities and experiences because each individual's learning style is different. It is due to these different learning styles that various teaching models have been developed to change learners' misconceptions into scientific conceptions.

In general, conceptual change has been described as part of a learning mechanism that requires the learners to change their conceptions about a phenomenon or principle either through restructuring or integrating new information into their existing schemata. This study followed the conceptual framework provided by Posner, Strike, Hewson, and Gertzog (1982), which described the following four steps: (1) learners must become dissatisfied with their existing conceptions; (2) the new conception must be intelligible; (3) the new conception must be plausible; and (4) the new conception must be fruitful. After these conditions have been met, learners can experience conceptual change.

5.2.3 Methodology

Chapter 3 covered the following aspects: research design, sampling technique, data collection plan, data analysis, validation and reliability and ethical consideration. The study was described as a case study and employed a mixed method approach using both qualitative and quantitative methods. The sample consisted of 26 learners in one Grade 10 class. For data collection various data collection methods were used. Firstly, a pre-test was administered to use as a baseline to determine learners' initial

understanding of the concept. Secondly, conceptual change lessons were given to help the learners better understand the concept of ions in an aqueous solution through the four stages of conceptual change. Thirdly, a post-test was given to determine learners' understanding after the lesson and, lastly, interviews were held with all the learners.

5.2.4 Findings and discussion

Chapter 4 presented the findings and discussion of the research to answer the following main research question and sub-questions:

How can the conceptual change approach be used to teach ions in aqueous solutions in physical science?

- (i) What were learners' initial understandings of the concept of ions in aqueous solutions?
- (ii) How were the lessons for the conceptual change approach implemented?
- (iii) What were learners' understandings of the concept of ions in aqueous solutions after implementation of the conceptual change lessons?
- (iv) What were the learners' perceptions of the conceptual change lessons?

This chapter presented a discussion of the findings by comparing the learners' results in the pre-and post-intervention tests. The discussion highlighted how learners interacted during the conceptual change lessons and also included the educator's experiences during the lesson. The perceptions of the learners with regard to their achievement were obtained and examined. The chapter was structured along the four sub-questions.

5.2.4.1 What were learners' initial understanding of the concept of ions in aqueous solutions?

In order to establish learners' initial understanding of the concept of ions in aqueous solutions, a pre-test was administered and the results of the pre-test were as follows. Looking at a question by question analysis of the pre-test, it was illustrated that learners had difficulty answering questions 4, 5, 7 and 9 as they obtained less than 30% on those questions and they performed better in questions 1, 2, 3, 8 and 10 as they obtained more than 50%. According to the results of the pre-test, very few of the

learners could answer the questions properly and had the required understanding of what the concept is all about.

5.2.4.2 How were the lessons of the conceptual change approach implemented?

This research question was answered through the implementation of the intervention. The findings from the initial understanding of the learners was used as a guidance on the conceptual change instructional activities. These activities were developed according to the four stages of the conceptual change model. These texts were used to determine the effectiveness of the conceptual change framework strategies. The results showed that, after the treatment, learners had better acquisition of scientific concepts with respect to ions in aqueous solutions.

5.2.4.3 What were learners' understandings of the concept of ions in aqueous solutions after implementation of the conceptual change lessons?

In order to determine learners' understanding of the concept of ions in solution after the developmental lesson, a post-test was given to the learners and the results of the post-test were as follows: For the question by question analysis of the post-test it was illustrated that learners still had difficulty answering question 9 as they obtained less than 30% on the post-test and performed better in questions 2, 6 and 8 as they obtained more than 50%. According to the results of the post-test, more could answer the questions properly and had the required understanding of what the concept is all about.

5.2.4.4 What were the learners' perceptions of the conceptual change lessons?

To determine learners' views on how the conceptual change teaching had contributed to their understanding of the concept, focus group interviews were conducted. In this section 25 learners indicated that their understanding of the concept had improved except for 1 learner who indicated that it had not improved. They even claimed that now they knew more concerning ions in aqueous solutions that they did before the lesson.

5.3 Major findings of the study

The study found that there was an improvement in the majority of learners' achievement from pre- to post-test even though some learners still held on to their original understanding of the ions in solution concept. The different areas that learners were tested on showed a variable rate of achievement. In seven of the ten questions that learners were tested on their results from pre- to post-test indicated that there was a definite improvement in the results obtained, while in the remaining three questions there was actually a reversal in their achievement scores. The particular areas tested in these three questions were considered particularly problematic by learners. In the focus-group interviews a number of learners pointed to their challenge in understanding these questions. One learner in particular articulated his problem: "I still need to understand the polarity of water". This learner's results did not improve from pre- to post-test as his achievement remained at 40%. Generally, the learners' conception of ions in solution seemed to have undergone a process of change which led to a better understanding of the concept studied.

The study found that learners enjoyed the involvement in the lessons that challenged them intellectually and required their involvement in a practical way. These lessons dealt with the stages of intelligibility and plausibility. However, the learners were found to be less interested in the video-lesson that involved a number of abstract terms that meant the teacher had to stop the video at various stages to explain what these terms meant. In the interviews learners expressed their satisfaction with the conceptual change approach adopted by the educators. They were particularly interested in the lesson that demonstrated fruitfulness when learners had to apply their knowledge to a real-life situation. It was during these lessons that the conceptual change occurred from their prior knowledge and limited understanding to a more viable and creative application of the gained and changed knowledge and understanding.

The study found the conceptual change approach had variable success as the learners' test scores indicated. However, it became evident from the interviews and the interaction during the lessons that learners' interest in the content of ions in solution became aroused and that there was an improved change in the majority of

learners' understanding of the concept. They asked more questions than during a normal lesson and, when given the opportunity to engage with each other and the teacher during the practical parts of the lessons, they started to question the teacher more on the content of the experiments. The framework of the conceptual change lessons and the four steps that needed to be followed guided not only the teacher's approach to the implementation of the lesson but also provided a structure along which learners' thoughts, discussion and interactions in the lessons could be directed.

The study found that the structure of the lessons for conceptual change should take into account the prior knowledge of learners and resources available to teach the content and the exposure of learners to the approaches used. Some learners became less interested during the video-lesson and the teacher had to resort to explaining the abstract terms used in the video before going further to keep learners on task. This unfortunately meant that the flow of the video had to be interrupted at times which served to be counterproductive to learners' concentration and involvement in the lessons. The lesson during the fruitfulness stage seemed to point out that when learners were exposed to lessons where they had to apply their curriculum knowledge and understanding to a situation in their own surrounding (the water quality of a local river), this advanced their curiosity and created an improved motivation to want to know more.

The study found that some learners still held onto their alternative conceptions of ions in solution. This situation was found not only for the test scores prior to and after the conceptual change intervention but also during their interactions in the lessons. These conceptions seem to have a deeper root in their cognitive make-up. This could be ascribed to knowledge acquired as part of their social interaction and cultural beliefs.

5.4 Implications of the study

This study has implications for future studies that want to use the approach. It clearly found that there was an improvement in learners' achievements but that there are clear indications that not all learners show an improvement. The majority of learners demonstrated a growth in their understanding of ions in solution and demonstrated it

during the practical application of the lessons. It is therefore imperative that lessons that use this approach should have a distinct section dealing with application of learnt knowledge to provide evidence-improved understanding and conception of the concept studied. Knowing learners' conceptions about a particular concept is of essence to educators to guide learners toward meaningful conceptual change, and to prepare future lessons for the next classes. Learner activities must be organised in a way that takes into consideration learners' conceptions similar to the ones that have been revealed in this study. In teaching any concept the educator should not only consider the learners' prior knowledge of the concept in question but should also integrate what is taught in class into their everyday lives. This will enable learners to acknowledge that science is not only what is taught in class but is also 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 integration of the everyday science in teaching should not only end in class but should be accommodated in the test and examinations.

The study also has implications for:

- (i) Heads of Science Departments (HoDs) in the schools to assist teachers when dealing with challenging concepts in the Natural Sciences curriculum. This study provides the science teachers with an understanding of how the conceptual change approach could support the learning of science and how this could add value to learners' everyday application of curriculum science. The conceptual change approach is a complex process, and promoting it requires the proper environment and equipment. It therefore requires a great amount of effort from the educator and for this reason, experiential training of educators is more than essential.
- (ii) School principals may find the study a point of reference because it arms them for discussions with education authorities regarding improvement of science results in the National Senior Certificate examination. The principal may use the content of this study to argue the need for additional resources to improve the teaching of Physical Sciences.
- (iii) The curriculum advisors when running teacher development programmes could use this study to help other science teachers to realise that the

conceptual change approach could be used to teach complex and abstract science concepts to prevent misconceptions that are taken for granted.

(iv) The study has implications for politicians and curriculum planners as it showcases the importance of the conceptual change approach as a strategy to improve learners' understanding of science concepts. The study documents the reality of implementing this strategy in a rural classroom and showcases the research as a means of improving learners' achievement in science. Most science second language learners have a low reading and comprehensive ability (Dinnie, 2000; Tesfai, 2001; Tewolde, 2001). For the same reason, learners tend not to read their textbooks. To try and alleviate this and make textbooks more reader friendly, their format needs to be changed. Textbook writers need to include pictures and cartoons with short descriptive notes. Teachers should also produce their own materials and also collect some from newspapers, magazines and the internet. But this requires the training and retraining of teachers. Certainly curriculum developers cannot assume that teachers would be able to develop their own instructional materials without any specific training on such tasks.

The study provides a baseline for future studies into the effect of using a conceptual change approach to improve learners' understanding of ions in solution as well the application of the approach to improve other areas of the Physical Sciences curriculum.

Teachers should try to include the use of sub-microscopic representations in order to simplify the abstract chemical ideas about ions in aqueous solutions; educators should be attentive about the use of sub-microscopic representations as these are models of an already abstract model (atomic model). Teachers should try and help learners make connections between the three levels of chemical thinking when teaching chemical concepts (thus scaffolding the learner) in order to develop a mental model in the learner about the particle theory. Teachers should provide learners with opportunities to carry out experiments (macroscopic level) involving basic concepts about the particular nature of matter and allow them to discuss their observations in terms of particles. In addition, teachers should carry out

demonstration experiments and discuss these in terms of the three levels of chemical conceptualization in class. This will enable learners to realize the connections that exist between the three levels of matter and will probably enhance their chemical understanding.

5.5 Recommendation for future study

Based on the findings of this study, the following recommendations for further research were developed:

(i) It would also be interesting to compare the long-term understanding of the learners of the same grade who did and did not participate in the study.

(ii) This study focused solely on learners in a particular class in this particular school. Further research should be conducted replicating this study at other secondary schools. The results of this research would strengthen the validity of the findings of this study

(iii) The effects of conceptual change model based instruction should be investigated in different physical science topics apart from ions in aqueous solutions.

5.6 Limitations of the study

The study is a case study which focused on one class at one particular school. The results are therefore not generalizable to other schools given the limited sample that was used in the study. The study investigated the application of the conceptual change approach on one topic in Grade 10 Physical Sciences, namely ions in solution. The findings are therefore limited to one section of the curriculum.

5.7 Conclusion

In this study, the learners' misconceptions of ions in aqueous solutions were examined. While the majority of the learners seemed to have made some progress in their conceptual development as a result of their exposure to the concept change method of teaching, others struggled with the approach.

The teaching of chemistry should give learners the opportunity to construct chemical concepts which are not only useful to their future studies but also have relevance to

their present everyday experiences. If science is to be more acceptable and worthy of its salt, it needs to be contextualized. Learners need to be made aware that science is not just a classroom subject prescribed in the syllabus but a human enterprise with practical implications for their daily life experiences. This needs to be promoted not only by the teachers but also be reflected in science textbooks, the curriculum as well as the examinations. Science teachers should examine their conceptions of how learners learn and what teaching methods can best facilitate learning. This will not only improve learners' conceptual understanding of chemical reactions but also their performance in science in general.



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Appendix A

Permission from the Eastern Cape Education Department (ECED)

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Cradock
5881
7 April 2014

The SG
ECED
14 Dundas Street
Cradock
5880

Dear Sir/Madam

To whom it may concern

Request for permission to conduct research study



I hereby wish to request permission to use J.A Calata Senior Secondary as a source to collect data for my research. I am currently a B.Ed. (Hons) learner at the University of the Western Cape and plan to conduct research on teaching of energy changes in reactions using a conceptual change approach.

I pledge to work within the framework of the Department's disciplinary arrangements and not to cause any disruptive or inconvenient actions at the school. I am sure that this research will benefit the school as it will be exposed to different methods of teaching.

Yours in Education
Mrs N Mboxwana

Appendix B

34 Bakwetheni Street
Cradock
5881
07 April 2014

The Principal and School Governing Body
J.A. Calata Secondary School
Cradock
5880

Dear Madam

Request for permission to conduct research study

I hereby request permission to conduct a research at your school as part of my studies as a B.Ed. (Hons) learner at the University of the Western Cape.

I would like to work with your learners in order to investigate how teaching of energy changes in reaction using conceptual change method will improve learners' understanding. I pledge to work within the framework of the Department's disciplinary arrangements and not to cause any disruptive or inconvenient actions at the school. I am sure that this research will benefit the school as it will be exposed to different methods of teaching. I will also ask permission from the Education Department and forward their response to you.

I hope to hear from you soon.

Yours faithfully
Mrs N Mboxwana

Appendix C

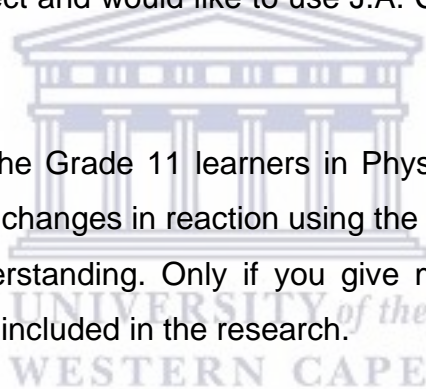
Letter to parents

34 Bakwetheni Street
Cradock
5880
07 April 2014

Dear Parent

I am a B.Ed. (Hons) learner at the University of the Western Cape. I am currently involved in a research project and would like to use J.A. Calata Secondary School in my research.

This research will involve the Grade 11 learners in Physical Science to investigate how the teaching of energy changes in reaction using the conceptual change method will improve learners' understanding. Only if you give me consent by signing the return slip will your child be included in the research.



I hope this will get your attention.

Yours faithfully

Mrs. N Mboxwana

.....

I Parent of give permission that my son/daughter may take part in your research.

.....

Signature

Appendix D

Pre & Post tests

Name & Surname:.....

Date:.....

Grade10:.....

MULTIPLE CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Tick(✓) or put a (X) on the correct answer.

1. In a solution of sugar in water:

- A. Sugar is called a solute
- B. Sugar is called a solvent
- C. Sugar and water are both called products
- D. Water is called a reactant

2. Which liquid is considered the “universal solvent”:

- A. Acid
- B. Base
- C. Water
- D. Oil

3. A solution is an aqueous solution if one of the following solvents is used in the reaction:

- A. Acid
- B. Base
- C. Water
- D. Oil

4. When acids react with metals they form:
- A. Bases
 - B. Water
 - C. Salts
 - D. Acids
5. A reaction where an acid reacts completely with a base to produce water and salt is called:
- A. Decomposition reaction
 - B. Synthesis reaction
 - C. Precipitation reaction
 - D. Neutralization reaction
6. When writing a chemical reaction:
- A. The reactants are written on the right of the arrow.
 - B. The reactants are written on the left of the arrow.
 - C. The reactants and the products are always on the same side.
 - D. Reactants and products means the same thing.
7. In a chemical reaction: $\text{NaCl} + \text{H}_2\text{O} \longrightarrow \text{Na}^+ + \text{Cl}^-$. The process is called:
- A. Polarization.
 - B. Hydration.
 - C. Dissolution.
 - D. Ionisation
8. An electrolyte:
- A. Is a solution that contains ions and can conduct electricity.
 - B. Is a process where ions are surrounded with water molecules in a water solution.
 - C. Is a process where solid ionic crystals are broken up into ions.
 - D. Is a process where an ion exchange occurs.

9. A precipitate is a

- A. Rocky edge.
- B. A solid formed from chemical reaction.
- C. A change in colour of the solution during a chemical change.
- D. A substance dissolved in a liquid.

10. Which equation represents the dissociation of NaCl?

- A. $\text{NaCl(s)} \leftrightarrow \text{Na}^{\text{-}}(\text{aq}) + \text{Cl}^{\text{+}}(\text{aq})$
- B. $\text{NaCl(s)} \leftrightarrow \text{Na}^{\text{+}}(\text{aq}) + \text{Cl}^{\text{-}}(\text{aq})$
- C. $\text{NaCl(s)} \leftrightarrow \text{Na}(\text{aq}) + \text{Cl}(\text{aq})$
- D. $\text{NaCl(s)} \leftrightarrow \text{Na}^{\text{-}}(\text{aq}) + \text{Cl}^{\text{-}}(\text{aq})$



Appendix E

LESSON PLANS

Lesson 1

Grade	10	Subject	Physical Sciences	Topic	Reactions in aqueous solutions - Ions in aqueous solution: their interaction and effects	Lesson	1
Lesson summary for: Date started					Date completed:		
Lesson objectives				<p>At the end of the lesson learners should be able to:</p> <ul style="list-style-type: none"> • Explain how water dissolves ionic solids by using diagrams and referring to the polar nature of water molecules. • Represent the dissolution process with balanced chemical equations. • Use the abbreviations (s) and (aq) in balanced equations. • Investigate different types of solutions (experiments) and write balanced ionic equations for the reactions. 			
TEACHING and LEARNING ACTIVITIES							
<p>1. TEACHING METHOD/S USED IN THIS LESSON: Question and answer, Explanation, Practical activity (experiment)</p> <p>2. LESSON DEVELOPMENT</p> <p>2.1. <u>Introduction [5 min]</u> 2.1. Introduction [5 min]</p> <ul style="list-style-type: none"> • Educator introduces the lesson with a practical demonstration, e.g.: Fill two beakers with water. Add a few iodine crystals (or any other insoluble solid to the water in beaker A and a few crystals of a soluble solid (sodium chloride) to beaker B. • Ask learners to explain why NaCl(s) is soluble in water and I₂(s) not. • Mention the rule that solutes dissolve in solvents when the intermolecular forces are of the same strength. Do not discuss different intermolecular forces in depth <p>PRE-KNOWLEDGE A basic understanding of the following:</p> <ul style="list-style-type: none"> • Atoms, molecules and ionic compounds. • Electronegativity and polar molecules. • Solutions as homogeneous mixtures. <p>BASELINE ASSESSMENT Design a worksheet to test pre-knowledge. (Hand out at the commencement of the lesson) [10 min] QUESTIONS for the BASELINE ASSESSMENT</p> <ol style="list-style-type: none"> 1. Define electronegativity. 2. Give formulas for the following compounds: <ol style="list-style-type: none"> 2.1 Potassium permanganate 2.2 Sodium hydroxide 3.2 Ionic compounds 4. Give an example of a homogeneous solution. <p>ANSWERS for the BASELINE ASSESSMENT</p>							

1. Electronegativity is a measure of the tendency of an atom to attract electrons towards itself.
- 2.
- 2.1 KMnO_4
- 2.2 NaOH
- 2.3 KNO_3
- 2.4 NaCl
- Non-metal atoms
- 2.5 Metal and non-metal atoms
5. NaCl(s) in $\text{H}_2\text{O(l)}$

- Educator provides answers to the baseline assessment and allows learners to do self-assessment.

2.2. Main Body (Lesson presentation) [20 min]

- Educator uses an appropriate model (ball-and-stick, or space-filling) to explain the bended (angular shape) of the water molecule.
- The oxygen atom shares one pair of electrons with each hydrogen atom to form two covalent bonds. There are two lone pairs of electrons on the O-atom, which repels the bond pairs to such an extent that the water molecule has a bended shape with an angle of $104,5^\circ$ between the H-atoms.
- The electronegativity of oxygen is 3,5 and hydrogen is 2,1. The shared electron pair in each covalent bond of the water molecule is closer to the O-atom than to the H-atom.
 1. The O-atom has a partial negative charge (δ^-) and each H-atom has a partial positive charge (δ^+).
- A water molecule is therefore **polar**, has a net **dipole moment** and is a good solvent for polar and ionic solids.
- Educator can demonstrate the polar nature of water molecules by doing the following demonstration:
 - Use a small piece of charged plastic.
 - Bring it close to a streamlet of water.
 - Observe and explain why the water is attracted to the plastic: The polar water molecules rotate and charged particles in the plastic attract like charges in the water.

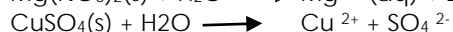
Educator explains that the process of dissolving solids in water as:

- (a) a process where an ionic substance breaks up into ions.
- (b) a covalent compound forms ions.

Learners should understand that the dissolution process implies that electrostatic forces must be broken between ions – energy is needed for this process. New bonds must be formed between ions and polar molecules – energy is released during this process. If the energy released is equal to or more than the energy absorbed, the solid will dissolve in the water.

- The process where ions are surrounded by polar water molecules, are called **hydration**.
- Learners must be able to define dissolution and hydration.
- **Dissolution** (dissolving) is the process where ionic crystals break up into ions in water.
- **Hydration** is the process where ions become surrounded with water molecules.
- Use the diagram to explain how polar water molecules attract the positive and negative ions during the process of dissociation.
- Educator explains how balanced chemical equations are used to represent the dissolution process.

Note that the solid is indicated by (s) and hydrated ions are indicated with (aq) derived from aqua or water. The symbol (l) is used for pure liquids.



LEARNER ACTIVITY [20 min]

EXPERIMENT

- Learners work in small groups.
- Each group prepare one of the following solutions: sodium chloride in water; potassium permanganate in water; sodium hydroxide in water; potassium nitrate in water.
- Learners have to write down their observations.

QUESTIONS for the PRACTICAL ATIVITY

1. Write balanced equations for the formation of each solution.

- Mention one exothermic and one endothermic dissolution process.
- Give the common name for sodium hydroxide and potassium hydroxide.

ANSWERS for the PRACTICAL ACTIVITY



2. Exothermic: NaOH(s) in H₂O– the temperature increases

Endothermic: KNO₃(s) in H₂O– temperature decreases

3. Sodium Hydroxide – caustic soda

Potassium Hydroxide –caustic potash

3. Conclusion [5 min]

- Educator discusses the answers of the experiment. Write the equations on the chalk board. Ensure that learners use the correct formulae (including capital letters) and that all the phases are indicated in the equation.

- Educator summarises important aspects of the lesson, reinforcing what needs to be remembered and recalled.

HOMEWORK QUESTIONS/ ACTIVITY Educator give learners a few questions to answer at home by either writing them on the chalkboard or giving an exercise from the prescribed textbook e.g. Physical Science written by volunteers (Siyavula) Exercise 18.1 pg 312 (30 min)

Resources: Relevant models to explain the shape and polarity of the water molecule, Apparatus to do the experiment, worksheets, power point presentation, transparency; prescribed text books, CAPS-document (page 46).

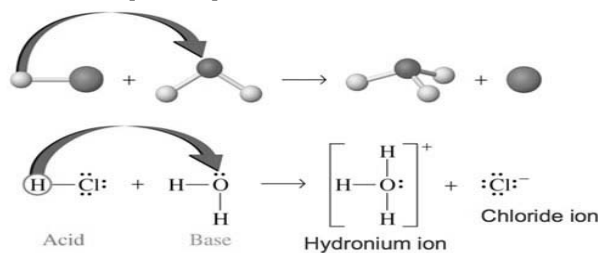
Name of the teacher:		Name of the HOD:	
Sign:		Sign:	
Date:		Date:	



Grade	10	Subject	Physical Sciences	Topic	Reactions in aqueous solutions	Lesson	2
Lesson summary for: Date started				Date completed:			
Lesson objectives				At the end of the lesson learners should be able to: <ul style="list-style-type: none"> Define the process of dissolving (solid ionic crystal breaking up into ions in water) Define the process of hydration (ions are surrounded by water molecules in water solution) 			
TEACHING and LEARNING ACTIVITIES							
<p>1. TEACHING METHOD/S USED IN THIS LESSON: Question and answer, Explanation, Practical activity (experiment)</p> <p>2. LESSON DEVELOPMENT</p> <p>2.1 Introduction and Baseline assessment. [10 min]</p> <ul style="list-style-type: none"> Educator mark homework assignment. Learners do corrections and clarify misconceptions. <p>PRE-KNOWLEDGE A basic understanding of the following:</p> <ul style="list-style-type: none"> Angular shape and polar nature of the water molecule. Meaning of the symbols (s), (aq) and (l). Writing balanced equations for different dissolution processes. <p>2.2 (Main Body (Lesson presentation) [40 min]</p> <ul style="list-style-type: none"> Educator explains that the process of dissolving solids in water as: <ul style="list-style-type: none"> (a) a process where an ionic substance breaks up into ions – dissociation. (See diagram). Ask learners to suggest a method to reverse the process of dissolving sodium chloride – by evaporating the water. (b) a process where a covalent compound forms ions – ionisation. <ul style="list-style-type: none"> Ionisation: Polar covalent molecules do not contain ions. When these solids dissolve in water, the molecules are ionised (ions are formed during the process). $\text{HCl(g)} + \text{H}_2\text{O(l)} \rightarrow \text{H}_3\text{O}^+(\text{aq}) + \text{Cl}^-(\text{aq})$ Use the diagram to explain how hydronium and chloride ions are formed during the process of ionisation. Acids like hydrochloric acid, sulphuric acid, nitric acid and acetic acid will form ions when they are dissolved in water. Ammonia (a base) will also form ions in water. Mention the importance of the dissolution process: if water was not able to dissolve different substances, life on earth would not be possible. Educator may discuss a few important dissolution processes in daily life. Explain the positive and negative impact – e.g. in rivers and oceans the dissolved oxygen allow fish and other organisms to breathe. Acid rain and “hard water” are negative results of the dissolution process. <ul style="list-style-type: none"> Hard water is water that has high mineral content (in contrast with “soft water”). Hard water is generally not harmful to one’s health, but can pose serious problems in industrial settings, where water hardness is monitored to avoid costly breakdowns in boilers, cooling, and other equipment that handles water. In domestic settings, hard water is often indicated by a lack of suds formation when soap is agitated in water. Wherever water hardness is a concern, water softening is commonly used to reduce hard water's adverse effects. Hard water contains a great amount of Ca^{2+} and Mg^{2+} ions and prevents soap from foaming. <ul style="list-style-type: none"> The process of ion exchange can be used to prevent the effects of hard water. The Ca^{2+} and Mg^{2+} ions are replaced by Na^+ ions. <p>3. CONCLUSION [10 min]</p>							

- Educator summarises important aspects of the lesson, reinforcing what needs to be remembered and recalled.
- Allow learners to start with the homework activity.

HOMEWORK QUESTIONS/ ACTIVITY [30 min]



1. Define the following:

1.1 Dissociation

1.2 Dissolution

1.3 Hydration

2 Classify the following substances as ionic or molecular.

2.1 Potassium chloride (KCl)

2.2 Ethanol (CH₃CH₂OH)

2.3 Sugar (C₁₂H₂₂O₁₁)

2.4 Lithium bromide (LiBr)

3 Write the formulas for the ions present in aqueous solutions of the following salts without writing the complete reaction.

3.1 AlCl₃

3.2 CaSO₄

3.3 Mg(NO₃)₂

4

4.1 What is "hard" water?

4.2 Name ONE disadvantage of "hard" water

4.3 Give ONE advantage and ONE disadvantage of soft water.

5

5.1 What is acid rain?

5.2 Name three gases that are responsible for acid rain.

5.3 Name TWO disadvantages of acid rain.

ANSWERS: HOMEWORK ACTIVITY

1

1.1 The process where an ionic substance breaks up into ions.

1.2 The process during which a substance dissolves in water to form an aqueous solution.

1.3 The process where ions become surrounded with polar water molecules.

2

2.1 Ionic

2.2 Molecular

2.3 Molecular

2.4 Ionic

3

3.1 Al³⁺; Cl⁻

3.2 Ca²⁺; SO₄²⁻

3.3 Mg²⁺; NO₃⁻

4

4.1 It is water that contains high concentrations of minerals such as Ca²⁺ and Mg²⁺, caused by contact with rocks and sediments.

4.2 It forms precipitations when the metal ion reacts with soap in the water; prevents soap from foaming; damages geysers and water pipes.

4.3 Soap foams in soft water; it tastes salty.

5

5.1 Acid rain forms when CO₂(g), SO₂(g) and NO₂(g) dissolves in rain water.

5.2 Carbon dioxide; sulphur dioxide and nitrogen dioxide

5.3 Acid rain damages buildings and plants.

HOMEWORK QUESTIONS/ ACTIVITY Educator give learners the homework activity or any other appropriate exercise from a prescribed text book. Learners can do an **informal research** task or poster to explain the effects of hard water or acid rain.

Resources: Diagrams to explain dissociation and ionisation, worksheets, power point presentation, transparency; prescribed text books, CAPS-document (page 46).

Name of the teacher:		Name of the HOD:	
Sign:		Sign:	
Date:		Date:	

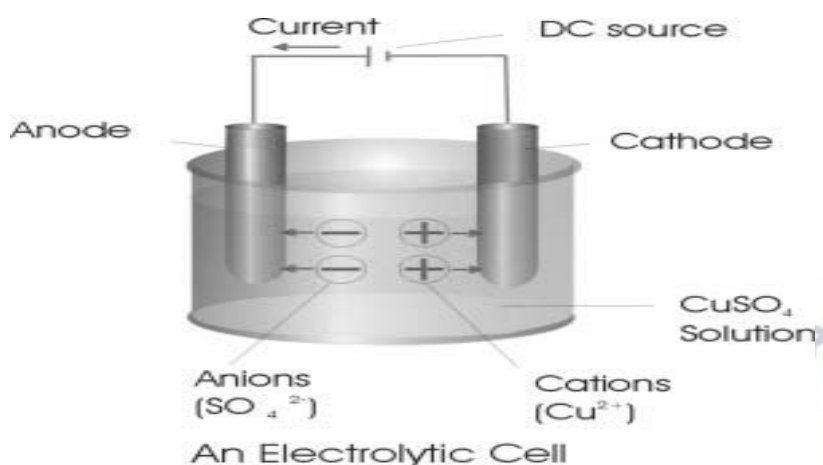
Grade	10	Subject	Physical Sciences	Topic	Reactions in aqueous solutions – Electrolytes and extent of ionization as measured by conductivity	Lesson	3
Lesson summary for: Date started					Date completed:		
Lesson objectives				At the end of the lesson learners should be able to:			
				<ul style="list-style-type: none"> Describe a simple circuit to measure conductivity of solutions. Relate conductivity to concentration of ions in solution and solubility of particular substances. Understand that conductivity will not always be a measure of solubility. 			
TEACHING and LEARNING ACTIVITIES							
<p>1. TEACHING METHOD/S USED IN THIS LESSON: Question and answer, Explanation, Practical activity (experiment)</p> <p>2. LESSON DEVELOPMENT 2.1 Introduction and Baseline assessment. [10 min] <ul style="list-style-type: none"> Educator mark homework assignment. Learners do corrections and clarify misconceptions. PRE-KNOWLEDGE A basic understanding of the following: <ul style="list-style-type: none"> The difference between ionic and molecular substances. Writing balanced equations for different dissolution processes (dissociation and ionisation). Understand the basic principles of flow of electric current in a closed circuit. 2.2 Main Body (Lesson presentation) [20 min] <ul style="list-style-type: none"> Educator explains the difference between metal conductors and solutions that conduct electricity. (a) Metals conduct electricity because they contain free, delocalized electrons and positive ions that can act as charge carriers. (b) In aqueous solutions, the charge carriers are the ions formed during the dissolution process. (c) A solution that contains ions is called an electrolyte. (d) The process of conducting electricity through an ionic solution is called electrolysis. <ul style="list-style-type: none"> Educator can use the diagram to explain how negative ions ($SO_4^{2-}(aq)$) are attracted to the anode of the electrolytic cell. Negative ions are called anions. The positive ions (Cu^{2+}) move towards the cathode and are called cations. A strong electrolytic solution contains a great amount of ions per volume and the concentration of ions is high. The result is that the electrolytic solution will be a good conductor of electricity. In weak electrolytic solutions, the concentration of ions is low and the aqueous solution can be considered as a weak conductor of electricity. Conductivity of an aqueous solution depends on three factors: (a) The nature of the substance </p>							

- (b) The solubility of the substance
 (c) the concentration of ions in the solution

- Aqueous solutions of all ionic substances will be good conductors of electricity and strong electrolytes.
- A few molecular substances will ionise in water to form strong electrolytes e.g. strong acids like HCl; H_2SO_4 and HNO_3 . Strong acids ionise completely and form many ions in an aqueous solution.
- Most molecular substances will form weak electrolytes e.g. weak acids like CH_3COOH and H_2CO_3 or not be electrolytes like alcohol and aqueous solutions of sugar. Weak acids ionise incompletely and form only a few ions in an aqueous solution. Non polar compounds do not ionise in water and no ions are formed.
- Pure water is a molecular substance and cannot conduct electricity – it contains no ions that can act as carriers of charge.

2.3 LEARNER ACTIVITY [25 minutes]

EXPERIMENT



Schools may have apparatus that are specially designed for this experiment, but if it is not available carbon rods can be used as conductors. Use a glass beaker for the different aqueous solutions and connectors to connect the rods to a power supply or battery and sensitive ammeter with a globe (if available).

A. Aim: To investigate the conductivity of different pure substances and aqueous solutions

- Test small amounts of $\text{NaCl}(s)$, $\text{CaCl}_2(s)$ and $\text{NH}_4\text{Cl}(s)$ for electric conductivity.
- Repeat the test, but use distilled water and tap water.
- Dissolve sodium chloride in distilled water and test for conductivity.
- Repeat with aqueous solutions of CaCl_2 , NH_4Cl , HCl , CH_3COOH , $\text{C}_2\text{H}_5\text{OH}$ and $\text{C}_{12}\text{H}_{22}\text{O}_{11}$.
- Tabulate the results. Indicate the following: no conductivity; weak conductors; good conductors very good conductors.
- Rinse the electrodes between every investigation.

B. Aim: To determine the relation between the concentration of ions in a solution and the electric conductivity.

- Dissolve a teaspoon full of sodium chloride in 50 cm^3 of distilled water,
- Use a medicine dropper and drop 1 drop of this solution in a glass beaker half filled with distilled water.
- Use carbon rods as electrodes and connect with connectors to a battery and ammeter. Note the reading on the ammeter.
- Add another drop of $\text{NaCl}(aq)$ and note the reading on the ammeter again.
- Repeat the process eight times.

QUESTIONS FOR PRACTICAL ACTIVITY

1. Classify the substances used in experiment A as molecular or ionic.
2. Why is it important to rinse the electrodes between the investigations?
3. Explain why the solid compounds did not conduct electricity.
4. Write balanced chemical equations for the good conductors.
5. List the solutions that do not conduct electricity and explain the observation.
6. What happens to the reading on the ammeter if the concentration of the sodium chloride solution is increased? Explain the observation.
7. Name two other factors, apart from concentration, that can influence the electric conductivity of a

solution.

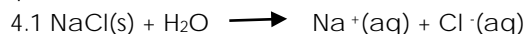
ANSWERS: PRACTICAL ACTIVITY

1 Ionic; NaCl, CaCl₂, NH₄Cl

2 To prevent one solution to become contaminated with another – it has to be a fair test.

3 The ions in a solid compound are bonded with strong electrostatic forces. The ions cannot move and cannot act as charge carriers.

4



5 CH₃COOH, C₂H₅OH and C₁₂H₂₂O₁₁ There are no ions in the solutions to act as charge carriers.

6 The reading on the ammeter increases – the solution becomes more concentrated – more ions per volume water.

7 The nature of the substances, the solubility of the substance in water.

3. Conclusion [5 min]

- Educator discusses the answers of experimental questions.
- Summarises important aspects of the lesson, reinforcing what needs to be remembered and recalled.

HOMEWORK QUESTIONS/ ACTIVITY Learners have to study the content of lesson 1 – 3. They will write an informal test at the start of the next lesson.

Resources: Apparatus to do the experiment, worksheets, power point presentation, transparency; prescribed text books, CAPS-document (page 46).

Name of the teacher:		Name of the HOD:	
Sign:		Sign:	
Date:		Date:	

Grade	10	Subject	Physical Sciences	Topic	Reactions in aqueous solutions: Precipitation reactions	Lesson	3
Lesson summary for: Date started					Date completed:		
Lesson objectives				At the end of the lesson learners should be able to:			
				<ul style="list-style-type: none"> • Classify precipitation reactions as ion exchange reactions • Write balanced reaction equations to describe precipitation of insoluble salts. 			
TEACHING and LEARNING ACTIVITIES							
<p>1. TEACHING METHOD/S USED IN THIS LESSON: Question and answer, Explanation, Practical activity (experiment)</p> <p>2. LESSON DEVELOPMENT</p> <p>2.1 Baseline assessment. [10 min]</p> <p><input type="checkbox"/> Learners write a short test (informal assessment) on content of lesson 1, 2 and 3.</p> <p><input type="checkbox"/> Educator can set questions from activities or use questions from prescribed text books, or use the questions below. [20 marks].</p> <p>QUESTIONS FOR INFORMAL ASSESSMENT</p> <p>1. Polar molecules ionise in aqueous solutions. Write the correct equation to represent the ionization of ethanoic acid (CH₃COOH) (3)</p> <p>2. Define the process of hydration. (2)</p> <p>1.</p>							

- (a) Explain the meaning of the word electrolyte. (2)
 (b) Classify the following substances as electrolytes when they are in aqueous solutions.
 (i) Ammonia
 (ii) Magnesium sulphate
 (iii) Sulphuric acid
 (iv) Sugar (C₁₂H₂₂O₁₁) (4)
 2.
 (a) How will you distinguish between an ionic substance and a molecular substance? (4)
 (b) Write a balanced chemical equation to show how ammonium sulphate dissociates in water. (5)

ANSWERS FOR INFORMAL TEST



2. Where ions become surrounded with water molecules in a water solution. (2)

3.

(a) An electrolyte is an aqueous solution that contains ions and can conduct electricity. (2)

(b)

(i) Electrolyte

(ii) Electrolyte

(iii) Electrolyte

(iv) No electrolyte (4)

1.

(a) Ionic substances consist of metal and non-metal elements.

Molecular substances consist of non-metal elements only (4)



2.2 Introduction [5 min]

• Educator introduces the lesson with a practical demonstration to investigate the reaction of ions in a solution.

- Prepare two aqueous solutions of potassium iodide (KI(aq)) and lead(II)nitrate (Pb(NO₃)₂(aq)).
- Note the colour of the solutions.
- Mix equal volumes of the solutions in a clean beaker.
- Allow learners to observe any changes in the beaker.

PRE-KNOWLEDGE

A basic understanding of the following:

- Writing balanced equations for different dissolution processes.

Main Body (Lesson presentation) [40 min]

- Educator uses the observation of the experiment to explain the concept precipitate.
- A precipitate is the insoluble substance that forms during a reaction between ions in an aqueous solution.
- During a precipitation reaction, positive ions exchange their negative ions to form an insoluble salt.
- Discuss some of the well-known precipitates like CaSO₄ (plaster of Paris) or MgSO₄ that is used as a purgative.
- Explain the process of ion exchange in any suitable manner, e.g.
 - Dissociation reaction of KI(s) in water: $\text{KI}(\text{s}) + \text{H}_2\text{O} \longrightarrow \text{K}^+(\text{aq}) + \text{I}^-(\text{aq})$ (1)
 - Dissociation of Pb(NO₃)₂(s) in water: $\text{Pb}(\text{NO}_3)_2(\text{s}) + \text{H}_2\text{O} \longrightarrow \text{Pb}^{2+}(\text{aq}) + 2\text{NO}_3^-(\text{aq})$ (2)
 - Balance equation (1) to obtain the correct amount of positive and negative ions in the solution:
 - $2\text{KI}(\text{s}) + \text{H}_2\text{O} \longrightarrow 2\text{K}^+(\text{aq}) + 2\text{I}^-(\text{aq})$
 - $2\text{K}^+(\text{aq}) + 2\text{NO}_3^-(\text{aq}) + \text{Pb}^{2+}(\text{aq}) + 2\text{I}^-(\text{aq}) \longrightarrow 2\text{K}^+(\text{aq}) + \text{NO}_3^-(\text{aq}) + \text{PbI}_2(\text{s})$ (3)
- Equation (3) represents the reaction in ionic form.
- K⁺ and NO₃⁻ appear on both sides of the arrow and are called the spectator ions. Spectator ions are not included in the net ionic equation.
- Only the reactants that is responsible for the formation of the precipitate appears in the net ionic reaction:
 $\text{Pb}^{2+}(\text{aq}) + 2\text{I}^-(\text{aq}) \longrightarrow \text{PbI}_2(\text{s})$
- Educator now discusses the general rules for the solubility of salts

Anion	Soluble Cation	Insoluble cation
Nitrate (NO ₃ ⁻)	All ions	-
Chloride (Cl ⁻)	Most ions	Ag ⁺ , Hg ⁺ , Pb ₂ ⁺

Bromides (Br.)	Most ions	Ag ⁺ , Hg ⁺ , Pb ₂ ⁺
Iodides (I.)	Most ions	Ag ⁺ , Hg ⁺ , Pb ₂ ⁺
Sulphate (SO ₄ ²⁻)	Most ions	Ca ₂ ⁺ , Sr ₂ ⁺ , Ba ₂ ⁺ , Ag ⁺ , Pb ₂ ⁺
Carbonate (CO ₃ ²⁻)	Li ⁺ , Na ⁺ , K ⁺ , NH ₄ ⁺	Most ions
Hydroxide (OH ⁻)	Li ⁺ , Na ⁺ , K ⁺ , NH ₄ ⁺ , Ca ₂ ⁺ , Sr ₂ ⁺ , Ba ₂ ⁺	Most ions
Sulphide (S ₂)	Li ⁺ , Na ⁺ , K ⁺ , NH ₄ ⁺	Most ions

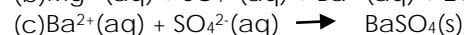
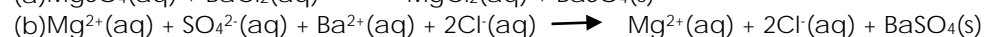
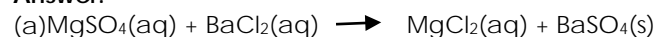
Allow learners to do another example in class e.g. write:

(a) molecular equations

(b) ionic equations and

(c) net ionic equations for the reaction between aqueous solutions of magnesium sulphate and barium chloride.

Answer:



3. Conclusion [5 min]

3. Educator summarises important aspects of the lesson, reinforcing what needs to be remembered and recalled.

- It is important that learners know the solubility rules

HOMEWORK QUESTIONS/ ACTIVITY Educator give learners a few questions to answer at home by either writing them on the chalkboard or giving an exercise from the prescribed textbook e.g. Physical Science written by volunteers (Siyavula) Exercise 18.2 pg. 319 (30 min)

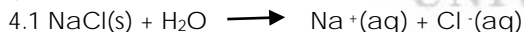
Resources: Worksheets, power point presentation, transparency; prescribed text books, CAPS-document (page 48).

1 Ionic; NaCl, CaCl₂, NH₄Cl

2 To prevent one solution to become contaminated with another – it has to be a fair test.

3 The ions in a solid compound are bonded with strong electrostatic forces. The ions cannot move and cannot act as charge carriers.

4



5 CH₃COOH, C₂H₅OH and C₁₂H₂₂O₁₁ There are no ions in the solutions to act as charge carriers.

6 The reading on the ammeter increases – the solution becomes more concentrated – more ions per volume water.

7 The nature of the substances, the solubility of the substance in water.

3. Conclusion [5 min]

- Educator discusses the answers of experimental questions.

- Summarises important aspects of the lesson, reinforcing what needs to be remembered and recalled.

HOMEWORK QUESTIONS/ ACTIVITY Learners have to study the content of lesson 1 – 3. They will write an informal test at the start of the next lesson.

Resources: Apparatus to do the experiment, worksheets, power point presentation, transparency; prescribed text books, CAPS-document (page 46).

Name of the teacher:		Name of the HOD:	
Sign:		Sign:	
Date:		Date:	

Appendix F

INTERVIEW SCHEDULE

1. Can you briefly explain how salts are formed?
2. Mention the few salts that you know and please tell which salts are soluble in water from what you have mentioned.
3. Is water a polar or a non-polar substance?
4. Explain how salts dissolve in water.
5. The response that you gave in questions (mention the question number) in the pre-test has changed to what you gave in the post-test. Why is that so?
6. Do you now feel that your understanding of this concept has improved? If yes, how has it improved and if not explain why not.
7. What benefits does learning ions in aqueous solution have in our everyday life?
8. How did practical experiments contribute to your understanding of the concept?

Appendix G

OBSERVATION CHECKLIST

In the checklist below, mark the box which best reflects your observation of the classroom practice. Where necessary make additional comments on your observation.

A. INTRODUCTION

Lesson Introduction

1. No introduction, i.e. no connection is made with previous lesson.

No direction for new lesson. No greetings.

2. Links with past lesson but no real focus for present lesson.
3. Links with past lesson and clear focus for present lesson.
4. Lesson is clearly contextualized and learners' interest is aroused.

Attention is focused. COMMENT (Was the lesson appropriately introduced?)

B. PRESENTATION and RESOURCES

B1. EXPLICIT ORGANISATION OF GROUP WORK

1. No group work.
2. Only two or three learners interact. Others just listen.
3. Group of learners with limited interaction/interact when teacher motivates.

- 4. Groups of pupils discuss problems, questions and activities by themselves. COMMENT (Does the organization relate to the type of lesson?) _____
-

B2. PUPIL-PUPIL INTERACTION WITHOUT TEACHER

- 1. Pupils don't question each other or probe for details.
- 2. Pupils question each other in secret because this is not allowed/ encouraged by the teacher.
- 3. Pupils only question or help other pupils when prompted to do so by the teacher.
- 4. Pupils freely enter into discussions with each other. COMMENT (How frequently is there interaction between pupils?):

B3. WHOLE CLASS TEACHER-PUPIL INTERACTION

- 1. Totally controlled by the teacher.
- 2. Mainly controlled by the teacher.
- 3. Teacher creates opportunity for pupil-pupil interaction.
- 4. Control of interaction shifts between pupils and teacher.

COMMENT (If no group work, what kind of pupil-pupil interaction is taking place, if any?) (Frequency):

B4. USE OF RESOURCES/MATERIALS/AIDS e.g. texts, chalkboard and notebooks

- 1. No materials available for pupils or teacher to use.
- 2. Only the teacher uses the materials in front while the learners are observing.
- 3. Some learners use materials.
- 4. Learners share and use materials.

COMMENT (Name materials used and frequency, or say if no materials used):

