

**GRADE 12 STUDENTS' CONCECPTUAL
UNDERSTANING OF CHEMICAL REACTIONS:
A CASE STUDY OF FLOURIDATION**

by

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DECLARATION

I declare that GRADE 12 STUDENTS' CONCECPTUAL UNDERSTANINGS OF CHEMICAL REACTIONS: A CASE STUDY OF FLOURIDATION is my own work and people who have made any contribution in its compiling have been acknowledged. It has never been submitted for any degree or examination in any other university. All the sources that have been used or quoted have been acknowledge with full reference.

Nomathemba Victoria Mpofu



September 2006

Signed:

ABSTRACT

The purpose of this study was to investigate grade 12 students' conceptual understanding of chemical reactions using fluoridation of public water supply as a practical example of chemical reaction. Further, the study attempted to find out the effectiveness of concept mapping in facilitating the students' understanding of chemical reactions, particularly redox reactions. More specifically, the study attempted to:

1. Explore the students' knowledge of concepts related to chemical change and chemical reactions, thus determining their prior knowledge of the concept.
2. Determine the effectiveness or otherwise of concept mapping and exemplary learning materials in solving problems as well as creating the students' awareness about chemical reactions and redox reactions.
3. Find out the effect of using practical work e.g. fluoridation to evoke the students' understanding of the application of chemistry in general, and chemical reactions in particular.
4. Determine if the exemplary materials used is effective in creating students' awareness about the concept of fluoridation, its benefits and risks to human kind.

Three groups of students were involved in the study, namely, the experimental (E), and two control groups (C₁ and C₂). All the three groups were exposed to exemplary materials on fluoridation but only E and C₂ were exposed concept mapping. Also, E and C₁ were pre- and post-tested with the Chemistry Achievement Test (CAT). Findings based on the CAT revealed that most of the students' conceptual understanding of chemical reaction, especially those exposed to the treatment, improved significantly (t-test value for E versus C₁ improved from 0.18 to 6.09 and $f_{(2,118)}$ for the three groups = 23.79). About 63 % of the students involved in this study were girls while about 37 % were boys. This ratio is neither reflective of reality in the tertiary institutions nor in the industry, where the males tend to dominate. Further the data collected on the CAT revealed no significant differences between the performances of the girls and boys. As in an earlier study (Ogunniyi, 1999), the girls seemed to obtain a high mean score both at pre- and post stage compared to the boys. With respect to career interests, there were no significant differences among the students on account of career choices. Although this was the case looking at their mean percentages they revealed that there was a slight difference between the performances of the students across their career interests, with those interested in the sciences out-performing the others followed by those interested in services, medical field, business, technology and lastly engineering.

The study also reveals that the students possessed the everyday notion of chemical reactions compared to valid scientific conceptions of chemical reactions (e.g. Ben-Zvi, Eylon & Silberstei, 1986). In terms of Bormuth's (1968) readability index, 97 % of the students were at the frustration reading level. That is these students cannot read or comprehend and might not show any progress even with the teachers' assistance.

Students exposed to concept mapping (i.e. E and C₂) outperformed those from C₁ who were not so exposed. This finding corroborates earlier studies indicating that concept mapping does improve students' conceptual understanding and facilitates meaningful learning (e.g. Novak & Gowin, 1984; Ebenezer & Conor, 1998; Tesfai, 2001; Tewolde, 2001). A pedagogy built on a sound theoretical construct as Ausubel's (1968) learning theory on which concept mapping is based, can help teachers to explore and link students' prior knowledge with school science as well as help students develop meaningful learning. During the interviews on the use of concept mapping, most of the students found concept mapping a useful learning tool but also indicated that more time was needed to teach how it could be used more effectively.

The findings of the study have further highlighted the need for textbook writers and the curriculum planers to work together to identify students' alternative conceptions of chemical reactions, which might hinder their conceptual understanding. In view of the poor readability level of the students it seems necessary to produce reader friendly textbooks that can promote the culture of reading among these science students. Such textbooks should incorporate everyday science into school science, to arouse the students' intellectual interests. The teachers also need to change their teaching methods and use methods that can facilitate meaningful learning by deploying effective instructional strategies such as concept mapping as has been used in this study.

The discussion on fluoridation as well as interviews revealed that the students involved in this study became more interested in the practical way in which the concept of chemical reactions was treated. They were even able to make informed decisions about whether or not fluoridation of water should be recommended to policy makers. Further, they felt that more research was necessary before any decision is reached about whether or not the fluoridation policy should be implemented.

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LIST OF ABBREVIATIONS

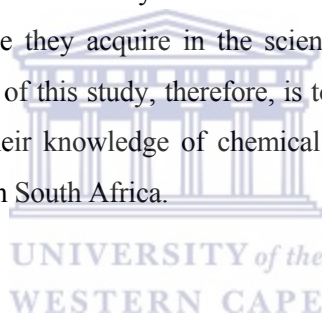
MCQ	MULTIPLE CHOICE QUESTION
CAT	CHEMISTRY ACHIEVEMENT TEST
CASS	CONTINUOUS ASSESSMENT
LO3	LEARNING OUTCOME 3
POE	PREDICT - OBSERVE - EXPLAIN
C 2005	CURRICULUM 2005
OBE	OUTCOME BASED EDUCATION
DET	DEPARTMENT OF EDUCATION AND TRAINING
WCED	WESTERN CAPE EDUCATION DEPARTMENT
UWC	UNIVERSITY OF WESTERN CAPE
ESL	ENGLISH SECOND LANGUAGE
DET	DEPARTMENT OF EDUCATION AND TRAINING

CHAPTER 1

INTRODUCTION

1.1 PREAMBLE

The topic, chemical change and chemical reaction, has always been problematic for students from the primary to tertiary level of education (e.g. Boo, 1998; Hesse & Anderson, 1992; Tewolde, 2001). Chemical change and chemical reaction are very important topics for any student studying or intending to study chemistry. It is a topic that forms the basics of chemistry. This is why it is imperative for grade 12 physical science students to have a clear understanding of this concept. Students come from certain communities and hence have varied experiences about the way substances interact. But whatever the differences in students' backgrounds, they all need to develop a scientifically valid understanding of what they learn at school. Also, they need to know how the knowledge they acquire in the science classroom, apply to their daily lives outside the school. The central concern of this study, therefore, is to determine how successful or otherwise grade 12 students are able to apply their knowledge of chemical reactions in dealing with the presently contentious issue of water fluoridation in South Africa.



1.2 BACKGROUND

Various governments have used the instrument of education to control, oppress, or even empower their people. The use of education as an instrument of oppression has been vividly demonstrated by the South African apartheid system of government. Hendrik Verwoerd, Minister of Native Affairs from 1951-1958 made sure that the native policy sought to, among other things, impose complete government control over African education in order to shape it as an instrument of apartheid (Oakes, 1995). As Tyobeka (2000) remarks:

It is a truism that education was used as one of the primary levers of a social engineering process in which the majority of our people were given a type of education that destined them for the periphery of society. Black people were discouraged from studying mathematics and science in government schools, and even encouraged not to finish school, hence the problem of illiteracy in this country (p.1).

After the release of our former president Nelson Mandela from prison, he made a call for everybody to go back to school. Many Adult Centres were opened, but these were not enough and were offered at night. The bulk of the unemployed youth, who had deserted school earlier began to join the mainstream students but were too old to be in those schools. Some of these youths came back from exile and needed focused attention to adapt to a formalised learning environment. This called for the establishment of specialised schools known as “finishing schools” to give students a second chance, so to speak, to complete their secondary education. Another category of the students in the finishing schools, are those who had attempted but failed their matriculation (matric) examination. They enrol in the finishing school mainly to improve their matric results.

One might say that after nearly a decade of experimentation these finishing schools have served their purpose and there is now no need for them anymore. In a way, this might be true, but we are faced with a different challenge of students who are not motivated in their education because (i) their brothers and sisters who are educated are unemployed and are very poor; (ii) their neighbours’ children, who are not educated, drive fancy cars, wear leather jackets and put on costly jewellery. In the view of these youths such persons are rich and hence worthy of their emulation. They are not concerned by what means such individuals have acquired their wealth, be it by selling drugs or by committing all forms of crime. In this regard, studying a demanding school subject, particularly science, no longer appeals to the students’ intellectual interests (Ogunniyi, 1995). Another problem facing science teachers is the scarcity of qualified teachers, thus in most schools students in the lower grades are taught science by teachers who are unqualified to teach science. For instance, it is not uncommon to find a Xhosa, History or any other teacher with no background in science to be assigned to teach science. The consequence of course, is that students taught by such unqualified teachers perform poorly in the matriculation (matric) examination.

The school where the study was conducted has been a finishing school since 1992. However, since 2002 it has gradually been phasing out the “finishing school” concept and has introduced grade 8-11 as well. Of the 40 classes in the school, 26 are grade 12 and out of this seven offer physical science. I teach three of these seven classes in physical science. Each class consists of about 45 students. My analysis shows their symbol distribution as: H (0-19%) - 65%; G (20-29%) -23%; F (30-39%) -10%; E (40-49%) -2%. This scenario is similar to what occurs in other subjects, e.g. Mathematics (with the worse results), English, Biology, etc. To teach these students successfully in science implies going back to as far as grade 8 work especially as their background in the subject is very weak.

Since the start of the Democratic Government in South Africa, there has been great emphasis on the promotion of science, mathematics and technology (STM). These fields are seen as the critical basis for socio-economic development of the country. This is not to suggest a linear relationship between STM and development, but that in modern economy, it is inconceivable to have the latter in the absence of the former (see Ogunniyi, 1999). Thus, in most countries of the world, STM education is construed as an essential tool for socio-economic development. One of the aims of science education, according to Habtemariam (2000) is to enable students to develop a valid understanding of science including problem solving, inquiry, information gathering, analysis, interpretation and other essential process skills needed to tackle practical problems on a daily basis.

In the old South African curriculum, the concept matter was introduced in grade seven as part of the primary science course. In grade eight and nine it was taught as part of general science. Only in grade 10 could students choose physical science, under which chemistry falls, as a subject. In the old curriculum, which is still being used by grades 10-12, one of the topics introduced in grade eight deals with chemical change. One therefore, expects students to have mastered topics like chemical change by the time they reach grade 12. However, in a finishing school the story is altogether different.

In the new curriculum, i.e. Curriculum 2005 (C2005) to indicate the year of its full implementation, chemistry falls under the Learning Area, Natural Science, and is part of the theme, Matter and Material, that is taught from the lower grades. Natural Science has three Learning outcomes (LO) including the ability to:

- Demonstrate an understanding of scientific principles, laws and concepts.
- Carry out scientific activities and apply scientific principles, laws and concepts.
- Demonstrate an understanding of the relationship between science and society, and the impact of science on society.

According to the Western Cape Education Department, (WCED), Natural Science Resource for Educators (2001) document, Natural Science is committed to:

- Broaden access to material, resources, knowledge, acquisition, and conceptual development.
- Redress past imbalances.
- Contribute towards socio-economic development and a better life for all.
- Challenge the perception that Science is predominantly a European discipline.

Ogunniyi (1999) conducted a study, which focused on determining what knowledge, attitudes or views about S and T were held by grades seven to nine students in the Western Cape. One of the instruments attempted to determine grade seven students' conceptions of chemical change of substances. One of the conclusions reached in that study was that the students' had a poor understanding of the concept. The students who held a valid understanding of the concept did so at a relatively low cognitive level (Ogunniyi, 1999). He further advises that for the students to be able to cope with the challenges posed by the syllabus on this topic, a lot of remedial work would be necessary. In another study done by Mumba, White & Rollnicks (2000) an attempt was made to determine what first-year students in the university and high school physical science teachers perceived as important for incoming students at the University of Witwatersrand, one of the suggestions made by their subjects was the need to possess an adequate understanding of chemical concepts outlined in the physical science syllabus.

From my experience as a grade 12 science teacher is that students have difficulty understanding chemical reactions. Their problem starts from their inability to write chemical symbols and formulae for certain elements and compounds. By not knowing the valencies of elements they are unable to know the ratio at which atoms, ions or even groups bond, yet such knowledge is critical in the study of chemistry.

In view of all the above and in the spirit of the Outcomes-based Education (OBE), Curriculum 2005 (C2005), I decided to explore ways in which I could assist my students develop a better conceptual understanding of chemical reactions and chemical change. To achieve this goal I decided to embark on a study which would not only broaden my students' knowledge and develop their conceptual understanding of chemical reactions, but also make them open-minded and better informed about controversial issues not strictly based on the grade 12 syllabuses but are relevant to chemistry and their life in general.

1.3 MOTIVATION FOR THE STUDY

This study has been inspired by various sources:

- Ogunniyi's (1999) findings about the level of grade 9 students' understanding of chemical reaction. In that study he found that grade 9 students performed poorly on the conception of chemical change.
- Using fluoridation as a relevant topic is also a response to Tyobeka's (2000) statement where he said:
We need a radical change in thinking, and new curriculum for teaching science, Mathematics and technology in schools and colleges, that are relevant to the local, social and physical environment. A more practical hands on approach is needed to make science more relevant to the everyday lives of school children, employing an interdisciplinary approach to the way science is taught and practiced,

and reflecting the interconnectedness of problems facing the developing countries (p. 2).

- Martin's (1991) book titled, "A Scientific knowledge in controversy: The fluoridation debates". Martin traces the roots of this debate from the 19th century. He also highlights the key areas of the debate, the views and arguments of those who are pro-fluoridation and those that are against fluoridation of public water supply. Having read this book I realised how little I knew about the debate. I decided to find out how much knowledge my students had about the debate as well the meaning of the term, fluoridation. I discovered they knew nothing of the debate and confused fluoridation with calcinations in tooth paste or chlorination in water.
- From the Internet (2002) I was able to find a lot of the research and debates about this topic which have been going on in South Africa since about 1997.
- The problems normally experienced by grade 12 students in understanding the concept of chemical reactions.
- The necessity to enhance students' conceptual understanding of a topic in grade 12 chemistry syllabus, redox reactions, which revolves around chemical change and chemical reactions.
- The need to find out the effectiveness of concept mapping in enhancing the students' conceptions of chemical reaction using fluoridation as a case in point.
- The emphasis of the strand, "Learning Science", in the new science curriculum is about helping students to broaden their knowledge of natural phenomena rather than the memorisation of a collection of scientific facts.
- The narrow focus of the chemistry curriculum, which seems to isolate chemistry from the students' everyday life, thus creating the impression that it is inaccessible and is only for examination purposes.
- The lack of interest of students in the subject which leads to a lack of enthusiasm, thus to a high failure rate and as Emerson quoted by Toon & Ellis (1973) asserts, "Nothing great was ever achieved without enthusiasm".
- The desire to know whether the students' gender and career interests influence the students' conceptions of chemical reactions and their applications.

I was also aware at the commencement of this study of the fact that the knowledge students possess or are able to demonstrate can also be influenced by a congeries of variables such as age, language, social and cultural background, etc, but these were not considered in this study.

1.4 PROBLEM STATEMENT

The seven critical outcomes in the revised Curriculum 2005 for the Natural Science expect students to be able to:

1. Identify and solve problems in which responses display that responsible decisions using critical and creative thinking have been made.
2. Work effectively with others as a member of a team, group, organisation, community.
3. Organise and manage oneself and one's activities responsibly and effectively.
4. Collect, analyse, organise and critically evaluate information.
5. Communicate effectively using visual, mathematical and / or language skills in the modes of oral and or written presentation.
6. Use science and technology effectively and critically, showing responsibility towards the environment and health of others.
7. Demonstrate an understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation (2001).

An examination of the above points indicates the need to prepare students who are able to identify and solve problems, collect, analyse, organise and evaluate information in making valid decisions

This study focuses on grade 12 students' conceptual understanding of chemical reactions, using redox reactions and a case study of fluoridation, a subject being hotly debated at the time of the study. The argument has been that adding fluoride to public drinking water would prevent tooth decay. Other fluoridated products, e.g. tooth paste, table salt, etc, have been used for years to prevent tooth decay. The fluoride in these products reduces the rate of chemical reaction between the plaque formed by bacteria from sugar leading to the erosion of the enamel and dentine. Students brush their teeth everyday to them this a simple and natural task and are unaware of the chemistry taking place. This enable them to realise that science is not an abstract concept taking place in the science classroom but everyday practice.

1.5 PURPOSE OF THE STUDY

The purpose of this study is to determine grade 12 students' conceptual understanding of chemical reaction and chemical change. Also, the study attempts to find out the effectiveness of concept mapping in facilitating the students' understanding of chemical reaction, particularly redox reaction, using fluoridation as a practical example. More specifically, the study attempts to:

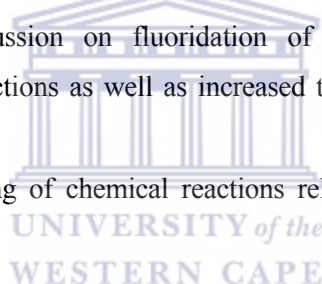
- Explore the students' knowledge of concepts related to chemical change and chemical reactions, thus determining their prior knowledge of the concept.

- Determine the effectiveness or otherwise of concept mapping and exemplary learning materials in solving problems as well as creating the students' awareness about chemical reactions particularly redox reactions.
- Find out the effect of using a practical, e.g. fluoridation to evoke the students' understanding of the application of chemistry in general, and chemical reactions in particular.
- Determine if the exemplary materials used is effective or otherwise in creating students' awareness about the concept fluoridation, its benefits and risks to human kind.

1.6 RESEARCH QUESTIONS

In pursuance of the purpose of the study, answers were sought to the following questions:

1. What conceptions of chemical reactions and chemical change do the grade 12 students involved in this study hold?
2. How effective or otherwise is concept mapping in enhancing the students' understanding of chemical reactions, particularly redox reactions?
3. How effective has the discussion on fluoridation of public water enhanced the students' understanding of chemical reactions as well as increased their awareness of the benefits and risks involved in such a practice?
4. Are the students' understanding of chemical reactions related to their reading ability, gender or career interests.



1.7 THEORETICAL FRAMEWORK

Teaching and learning usually go together, i.e. one has to be taught by a person or read an instructional material in order to learn, and learning is evidence that one has been taught. According to Ramorogo & Kiboss (1997) if learning is considered to be a process of knowledge construction, then the role of the student in constructing such knowledge becomes important. It is incumbent upon the teacher to create an environment which encourages learning. The teacher should use teaching methods that will make the lesson interesting and encourage students' creativity and critical thinking.

This study is situated within the socio – cultural constructivist paradigm as espoused by Piaget, Feuerstein & Vygotsky. Some brief allusions are also made to one or two learning theories within the socio –

constructivist regime. According to Piaget knowledge cannot be given to students, it is the students' duty to construct it from their mental and physical experiences with the environment. Feuerstein adds that an adult, in this case a teacher, has to mediate this learning. According to Kilpatrick (cited by Rossouw & Smith, 1999) the acquisition of knowledge takes place when the learner incorporates new experiences into existing mental structures and reorganizes those structures to handle, more problematic experiences. In the constructivist perspective, knowledge is not passively received from others, or necessarily from authoritative sources but constructed as one makes sense of the experiential world around him/her.

More details of this theoretical construct in which the study is situated are presented in chapter 2. The point here (in the context of C2005) is that students must take responsibility for their own learning. But this presupposes that the teacher plays a facilitative role by providing an enabling learning environment for their students. However, this sort of learning environment is not likely to occur if the teacher dominates the instructional process through the talk – and – chalk approach and all the students do is to copy down chalkboard notes verbatim.

1.8 SIGNIFICANCE OF THE STUDY

The use of a topical subject, e.g. fluoridation of public water supply is in line with curriculum 2005, which requires science teachers to promote learners thinking about science as a social enterprise. The Department of Education and Science (1985:7) puts this quite succinctly by asserting that:

Although there are some impressive exceptions, too much of the time spent learning science by too many pupils consists of the accumulation of facts and principles which have little perceived, or indeed actual, relevance to their lives as young people or as adults.

In this study fluoridation, a practical issue, was used as a vehicle for enhancing my students' understanding of chemical reactions. Also, the use of concept mapping as an instructional tool is emphasised in curriculum 2005. The opportunity to work with my students in developing a better understanding of chemical reactions and how such an understanding can have a positive effect in enlarging their awareness of the application of the knowledge they learn at school has always been a fascinating experience for me. It is hoped that the experience gained in this study would prove to be fruitful and useful in motivating the students involved in the study to want to study not just chemical reactions but other topics in chemistry as a whole. It is also hoped that the findings would also contribute to future research on chemical reactions and related concepts.

1.9 LIMITATIONS

My biggest challenge at the time of the study was how to have sufficient time while confronted at the same time with preparing my students for the matriculation examination. Because of these students' weak academic background, I had to cover concepts of chemical reactions, which they ought to have learnt in the lower grades before preparing them for the examination. I had to also teach them how to develop and use concept maps as a learning tool.

Another challenge I faced was the students' apathy, lack of enthusiasm and interest in their work as well as their poor attitudes towards education in general. As a teacher I had to make my lessons as interesting as possible. Also, I had to accommodate the students' weaknesses without compromising the standard of the lesson. Despite these obstacles a concerted effort was made to ensure that all the students gained sufficiently in the exercise.

The lack of support by the Department of Education in terms of bursary and the creation of opportunities for professional development including the acquisition of research skills implies that the study I was undertaking could not be pursued on a long-term basis. For instance, the permission to be granted a study leave to pursue the study was denied, on the basis that I am a qualified teacher I could not be granted a study leave. The problem of course, is whether or not a qualified teacher really needs to improve himself/herself professionally. But equivocal as this stance on the part of my employers are, space limitation would not permit any further elaboration.

1.10 DEFINITION OF TERMS

Meaningful learning: It is a process of assimilation where new knowledge is linked to existing cognitive structures. To learn meaningfully individuals must choose to relate new knowledge to relevant concepts and propositions they already know. The essential features of meaningful learning is that it embodies a distinctive kind of learning process in which the learner employs a "set" to incorporate within his cognitive structure, in nonarbitrary, nonverbatim fashion, potentially meaningful materials which are subsumable by established entities within that structure (Ausubel, 1963).

Concept mapping is either a teaching or a learning tool that aids in identifying main concepts and sub-concepts and shows the interrelationships of these knowledge structures. They are intended to represent meaningful relationships between concepts in the form of propositions. Propositions are two or more concept labels linked by words in a semantic unit (Novak & Gowin, 1984).

Exemplary learning material embraces both content and instructional procedures that one presented in a unique and distinct way from the way they are normally presented in a traditional science lesson. This involves the use of concept mapping, experiment using the predict, observe and explain method and the inclusion of discussion on fluoridation.

Misconceptions or what some have called alternative conceptions are conceptual ideas and thinking patterns which are in contradiction to those taught by their educators (Bradley & Staton, 1986). Driver & Easley (1978), perceives misconceptions as ideas manifested after exposure to formal models or theories, which are at variance with those currently accepted by the scientific community.

Constructivism: It emphasizes learning and not teaching. This study recognizes the fact that students come to class with prior knowledge. This knowledge has been gained from the previous grades, home, peers and social environment also known as everyday science. In facilitating the learning process the teacher pays close attention to the students' everyday science. According to Taylor (1997) constructivism is a theory of epistemological inquiry that empowers teachers to draw from life the thread of being and weave it into their emerging pedagogies.

Everyday science is the way natural occurrences encountered in one's daily life is interpreted or explained. Often such interpretations or explanations are not scientifically valid. They are usually based on a commonsensical rather than a scientific viewpoint.

Fluoridation is the addition of fluoride (usually sodium fluoride) to drinking water to reduce dental caries (tooth decay), especially in children. The fluoride combines with apatite, the chief constituent of tooth enamel, to form fluoroapatite, which has a greater resistance to bacterial decay (Webster's Family Encyclopaedia, 1992).

Redox reaction: Oxidation reduction reaction. Oxidation is a chemical reaction where an element or compound combines with oxygen forming an oxide. Reduction is a reaction in which oxygen is removed from an oxide. This reaction is also defined as an electron transfer from one particle to another. Whereas

oxidation is a reaction in which an atom, molecule or an ion loses electrons, reduction is a reaction in which an atom, molecule or ion gains electrons (Toon & Ellis, 1973).

Chemical reaction: A process where a chemical substance changes its chemical composition, i.e. the substance changes its molecular structure to form another substance. A chemical reaction involves transferring or sharing of electrons between reacting species (DET, 1989).

Chemistry Achievement Test is a test developed to measure the cognitive achievement of the students in the experimental and the control groups.



CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Science is a particular way of knowing about the world and the way the world works. Chemistry is a branch of science which, deals with the study of the properties and changes of material and chemical substances. One can only understand chemical substances the way in which they behave and their uses by learning and understanding their structures. To be able to do this, chemical principles, laws, and theories have been formulated (DET, 1989). Lavoisier cited by Toon & Ellies (1973) asserted that:

We must lay it down as an incontestable axiom, that in all the workings of life, art and nature, nothing is made from nothing, an identical quantity of matter existed before and after the experiment ... upon this principle, the whole art of performing chemical experiments depends (p. 85).

Thus it is essential that the teacher has vast knowledge and understanding of the theories and principles around chemical changes before he/she is able to teach it. The views and attitude of the teacher towards a subject matter will determine to a large extent how he/she teaches that subject matter or how his/her students would value what he/she teaches. This will also enable the teacher to easily identify students' misconceptions and be able to choose the appropriate teaching-learning methods to address and try and correct those misconceptions.

Students come to the learning environment with their own conceptual understandings, which may or may not be scientifically valid. However, as they interact with the teacher and learning materials, they ultimately construct, de-construct and modify their own understandings based in their new learning experience. Depending on the success of the instruction, students might accommodate, assimilate or reject what they have been taught in a given lesson or a set of lessons.

The success or otherwise of instruction to a large extent, depends on the relevance of what is taught to their daily lives. Hence, a student might partially or totally accept new knowledge or keep his/her own ideas and what is taught in a science class side by side. This is what Jegede (1995) calls "collateral learning" or what Ogunniyi (1998) terms "harmonious dualism". Further Ogunniyi (1997) modified his harmonious

dualism theory to what he termed the “Contiguity theory”. Since then he has explicated the theory to the learning of science (e.g. Adams, 1999; Ogunniyi, 2000, 2004). Both collateral and contiguity theories fall under the general ambit of socio-cultural constructivism, particularly the so-called border crossing.

2.2 BORDER CROSSING

A number of studies have been done on how students negotiate the movement from everyday science to classroom science (Aikenhead, 1996; Fakudze & Ogunniyi 2002; Ogunniyi, Jegede, Ogawa, Yandila & Oladele, 1995; Phelan, Davidson & Cao, 1991). For most students, especially in Africa, everyday experiences and the scientific worlds are different thus requiring adjustment and reorientation as they move between their home contexts into the school. Hence, Phelan et al. (1991) assert that:

As educators attempt to create optimal school environment for increasingly diverse populations, we need to know how students negotiate boundaries successfully or alternatively, how they are impeded by barriers that prevent their connection not only with institutional contexts, but also with peers who are different from them.

2.2.1 COLLATERAL AND CONTIGUITY LEARNING THEORIES

These constructivist theories attempt to explain the intellectual obstacles that students must overcome to succeed in learning school science. According to Aikenhead & Jegede (1999) students, particularly in non-western cultures, display four types of cognitive border crossing when they come in contact with school science. These are: parallel, dependent, simultaneous and secured collateral learning.

In parallel learning the schemata from two distinct worldviews do not seem to interact at all. In dependent collateral learning, the schema from one worldview challenges another to the extent that the student modifies his/her existing schema without radically restructuring the existing worldviews. In simultaneous collateral learning, the schema of one worldview reinforces or facilitates the learning of a similar concept in another worldview. In a secured collateral learning the conflicting schemata consciously interact and the conflict is resolved in some manner.

The contiguity learning theory according to Ogunniyi (1997, 2000, 2004) is a dialogical theoretical construct depicting the way students go about reconciling conflicting schemata e.g. between their commonsensical and anthropomorphic worldviews with the mechanistic and counter intuitive school science. According to Ogunniyi (2005) there are at least five types of contiguous associations between two or more conflicting schemata (i.e. dominant, suppressed, assimilatory, emergent and equipollent) depending

on the context and the purpose to be served. A thought system might be dominant or suppressed depending on which thought system is appropriate for the occasion. 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 Ogunniyi (2005) calls “equipollent”. However in a case where the new idea is preferred to an old one is what he calls “assimilatory”. But interesting and relevant as these theories are to the study space limitation would not permit any further elaboration. However, our awareness of the struggle that students undergo in learning any science topic should help us appreciate the relevance of these socio – cultural constructivist theories.

2.3 SOCIAL CONSTRUCTIVISM

Learning theories proposed by Piaget, Bruner, Ausubel, Vygotsky and Feuerstein, all emphasize the importance of prior knowledge learning experience as basis for further learning. Thus this study has been influenced mostly by Vygotsky’s social constructivism, which construes teachers as facilitators of the learning process and students as active constructors of knowledge. The thrust of constructivism is that teachers should facilitate students’ learning process in creating a conducive environment for students to be able to construct their own knowledge. The Outcome Based Education (OBE) Curriculum 2005 for the natural sciences is based on constructivism in that the teacher is expected to guide the students 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 resultant of a variety of interactions e.g. peer, classmates, teachers, parents, etc.

As Leach & Scott (2000) assert “... pupils in our schools live within a community that has its own, ‘everyday’ or ‘commonsense’ ways of talking and thinking about events and phenomena which are of interest to scientists”(p.42). For example, dissolving salt in water in everyday situation is viewed as a physical activity like melting of ice into water. To them, salt changes into salty water they do not view this as a chemical reaction where the salt has dissolved into an aqueous solution.

When students reach grade 12, they have already been taught chemical reactions and they have already constructed their own knowledge based on what has appealed to them. As a teacher one cannot assume that they are either blank or that they all understand and know all the concepts they are supposed to have learnt in the previous grades. The teacher has to be alert to students’ prior knowledge and misconceptions. However, for him/her to be able to present the lesson in a way that is meaningful to the students, he/she has to find a common ground with the students to enable the students to integrate this new knowledge with their existing

knowledge. Also, in terms of misconceptions held by students, the task of the teacher is to seek for conceptual change in favour of science, but this is not easily accomplished. Students' willingness to accept the scientific viewpoint depends on the strength of their prior knowledge and the meaningfulness of the new one.

Students decide what is meaningful to them. They can understand new concepts and use them correctly without changing their prior knowledge. Cobern (1994) asserts that:

In constructivist thought all knowledge entails ambiguity. There are no ambiguous facts. There are no determined theories. So, if scientific concepts do not have the inherent certainty assumed by the mythology of school science, the consistent constructivist must eventually ask what we do. Constructivism suggests that the concepts of knowledge and belief are not strictly separable (p. 10).

Aikenhead (1996) cited Kawasaki's response to Cobern's notion of constructivist learning in terms of the following assumptions:

1. Scientific concepts are constructed in one's mind where no concept existed before.
2. Prior / pre-conceptions are replaced by scientific concepts.
3. Concepts are constructed by modifying or extending pre-conceptions into more accepted scientific concepts (p. 165).
4. Learning is adding a new and different context to one's repertoire of contexts, and constructing new concepts to fit into that new context. New concepts have significance because they enable one to do something better or to communicate more effectively with others by being able to see the world in different ways. Old concepts are not modified, but are relegated to their familiar contexts (p.178).

According to Piaget, knowledge cannot be given to students it is the students' duty to construct that knowledge from their mental and physical experiences with the environment. Learning is both a physical/psychological activity and to be meaningful one has to understand and integrate knowledge into one's cognitive structures. Like Ausubel, he sees learning as a process of assimilation and accommodation where new knowledge is linked to existing cognitive structures depending on the students' prior knowledge (Ogunniyi, 2002).

I concur with Feuerstein that an adult, in this case a teacher, has to mediate students' learning experience by selecting from their environment significant sources of experience which will develop their cognitive structures. During instruction, the teacher has to draw examples from the students' everyday lives.

But in doing so he/she has to ensure that these examples are relevant to the lesson and will be able to stimulate the students' cognitive structures. As stated earlier, knowledge is not passively received from others, or from authoritative sources, but constructed as one makes sense of the world around him/her. As Smith (1995) puts it, knowledge refers to the internal constructions of the individual and so one can never know completely what is in the mind of another person. Feuerstein regards students as active constructors of knowledge. Like Vygotsky, he sees teachers as mediators of the learning process. He refers to learning as a social activity in which both the social context and the language play a fundamental role. However, learning from the students' perspective, is not the same activity for all. Each student constructs his/her own meaning and understanding about a given situation depending on his or her context (Smith, 1995).

Phillips (1995) equates constructivism to evolution, and agrees with Midgley that the theory of evolution is a powerful folk tale about human origin and not just a theoretical science. He went on to assert that constructivism is also a "powerful folk tale" about the origin of human knowledge. Quoting various constructivists (e.g. von Glasersfeld, Kant, Alcock & Potter, Kuhn, Piaget & Dewey) he highlights the differences and overlaps in their viewpoints. He summarises their views by stating that constructivism can be developed in interesting psychological, sociological and historical directions. To deal with the vast differences among the constructivist theories, he spreads them along three dimension so as to show their inter-relatedness within a given dimension as follows:

1. He refers to Piaget and Vygotsky who are both interested on how the individual student goes about constructing knowledge in his/her own cognitive apparatus. He suggests that the way the two scholars consider this activity differs somewhat in that Piaget stresses a biological/psychological mechanism while Vygotsky stresses the social factors that influence learning.
2. According to Phillips (1995) "The second dimension or axis along which the various versions of constructivism can be spread is, arguably, the most crucial one as it allows us to define a thinker as a constructivist. This can be labelled as "Humans, the creator and nature, the instructor". When knowledge is constructed, (whether it is in the mind or cognitive apparatus of the individual student, or whether it is a public discipline), it is the process that is influenced chiefly by the minds or creative intelligence of the knower or knowers, together perhaps with the "socio-political" factors that are present when the knowers interact in a community? ... Is the new knowledge – whether it be individual knowledge, or public knowledge - made or discovered?" (p. 7).

3. The third dimension is that construction of knowledge is an active process, but the activity can be described in terms of individual cognition or else in terms of social and political processes. It can either be physical or mental or both (Phillips, 1995).

Phillips (1995) contends further that there is a lot of confusion among constructivists. In his analysis he construes construction as dealing mainly with the following:

- How developing individuals learn.
- How the public disciplines originate.
- Knowledge production comes about solely from intellectual or cognitive processes internal to each individual knower.
- Knowledge production process is regarded as socio-political and therefore in a sense public and not simply or solely inner mental or intellectual in nature.
- Popper's view that "man proposes nature disposes" offers both an account of the growth of public bodies of knowledge but can also be interpreted as psychology and epistemology of individual learning.

Based on my perusal of these constructivist theories, I agree with Kesamang (2002) that the curriculum developer, the science teacher and science textbook writer should be aware of the fact that the students' socio-cultural background may impede the ease with which they learn school science. Hence, efforts should be made to identify those elements of the students' culture that are at variance with the scientific culture and which could impact negatively on their achievement in school science.

2.4 MEANINGFUL LEARNING

Like Piaget, Ausubel was interested in cognitive development. He developed a theory of learning which distinguished between rote learning and meaningful learning (Ausubel, 1968). According to Ausubel meaningful learning takes place during the internalisation process when symbolically expressed ideas are incorporated into some specifically relevant structures of already existing knowledge, as opposed to rote learning where tasks are relatable to cognitive structures only in an arbitrary, verbatim fashion (Chandler, 1984). Ausubel, like Piaget, sees meaningful learning as a process of assimilation where new knowledge is linked to existing cognitive structures. If by the end of the study the students show signs of having incorporated the new knowledge about chemical reaction and chemical change, especially redox reactions, to the

knowledge gained from the previous grades, then one might say that they have learned the concepts meaningfully.

Rote learning involves drilling and memorising of facts and concepts for the sole purpose of recalling them for a test or examination and is stored in the short memory while meaningful learning involves understanding and integrating knowledge into one's cognitive structure (Ausubel, 1963). For meaningful learning to occur, one needs to take cognisance of the different alternative conceptions, their forms as well as their origin. One of the aims of meaningful learning is to remove these alternative or common sense "erroneous conceptions and replace them with the scientifically valid.

2.5 CONCEPTUAL CHANGE

To understand the nature of the gap between what my students knew and what they were expected to know I sought insight in the extant literature. The following section depicts my exploration of the literature in order to understand the nature of the disparity between my students' understanding and what they needed to know about chemical reactions or any other subject matter in chemistry.

2.5.1 What Is Conceptual Change?

Students come to class with different worldviews, which are alternative to the scientific or classroom concepts. Leach & Scott (2000) argue that the scientific view is the one that offers an alternative perspective to everyday views in that the latter is metaphysical and has been developed over the years. Some of the beliefs are sometimes misinterpreted as superstitions and hence are not taken into consideration in the instructional process. These beliefs can act as barriers to learning school science. Posner, Strike, Hewson & Gertzog (1982) proposed four required for conceptual change to occur. Firstly, the teacher needs to create a conflict in the students mind, i.e. create dissatisfaction with their existing knowledge. Secondly, the new concept being introduced must be intelligible. Thirdly, the new concept must appear initially plausible. Finally, the new concept should suggest the possibility of a fruitful research. In many researches done on conceptual change, scientific conceptions are assumed to be superior to other conceptions. This might be one of the reasons students perceive science subjects as difficult and unattainable.

As much it can be easy for one to satisfy the four conditions above, a student may understand the new concepts but there is no guarantee that he/she has changed his/her prior concept. According to Cobern (1994) Posner et al.'s (1982) model of Conceptual Change is very narrow by assuming that Western Science can be

easily incorporated into learner's knowledge – a knowledge that is non-western in origin. For example, a Xhosa child is brought up with a saying 'ungabolahl' imbo yakho ngophoyiyane', meaning 'do not throw away what you have because of anything new and unknown in your life', this enables you to always weigh any new thing against what you already know or have.

Cobern (1994) makes reference to Gunstone's (1990) example of students "clashing current model" as follows:

After I had spent a number of science periods with the grade 8 class, providing what I thought was a wonderful sequence of experiences and discussion to challenge existing models, a student who had begun the sequence with a clashing current model informed me that he still held to this belief. Why did he believe this, I asked? His father had told him this, and his father was an electrician. It was suddenly very clear that I would not provoke him to reconsider and reconstruct (p. 5).

He further asserts that conceptual change makes little sense when the change is to science concepts that have been presented to the student in such a manner as to hold little meaning for most students. With Posner et al.'s (1982) conceptual change model, science conceptions are looked at from the positivist angle, where knowledge construction is more of a hypothetical-deductive logic and values, emotions, attitudes and culture are relegated to the background.

Cobern (1994) equates conceptual change to the story of Rosaldo who could not understand why the older Illongot men hunted heads. The Illongot man explained that when a loved one passes away, rage born of grief, impels him to kill a fellow human being. Rosaldo did not understand, because he was looking for a scientific explanation.

When his wife died hiking, in grief at his loss, he was filled with rage at the unjustly death of his loved one; and through that time of personal tragedy he began to understand the Illongot... He discovered through personal tragedy that ... a concept or a belief has force if it is central to an individual's thinking rather than marginal. A concept or belief has scope if it has relevance for the individual over a wide range of contexts. (p. 2)

This story shows that commonsensical ideas and beliefs held by students can have both scope and force and hence conceptual change tactics will ultimately fail because scientific conceptions as commonly interpreted at the secondary and tertiary level of education hold no force and little scope for most students.

From my initial conversations with my students I was convinced that they were aware that the presence of fluoride in toothpaste helps to keep the teeth white and strong. Therefore, in using fluoridation of public water supply as an example of chemical reaction I was trying to make the topic more meaningful to them. In other words, I wanted to give the topic both scope and force so that the students would see this new knowledge as part of their knowledge system. By exposing the students to this controversial debate, I was hoping that they might discover the merits and demerits of the controversial topic not only with respect to toothpaste but other products such as salt and public drinking water as well.

2.5.2 Phases of Conceptual Change

In agreement with Bereiter (1994) it seems that children are born pre-programmed to conceptualise numbers and physical realities in certain ways. As they grow up, they even go to school, in an effort to make sense of the world around them, they construct knowledge which is influenced, tempered and manipulated by interaction with parents, families, peers, friends, culture, television, radio, internet and many other factors that are part of our environment (Pine & West, 1986). This knowledge acquired over time constitutes the students' reality and belief system.

Changing students' conceptions is such a mammoth task. In changing students' conceptions three phases have been used by a number of researchers, these are: awareness, disequilibria and reformulation. Pine & West (1986) assert that during the awareness phase, the teacher provides a range of activities followed by class discussions, designed to elicit and highlight the existence and nature of competing points of view. The teacher then diagnoses thinking errors and identifies moves that students use to ignore inconsistencies, avoid dissonance and thus resist conceptual change.

The disequilibria phase is more of Posner's brainchild. This is where the teacher introduces anomalies that challenge existing belief systems. These anomalies stimulate students to articulate inconsistencies and discrepancies between the events they were observing and their own particular frameworks used to explain the world of natural phenomena. Posner suggests that the teacher needs to adopt an adversary role, a devil's advocate, during this phase.

The reformation phase as suggested by Champagne, Gunstone & Klopfer (1985) involve the presentation of formal concepts that lead to the resolution of anomalies and to the dissipation of the cognitive dissonance so ingeniously engineered by the teacher. If students are uncomfortable with the cognitive dissonance brought about by discrepancies between existing belief system and the anomalous events

observed, they will eagerly accept the formal theories being offered as their own. This is often the ease in an examination driven instructional process where students willingly surrender their own conception to that presented by the teacher or textbook.

2.6 ALTERNATIVE CONCEPTIONS

The extant literature is replete with research on students' misconceptions of chemical interactions (e.g. Abraham, Grzybowski Renner & Marek, 1992; Ahtee & Varjola, 1998; Beeth, 1998; Boo, 1998; Chandler, 1984; Chiu, Chou & Liu, 2002; De Posada, 1998; Garnett & Treagust, 1992; Griffiths & Presto, 1992; Hesse III & Anderson, 1992; Ogguniyi, 1999; Soudani, Sivade, Cros & Medimangh, 2000; Stavridou & Solomonidou, 1998; Teichert & Stacey, 2002; Van Driel, Verloop & Dekker, 1998; Yaroch, 1985). However, space limitation would not permit an extensive review of these studies. All that will be done here is to briefly allude to the nature of these misconceptions and of the factors responsible for their emergence during the teaching – learning process.

2.6.1 What Are Alternative Conceptions?

A lot of research has been done in chemistry to determine students' conceptions of various chemical phenomena. Based on these studies, it has been found that many students harbour a lot of conceptions, which are in contradiction to those taught by their teachers. These conceptions are mostly termed 'misconceptions'. Bradley & Staton (1986) states that:

Despite traditional instruction in the accepted scientific viewpoint, students frequently persist in holding on to a misconception, since to a greater or lesser extent it continues to make sense to them within an alternative conceptual framework, hence 'alternative conceptions'. (p. 539)

A common feature of misconceptions as revealed in a plethora of studies is that they are not easily replaced by the valid conceptions presented to them in the science classroom. As stated earlier, these misconceptions or alternative conceptions are inextricably linked to the commonsensical and intuitive knowledge about diverse natural phenomena.

Driver & Easley (1978), perceive misconceptions as ideas that emanate from an unsuccessful teaching – learning process such that what the student hold are at variance with what the teacher or text expects them to hold. Hence, the knowledge they acquire becomes a barrier rather than a catalyst to further learning.

2.6.2 Causes of Alternative Conceptions

Posner et al. (1982) suggests that many alternative conceptions held by students have originated from knowledge they have acquired prior to instruction. When a student comes to the science class, he/she comes with a lot of knowledge gained from home, peers and previous grades. In the science class, the student is torn between two worlds, the scientific and the everyday world. The student will attempt to reconcile the two domains. Concepts in the scientific domain are defined based on rules, laws and theories, whilst the everyday domain is based on the students' experience gained while interacting with the environment. Reif & Larkin (1991) suggest that students have an additional problem because school science often differs from the scientists' science. Campbel & Lubben (2000) assert that:

The difference in the goals and cognitive means for both domains are not made specific for students as a result students are unconsciously importing alternative concepts and ways of thinking which are effective in everyday life but not in science (p. 240)

The students' reasoning is governed by their experience accumulated over time and is embedded in their cultures' subconscious. Adams (2000) asserts that this causes alternative concepts, which affect their science learning. Some concepts are too abstract and foreign to the student, like chemical equilibrium, atom, molecule, etc. and consequently students tend to form their own imaginative and unconventional conceptual understanding, which might differ from the scientific one. What makes it more difficult is the fact that there often is a logical argumentation in the students' explanation. For example, students use the octet rule in explaining chemical reaction, e.g. in the reaction between sodium and chlorine, students assume that during this reaction the giving off of an electron by sodium, occurs so that sodium can achieve a full outer shell status while chlorine has to try to gain this electron to complete its outer shell (Taber, 1998).

In South Africa, most science teachers at the junior secondary school level are under-qualified, thus exacerbating students' problems. Added to this is the fact that these teachers are ill - equipped to deal with students' alternative conceptions and pre-conceived knowledge they bring into the science class. Bradley & Staton (1986) suggest that teachers must adopt a student dominance model, which accepts that alternative conceptions do exist on a broad base, and are sufficiently strong that they could persist or interact with teaching activities in a significant way. They further quote Watts and others as asserting that, " We must be aware of alternative conceptions, be acknowledgeable as to the forms they can take, and have a positive attitude towards them in that they are the starting point in efforts to remediate them". (p. 539)

The current curriculum, underpinned by the constructivist epistemology emphasises the students' independent construction of knowledge and the teacher as a facilitator of learning. But to perform their task effectively science teachers must be aware of the need to distinguish between the students' personal and psychological knowledge structures and knowledge as presented in the textbook (Taber, 1998). For meaningful learning to occur, the teachers need to take cognisance of the different alternative conceptions, their form as well as the way they influence learning. Unless teachers are well aware of such alternative conceptions their instructional activities will not be comparable with the model, which makes students to prefer the new concepts to which they are introduced to what they already held. Bradley et al. (1986) asserts that educational disadvantages can be seen not just to be a lack of correct conceptual thinking, but holding of entrenched inappropriate cognitive structures.

2.6.3 *Everyday Versus Science Worldviews*

Everyday experience and ways of talking and knowing are seen not only as discontinuous with those of science but also as barriers to robust learning (Warren, Ballinger, Ogonowski, Rosebery & Barnes, 2001). According to Warren et al. (2001):

Students' ideas and ways of knowing and talking are largely different from, and incompatible with those of science. They further argue that the way of talking, making arguments, and developing theories which are thought to constitute science are seen as distinct from the linguistic and social practices used in everyday life, especially those used in certain minority communities (p.546).

These everyday experiences, ways of talking and knowing are strongly held and may interfere with learning and need to be replaced with correct conceptions.

Both teachers and students bring to class their own beliefs, which may differ depending on their backgrounds. These beliefs may or may not be compatible with the scientific worldviews. As Phelan, et al. (1991) put it, teachers need to know how students negotiate boundaries successfully or how they are impeded by barriers that prevent their connection not only with institutional context, but also with peers who are different from them.

2.7 LANGUAGE

Lemke cited by Duran, Dugan & Weffer (1998) describes learning in high school as a process of understanding the linguistic organisation of content and acquiring the functional use of science language in the classroom. Students need to be taught the vocabulary of science. They assert that many misconceptions are a product of misunderstanding and lack of knowledge of the science vocabulary. If the students learn to

use the scientific vocabulary with precision, it is almost likely that the whole subject will become much clearer and more sensible than otherwise would have been the case.

Like any language in order to be able to understand, read and write it one needs to practice it. Teachers need to create an environment and opportunities for the students to practice science language, learn how to read, write, and talk science e.g. by giving students cloze tests, involving them in discussions or debates, etc, will help them to develop their language.

2.7.1 Language as A Medium of Instruction

In South Africa, Afrikaans and English are used as the media of instruction. Only a minority of students are fluent in both European-based languages. Due to the fact that the majority of students are neither English nor Afrikaans speaking, it becomes obvious why they encounter difficulty when a subject is written in either of the two languages of instruction. Besides, to most students English is more of a foreign language as they use it only in the classroom. Outside the classroom and at home they speak their own languages or mother tongues. Only a few countries in Africa use the local languages as the media of instruction beyond primary education (Rollnick, 1998: p.129). According to Naidoo (2000), the use of the home language as a medium of instruction enhances students' comprehension, thereby improving academic performance, and also provides concrete evidence that the home language is a useful and valuable tool.

The new South African constitution provides for certain human rights, one of them being language rights. It encourages multilingualism in education. According to the new language in education policy as cited by Selati, Adler, Reed & Bapoo (2002):

Subject to any law dealing with language-in-education and the constitutional rights of students, in determining the language policy of the school, the governing body must stipulate how the school will promote multilingualism through using more than one language of learning and teaching, and/or by offering additional languages as fully fledged subjects, and/or applying special immersion of language maintenance programmes ... (Department of Education, 1997:8)

They further argue that not only should South African schools and students now choose their language(s) of learning and teaching, but also there is a policy environment supportive of multilingual language practices like code switching.

2.7.2 Code Switching

Code switching is switching between two languages while teaching in order to enhance the students' understanding of concepts and ideas, and for communicating these ideas. The teacher or the students code switch between home language and the instructional language. The home language serves a very important function in the sense that it serves as a mediator of thought. The teacher understands what is said and the student is able to construct a correct idea or meaning of the science concept. In a study conducted by Rollnick & Rutherford (1996) they found the use of students' home language to be a powerful means for students to explore their ideas. They further argue that without the use of code switching some students' alternative conceptions would remain unexposed. My observation as a science teacher is that students' written work may conceal misconceptions which are more likely to be revealed in peer discussion in the students' home language.

My experience in teaching "English second language (ESL)" students is that during group discussions those who have grasped the concepts contribute more meaningfully to a discussion than those who have not. When probed in their mother tongue even the quiet students begin to talk and contribute to the discussion, though they try as much as possible to speak in English. They prefer to speak in English because they do not want to be construed as being stupid. In trying to speak in a language in which they are not so fluent they inadvertently expose their misconceptions and incoherence in English.

It is therefore imperative that teachers encourage the students to formulate their thoughts and ideas in their home language and then translate them into English. This should start with the teacher using code switching when in class so that the students could understand him/her better as well as realise that using their home language is not a sign of stupidity. I have found that by asking one student to give an answer in his/her home language and another to translate it makes students more confident in giving answers in their home language. When one is teaching and sees that his/her students do not understand what one is explaining to them, without making it obvious to them one should repeat what he/she said using a simpler way or even their home language. This can be easy when all the students have the same home language or they have a language that they can all understand besides the instructional language.

Although science teachers see their subject as a practical one, science teaching and learning occurs almost exclusively through the medium of language, spoken and written. In other words, learning science is like learning a new language. Many of the barriers to successful learning in science are related to language. One of the keys to a better understanding of science is the understanding of its language. Hence, teachers have a big and an important role to play in helping their students to acquire the language of science.

2.8 CONCEPT MAPPING

Concepts are the meaning attached to scientific facts (Ogunniyi, 1986). The learning of science for most students is a big challenge. Students have a tendency to isolate elements of knowledge and do not possess a well-founded basic framework in which newly acquired concepts can be integrated (Brandt, Elen, Hellemans, Heerman, Couwenberg, Volckaert & Morisse, 2001). This lack of integration can be due to the students' difficulties concerning concept formation and application of acquired knowledge in exercises (Pendley, Bretz & Novak, 1994), curricular tendency to compartmentise concepts, teachers' inability to integrate these concepts whilst teaching and misconceptions acquired from common sense experiences. The ability of teachers and students to integrate concepts is what Ausubel calls meaningful learning. It is an attempt to accomplish this integration of concepts or meaningful learning that led Novak & Gowin (1984) to design an instructional tool known as concept mapping.

2.8.1 What Is Concept Mapping?

A concept map is used as either a teaching and/or learning tool that aids in identifying the main concepts and the sub-concepts and to show the interrelationship of these knowledge structures. Concept mapping was initially defined by Novak & Gowin (1984) as a visual lens to promote new knowledge production and understanding. Concepts or ideas are organised in a logical, hierarchical pattern. Novak initially used concept mapping for organising biology concepts but now it is used in all school subjects as a schematic device for representing a set of interrelated, interconnected conceptual meanings. It is created by an individual in the way he/she perceives reality by transforming the knowledge to be mapped from its current, linear form to a context-dependent hierarchical form. During this transformation of knowledge the student is presented with an opportunity for creativity and may serve (a) to challenge his/her assumptions,

(b) to recognise new patterns, (c) to make new connections and (d) to visualise the unknown (Wandersee, 1990: 927).

Nicoll (2001) sees concept mapping as a qualitative representation of students' conceptual understanding. He further suggests that teachers can use concept mapping as a tool to "peer" into students' minds and ascertain what and how they are learning as well as an assessment technique to gauge how well they are assimilating the new information. Wandersee (1990) sees concept mapping as a science education's major psychological theory that is designed to help students to "learn how to learn" science.

The concept of chemical reaction has been found by teachers and researchers to be particularly difficult for students and may well be one of the sources of the alternative conceptions they hold (e.g. Boo, 1998; Hesse & Anderson, 1992; Tewolde, 2001). Hesse & Anderson (1992) and Tewolde (2001) attributed the difficulty that students encounter with chemical reaction and chemical change, and their misconceptions to the students' learning methods as well as to the teachers' teaching methods. Hesse & Anderson (1992) found that traditional teaching methods are ineffective in helping students learn these concepts. To overcome students' difficulty in the area, several instructional methods have been used. One of the most frequently used instructional methods in this regard is concept mapping. According to Novak (1990) concept mapping may help teachers to move their own learning approaches towards more meaningful practices. Thus, they will emphasise the meaning of key concepts and principles in ways students can form a conceptual understanding of the subject. Concept mapping enables the students and the teachers to visualise concepts and arrange them in a systematic way. It presents a clear picture of what students are thinking. Concept mapping has been hailed as a powerful tool and effective teaching and learning tool (e.g. Ebenezer & Connor, 1998). For students to be able to understand any scientific concept, it is of necessity that they have an insight into the constituent concepts and their respective relationship (Dinie, 2000). If students have a clear picture and understanding of their concepts their attitude towards the concept and the subject as a whole does improve (Horton, Conney, Gallo, Woods, Senn & Hamelin, 1993). Roth (1994) found that a large number of students identified concept mapping as a tool that provides them opportunities for engaging in collaborative construction of knowledge and negotiation of meaning.

2.8.2 Relevance to Current Study

Concept mapping is considered to be appropriate to this study in that it is based on constructivism, which encourages students' independence in constructing their own concepts from the material presented in class. Tewolde (2001), in a similar study to this one, found concept mapping to enhance students' understanding of chemical reactions. Brandt, et al (2001) in tried to find the impact of concept mapping and visualisation on students' learning of redox reaction. I have used the same topic in this study.

Novak (1990) in his study of concept mapping as a useful tool for science education worked with graduate students. He found that concept maps were not only a useful tool to represent changes in the knowledge structure of students over time, but also helped them to "learn how to learn." He found that concept maps were useful to represent knowledge in any discipline and aided in organising and understanding new subject matter. He also found that when controlled quality instruction is offered, concept map could be a highly sensitive tool for measuring changes in knowledge structure.

2.8.3 Effect of Concept Mapping on Learning

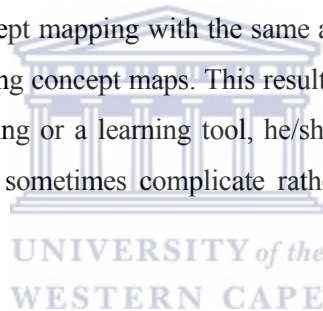
Concept mapping has been found to present a clear picture of what students are thinking as it enhances meaningful learning and clarity on learning (Heinze-fry & Novak, 1990). Concept mapping has been hailed as a powerful tool to help students to learn meaningfully and the teachers to become more effective. Novak (1990) cited Helen & Novak as well as West & Pine as asserting that a concept map helps students to elaborate their conceptual understanding and to modify the knowledge structures that contain misconceptions, alternative conceptions or frameworks. Novak (1990) asserts further that:

The primary limitation for young children was not their "cognitive operational capacity" as indicated in the work of Piaget (1926), but rather the quantity and quality of their relevant knowledge acquired through experience and instruction. (p. 938)

A review by Regis, Alberterzzi & Roletto (1996) showed that in 75% of the cases they studied, students had a dramatic change on the understanding of material presented to them in chemistry as a result of their exposure to concept mapping. Also, a study conducted by Czermiak & Haney (1998) on the effect of

collaborative concept mapping on elementary pre-service teachers' anxiety, efficiency, and achievement in physical science, showed that concept mapping not only lowered anxiety about learning physical science but also enhanced achievement in science. There was no significant effect on anxiety towards teaching physical science, self-efficiency, or outcome expectancy. Horton et al. (1993) found that students' attitudes and achievement improved with the use of concept mapping.

Brandt et al. (2001) studied the impact of concept mapping and visualisation on the learning of secondary school chemistry students. They found a positive effect on visualisation, which they attributed to the fact that it was similar to the ordinary teaching practice. However, there was no significant effect on achievement probably because it was a totally new technique to the students and was complicated to them. Stenvold (1990) examined the interaction effect of verbal ability with concept mapping in learning from a chemistry laboratory activity. They found that students using concept mapping achieved lower scores compared to those not exposed to concept mapping with the same ability and that students with high verbal ability prefer rote learning to constructing concept maps. This results show that if one wants to teach how to use concept mapping either as a teaching or a learning tool, he/she needs to undergo a thorough training. This is because concept mapping can sometimes complicate rather than facilitate knowledge acquisition (Brandt et al., 2001).



2.9 FLOURIDATION

2.9.1 The Debate

As indicated in chapter 1, the debate over the Fluoridation of public water supply, as a measure to help prevent tooth decay in children, started in the Western Countries. There are at least four areas of debate: (i) The benefits of Fluoridation; (ii) the risks of Fluoridation; (iii) individual rights, and (iv) decision-making (Martin, 1991). Although the idea of using fluoride to prevent caries, tooth decay, probably started in Europe in the 1800s, it was only in 1901 when research on fluoridation was started, by Mc Kay, an American dentist. He noticed staining of teeth in his Colorado patients. After pursuing its origin, he concluded that water supplies were responsible for the tooth decay. In 1931 Churchill with the help of Mc Kay ran tests samples of people drinking fluoridated water and those drinking unfluoridated water. They were further

joined by Smith, Hartz and others. The conclusion reached in their effort convinced them that water supplies were responsible for tooth decay (Martin, 1991). These findings and subsequent debates sparked up interest both in the health service sector in the USA and the general public. Since then the debate has become intensified in many countries around the world.

A lot of people, scientists, dentists, medical doctors, politicians and concerned communities, have been involved in this debate. Some of these are pro fluoridation and others are against it. On the one hand are arguments based on the benefits such as the prevention of tooth decay, while on the other one are health risks associated with toxic response by hypersensitive individuals to small doses of fluoridation, skeletal fluorosis, its association to cancer deaths, its effect on kidney function, enzyme activity and mutation resulting in genetic effects (Gibson, 2002; Martin 1991). The questions that arise from these debates include among others the following:

- If fluoridation prevents tooth decay, why add it to water, which is swallowed?
- Since breast milk, saliva and most foods have fluoride and some water supplies have it, what is the necessity for adding fluoride into water supplies?
- Considering the risks, is the individual's right not violated when fluoride is added to public water?
- Do benefits of fluoridation outweigh risks?

2.9.2 South African Debate

The questions above do not have easy quick fix solutions. In the final analysis the decision reached must include all the stakeholders: the government, scientists and the citizens. South Africa has never been a part of these debates. Although the Health Act, 1977 allowed the Minister of Health to regulate the introduction of fluoridation, this never happened. However, due to increased worldwide interest in the subject the Department of Health had carried out a number of investigations. But again no concrete step was taken to implement the findings. According to Smit in a Cape Argus (2002), the plan to fluoridate South African water will be done with the view to improve oral health and consequently, the overall health of the citizens. There are many South Africans who are opposed to the fluoridation of drinking water. A strong opponent to the idea of fluoridation is Richard Weeden of African Health and Development Organisation. The opponents to fluoridation argue that an overdose of fluoride is highly toxic, and in South African conditions, it may not be possible to ensure safety levels are adhered to them.

After the new government came into power in 1994, under the leadership of the then Minister of Health Dr Nkosazana Zuma, fluoridation research recommenced. The findings that have emerged from these investigations include the following:

- Fayazi (2002) from the Directorate of Geohydrology in the Department of Water Affairs, has found that the Karoo has high fluoride underground water and fluoride level in the Northern Springbok Flats is strongly controlled by the geochemistry of the rock in which groundwater is encountered.
- Ginster & Fey (2002) from the Department of Geological Sciences at the University of Cape Town (UCT), discovered that the grass pasture SASOL irrigated with water containing fluoride, have a fluoride concentration sufficient to inhibit plant growth. He suggested that to reduce the concentration of fluoride, the soil has to be pre-treated with gypsum to maintain a near-neutral pH.
- Van Zyl & Hartley (2002) from the Department of Water and Forestry are proponents of fluoridation and insist that the Government has a duty to ensure that all citizens have an access to clean water.
- McCaffrey (2002) from the Department of Geological Sciences in UCT discovered that Lebowa and Nebo, which are in the former Republic of Bophuthatswana (now Northwest Province) have a high fluoride concentration groundwater, which is due to dissolution of Fluoride bearing minerals in the bedrock and soil in the area. He also discovered that the area is known to have high dental fluorosis and skeletal fluorosis, which occur sporadically. Rudolph and others from the Department of Community Dentistry in the University of Witwatersrand, also did some research where they compared the level of fluorosis between children and adults, they discovered that subjects that were exposed to water containing high level of fluoride manifested severe fluorosis. Mothusi from the Department of Health, North West Province has also echoed the dental fluorosis problem among the local inhabitants of North West. He blames this health problem on the high fluoride level in the water and recommends de-fluoridation.
- Schoeman & Lebone (2002) from Watertek, CSIR, looked at various ways of de-fluoridating water and came up with three methods for reducing the fluoride level in Water. This was published in a White Paper in the South African Government Gazette, 16 April 1997 by the Department of Health. It entails the following:
 1. Systematic water fluoridation should be implemented immediately, at least in the major metropolitan area of South Africa, the remaining areas being phased in systematically.
 2. Alternative methods of fluoridation, such as the use of fluoride toothpaste and fluoride mouthwash- rinses should be introduced in schools and among priority groups.
 3. Legislation to enable the fluoridation of milk and salt and the inclusion of dietary supplements (fluorides and vitamins) as part of an Integrated Nutrition Programme.

From the debates and researches conducted here in South Africa it is clear that there are contradictory ideas about water fluoridation. These are due to a number of reasons including the fact that water used for drinking purposes constitute a small fraction and most water is used for irrigation and cooking. Heating water by either cooking or kettle increases the concentration of fluoride. This outweighs fluoridation benefits as they are minimal and its toxicity high. Continuous use and exposure to high levels of fluoride may result in dental and skeletal fluorosis, tooth loss, crippling due to vertebral damage as well as death from acute fluoride poisoning.

In a parliamentary debate (2002) the members likened fluoridation of water to “mass medication” and that this had failed in Ireland. They also argued that it was toxic and would not reach the people who needed it most as more than seven million South Africans have no access to tap water. It was also raised that no local comprehensive studies have been done to ascertain whether or not fluoride can be added to other substances such as mealie meal, as a more effective way of reaching the population worst affected by tooth decay. Smit in a Cape Argus (2002) claimed that 70% of six-year-olds in South Africa, the figure rising to 90% in adults, were affected by tooth decay. He claimed that fluoride at the optimal level, one part per million, would reduce tooth decay by up to 60%. This will result in less toothaches, and so less time off school and work, and fewer and smaller dental bills. He also claimed that water fluoridation, at R1 a person per year, was 18 times cheaper than toothpaste and 61 times cheaper than filling a tooth.

Weeden (2002) has argued that the benefits have not been weighed adequately against the risks. He further argued that fluoride added to water, unlike that occurring naturally in water, was a highly toxic substance in overdose, a bit more toxic than lead but not quite as arsenic. Kasan in a Cape Argus (2002) suggested that an investigation be done on what is in the best interest of South Africans with respect to the fluoridation controversy.

Chilkte & Josie-Perez from the Department of Community Dentistry, Wits University in South Africa, felt that fluoridation of drinking water is influenced by social, political, environmental as well economical factors. They carried out a national survey in South Africa designed to assess public perceptions with regard to the knowledge, purpose and desirability of water fluoridation. They discovered that a high percentage of people did not have an accurate knowledge about water fluoridation.

2.9.3 Relevance to The Study

At the time I came across Brian Martins book titled “Scientific Knowledge in Controversy: The Social Dynamics of the Fluoridation Debate,” I realised how very little I knew about the fluoridation debate. Although I probably heard about the debate over the radio or skipped through newspaper articles on the subject, it did not engage my intellectual interest. My overall lack of clarity on the subject as a chemistry teacher seems unjustified but it probably reflects a deeper problem about the type of education one has had. In other words:

- The type of education we received, as students as well as teacher trainees, never equipped us sufficiently enough to be open-minded.
- The chemistry curriculum and syllabus were rather narrow and examination oriented.
- The enormous work- load of teachers leaves them with little time to discuss topical issues.
- Our ignorance and general laziness as teachers to read extra-curricular materials make us to be less informed about critical science related social issues.

The Learning Outcome 3 (LO3) from the revised Curriculum 2005 for the Natural Science published by the Department of Education (DOE) requires that students be able to: Demonstrate an understanding of the relationship between science and society, and the impact of science on society (DOE, 2002).

The present study was considered as one of the ways to stimulate the students’ interest in resolving science related social issues such as fluoridation. One way was to explore the students’ awareness about the topic. Even if they were not familiar with the subject of fluoridation they could be confronted with relevant information and assisted with problem-solving strategies to make valid decisions in terms of: (i) acceptance of knowledge claims; (ii) evaluating information critically; (iii) acceptance or rejection of expert opinions and (iv) evaluating sources of information in terms of interests, neutrality or competence.

In view of the above and in the spirit of the goals of the Outcome-based Education Curriculum 2005, I decided to explore ways in which I could assist my students to be open minded and better informed about controversial issues (not strictly based on the grade 12 syllabus) but which have relevance to chemistry education. It was my view that the students later in life would be confronted with a lot of social issues and decision making requiring a modicum of scientific literacy. To achieve this goal I decided to explore the students’ understanding about the following:

- Fluoride reaction
- Aqua-fresh (tooth paste) which is used to prevent tooth decay

- Fluoride in table salt

When I asked the students about water fluoridation, none of them knew anything about it or about the fluoridation debate. They only knew about chlorination, which is the process where chloride gas is bubbled through water, drinking and swimming pool water, to kill bacteria. Their ignorance can be attributed to a number of factors such as:

- Most of my students come from poor backgrounds and hardly read newspapers or watch TV news or debates. In these communities reading a paper or watching news is something done by adults or the “so called” educated people.
- The curriculum is more examination orientated and does not accommodate topics that are not examinable.
- Teachers know very little to nothing about the debate on fluoridation, thus cannot make their students to be aware of it or encouraged them to be involved in the debate.
- Information on fluoridation as well as on the debate is written in English, thus making it inaccessible to most of these ESL students.
- These debates about fluoridation mostly take place in the west and not in the developing countries (including South Africa). Thus, there is very little information available on the subject. Also, despite the Health Act of 1977 which mandated the Minister of Health to implement the fluoridation policy nothing concrete was done. Hence, for nearly two decades government for one reason or the other has been dragging its feet on the matter.

Seeing that my students were unaware of the fluoridation of water debate, I decided to include fluoridation in this study, to try and evoke their awareness on fluoridation as well as determine how they utilize information to evaluate the validity or otherwise of the fluoridation controversy. Also, unlike the case of adverse effect of tobacco only the benefits of fluoridation are widely publicized. My hope therefore, was that the study would not only make my students aware of the risks of fluoridation but that their peers and families would be made aware as well.

2.10 CONCLUSION

Knowledge has to be constructed and made available to the student. Whether the student is going to understand the knowledge or not depends entirely on the student. As Cobb (1995) argues, knowledge is in the mind of the knower and is inaccessible to others. All teachers need to do, is to facilitate the learning

process by guiding the students on how and where to get the knowledge required, developing in them skills of acquiring information and gathering knowledge. As von Glasersfeld (cited by Phillips, 1995) argues, teachers need to give guidance about how bodies of understanding are built up. Students need to experience any concept or situation in order to be able to construct any concepts and acquire knowledge about it. Like Piaget, Ausubel and Feuerstein I believe during learning, the new knowledge has to be rendered in a way that students can incorporate it into the cognitive structures, where it is linked to the prior knowledge whether passed down by knowledgeable adults in the community, learnt in the previous grades or gathered from peers. The ultimate goal according to the contiguity theory (Ogunniyi, 1996, 2004) is that the student would be positively disposed to the emergence of new knowledge compatible with new demands. However, for this new knowledge to be worth learning, it has to appeal to the student, be meaningful, reliable, consistent and applicable not only in the classroom situation but in everyday life as well. Depending on the context as well as the origin and strength of the prior knowledge students might either change their views to accommodate a new idea (e.g. a scientific concept) or decide to hold both views collaterally (Aikenhead & Jegede, 1999) or contiguously (Ogunniyi, 1996, 2004). As Gunstone & White (2000) having reviewed a large number of studies dealing with conceptual change concluded that:

The issue now appears to be not one of abandonment and replacement, but one of addition, so that the earlier belief and the scientific belief co-exist. The learner's task is to learn the scientific belief, and to become clear about when it is appropriate to apply one belief or the other. (p. 288)

The next chapter presents the procedure adopted in the study to introduce the students to the concept of chemical reactions with fluoridation as the case study.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

In chapter one I presented a historical account of the school where I teach and the type of students who attend the school. There, I explained that most of my students are very demotivated and regard themselves as failures. As underachieving students, it is not difficult to know why they hold a negative view about science or education in general. Therefore, to motivate this type of students, one needs to be creative. One way to do this is to engage them on topics with direct practical application to their lives outside the school environment. The integration of everyday, outside - school phenomena in science teaching is not only necessary but also urgent (Soudani et al., 2000). One of such topics is the current controversy that has emanated from government policy to add fluoride to drinking water to prevent tooth decay.

The fluoridation policy, strongly supported by chemists and pharmaceutical organisations, has always resulted in arguments and counter arguments worldwide. While the proponents claim that the fluoridation of drinking water retards tooth decay, the opponents claim that it encourages high blood pressure, skeletal fluorosis, cancer, affects kidney functioning, enzyme activity and mutation resulting in genetic effects (Martin, 1991). According to Weeden (2002) as indicated in chapter 2, fluoride added to water, unlike that occurring naturally in water, is a highly toxic substance in overdose. In terms of this study, this controversial topic, which revolves around chemical reaction, was thus construed as a window of opportunity to arouse my students' intellectual spirit. In other words, instead of studying the concept of "Chemical Reaction" directly as presented in their textbook, the students explored the concept in its applied context.

Fluoridation was introduced to all the students in order to capture their attention about a topic that was going to affect their lives. This topic also gave the students an opportunity to make an informed decision whether or not to use fluoridated products. This also made them to become aware of the controversies surrounding the topical issue of fluoridation. As Tobin (1997) asserts, "the teacher, representing society, has an obligation to educate students, to assist them to learn what is currently regarded by society as viable knowledge" (p.33).

3.2 SAMPLE

The subjects consisted of 121 grade 12 students, 76 girls and 45 boys from the same school. To select the subjects, a convenient sampling approach was adopted. With the current strict research policy, it became necessary and convenient for me to use my own students than the students of other science teachers. With the exception of my students and the school administration, I did not have to ask permission from anyone to conduct my research. To avoid the effect of history, three identical groups, experimental (E) and two control groups (C₁ and C₂) were used. The three groups had similar social backgrounds and had passed through similar historical events and disadvantaged school settings.

The question of using students in the same school normally raises the question of contamination of data. In chapter one as well as in the introduction of this chapter, I have explained the type of students I am working with. Firstly, these students come from different townships in Cape Town: Langa, Gugulethu, Nyanga, Phillipi and Khayelitsha. When they leave school they normally rush for the gate. Secondly, the fact that they are generally de-motivated and construe themselves as failures and also the fact that science, as a subject, does not really appeal to their intellectual interest create a setting where it is unlikely that the students would ask or discuss what has been taught in class. Thirdly, the needs of students vary widely. The subjects taken by the students to meet matriculation exemption range between two and four subjects and as soon as they finish attending their classes they rush for the trains either to go back home or to return to work. Fourthly, these students do not have fixed classes, fixed periods or fixed groups. Rather the subjects are available for them for the whole day and they move around from one room to another and only teachers remain in fixed classes where they offer a particular subject. To ensure that these students stay within the chosen groups, firstly I chose the first three groups that I see every morning, which are usually consistent. Secondly, I had to explain my problem and also appeal to them to remain within the chosen groups for research purposes.

Table 3.1 Composition of Students by Gender and Career Interest

Gender	Career Interest						Total
	Medical field:	Engineering	Information technology	Sciences	Business	Service	
Male	14 (31)	13 (30)	09 (20)	03 (7)	03 (7)	03 (7)	45
Female	33 (43)	18 (24)	07 (9)	09 (12)	04 (5)	05 (5)	76
Total	47 (39)	31 (26)	16 (13)	12 (10)	07 (6)	08 (7)	121

n(%); N = 121

The sample used for collecting data in this study is indicated in Table 3.1. The students have been divided according to gender as well as career interest. This is because the study is also concerned about the effect gender and career interest on the students' conceptual understanding of chemical reactions. As shown in Table, 62.8 % of are females and 37.7 % are males. This seems to be a new trend where more female high school students do science. This could be attributed to the Department of Education's programmes like Girls in Science Camp, launched in 1999, which concentrated on girls from grade 9 but now include those from grades 10,11 and 12. 39 % of the students are interested in the medical field, followed by engineering (26 %), information technology (13 %), the lowest being business (6%) and services (7%). There are more girls interested in the medical field and sciences than boys, whilst in other fields boys are more than girls.

3.3 METHODOLOGY

The initial pool of this study consisted of 141 grade 12 students. However, because some students did not write the pre- or post-test, the total number was reduced to 121. The study was conducted during the third term over a period of three weeks, nine periods of 50 minutes each and six periods of 40 minutes each. The topic redox reactions, was selected as the topic for this study. Redox reactions are an essential and examinable part of the grade 12 chemistry curricula. Redox reactions is considered to be a rather difficult topic by many students as well as teachers (Brandt et al., 2001). From my experience as a physical science teacher, redox reactions have a lot of easily observable experiments. Also, this topic is easily amenable to real life experiences, e.g. the formation of rust on metals, petroleum burning, the colour change of an apple, etc. The definition and application of the concepts involved in redox reactions are particularly problematic in that they apply to many other grade 12 chemistry curriculum topics. Further, the topic was considered appropriate for this study in that the underlying concepts can be easily visualized with the use of a concept map as an exemplary teaching-learning tool. Also, the study was considered appropriate in that it was carried out about six weeks before the trial matriculation (matric) examination, thus serving as a useful revision tool for the students.

Before starting with this topic, the periodic table, bonding, chemical reactions and balancing of equations were revised. Students of groups E and C₂ were also introduced to concept mapping. Concept mapping can be used as a visual text to manipulate information and to reproduce the original explanation as well as a scaffold to answer questions (Duran et al., 1998). The students were first taught how to develop their own concept maps. They were given notes on how to construct a concept map as well as three passages

in preparation for the following day lesson. One of the concept maps on a passage dealing with a concept was constructed on the overhead projector (OHP) by both the teacher and the students (see Appendix A₁). Later they had to construct concept maps of the other two passages in groups and then presented them to the entire class on the overhead projector (see Appendix A₂). The whole class discussed each concept map and scored.

In teaching redox reactions the key concepts and their definitions were written as chalkboard summary. From this summary students, in groups of five, had to construct concept maps and present them to the class. They developed different concept maps but eventually agreed on one from each group, i.e. E and C₁, which made more sense, (see Appendix B₁). At the end of the study, with the students, we developed another concept map, combining the two concept maps from the two groups, as part of revising the topic, (see Appendix B₂).

The controversial debate on the fluoridation of public water supply was introduced as an example of chemical reaction, particularly redox reaction as tooth decay results in the erosion of enamel i.e. oxidation reaction. Having ascertained from them that the fluoride present in tooth paste was there to prevent tooth decay, I explained the reaction between fluoride and apatite, the main constituent of tooth enamel, to form fluoroapatite, which has a greater resistance to bacterial decay (Webster's Family Encyclopaedia, 1992). Thus, the use of fluoridated products reduces the rate of chemical reaction between the plaque formed from sugar and bacteria, and the enamel of the teeth, i.e. erosion of the enamel and dentine. Students were further given material to read further about the debate in preparation for the following lesson, where both the advantages and disadvantages were highlighted and debated by both the proponents and opponents of fluoridation of drinking water. Also, books were made available at the reserve desk in the school library. This was to ensure they were all exposed to the necessary information needed for the lessons, discussions and interviews on the topic. To ensure maximum participation, during class discussions marks were allocated per group as part of the continuous assessment (CASS). There were six points on which the students had to focus their discussions on. These were: (i) the students' understanding of fluoridation; (ii) their opinions about fluoride in tooth paste preventing tooth decay; (iii) their perceptions of the effect of chewing or not chewing gum on tooth decay; (iv) the use or lack of use of calcium in tooth paste; (v) their perceptions of the logic of drinking fluoridated water to prevent tooth decay against their use of tooth paste and (vi) the relevance of fluoridation in the lesson. Each group had to write their own arguments to the focus points and had to report to the entire class. All the students further discussed the answers given by the groups. The discussion was audio recorded for analysis later. At the end of the lesson I felt we could have

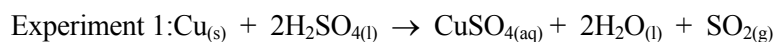
discussed the topic further as the students seemed to show great interest in the topic. However, timetable constraints allowed for only three weeks treatment though four could have been more appropriate. Although the science syllabus stipulates that this topic be taught in one and half weeks, with the consent and help of the Head of Science Department, I managed to manipulate it in such way that I could at least have three weeks.

To further demonstrate and enhance the students' understanding of the topic, two experiments on redox reactions, dealing with chemical reactions in terms of transference of electrons were conducted. Hudson (1998) suggested that practical work can be used for three purposes:

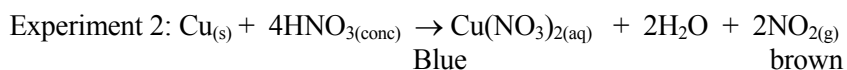
- To help students learn science – acquire and develop conceptual and theoretical knowledge.
- To help students learn about science – develop an understanding of the nature of the methods of science and an awareness of the complex interactions among science, technology, society and environment.
- To enable students to do science – to engage in and develop expertise in scientific enquiry and problem solving.

According to Abraham, Rochford & Inal (2000) practical work could be a very powerful tool in developing students' conceptions and procedural understanding. Thus I decided to include some of the data from the experiments although they are not part of the questions investigated in this study.

The students had to work in groups of five. The first experiment was a teacher demonstration of the reaction between copper and sulphuric acid.



The students were provided with a worksheet (see Appendix C₁) with questions for them to answer during the demonstration. The students had to first predict observation before it was demonstrated and give reasons for their answers. After demonstration, they had to compare their predictions with the actual observation, if different they had to explain why. The second experiment, which was the reaction between copper sulphate and steel wool (iron), was done by students in groups, (see Appendix C₂) using the same method of predict, observe and explain as used in experiment 1.



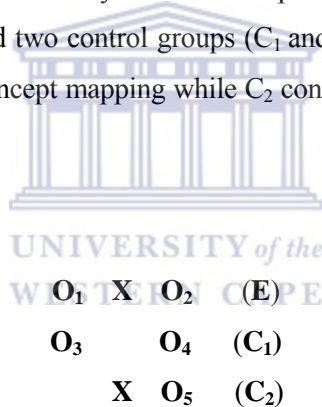
This method of predicting observations with explanation before the actual observation i.e. POE, was adopted by Mthembu (2001). He claims that it is slow but can enhance students' critical thinking skills.

This study recognises the central role of the students in defining the completion of any lesson. According to Ramarogo (1998) a hermeneutic perspective of teaching and learning should take into account the perspectives of the students about teaching and learning. Thus, at the end of the three weeks of the study, students were given three questionnaires to indicate their perceptions of the study, particularly with respect to the concept mapping and the argumentative approach based in a controversial topic, fluoridation.

3.4 THE RESEARCH DESIGN

This study involved the use of both quantitative and qualitative designs. The quantitative research design used in the study was a quasi-experiment model based on the Solomon – 3- Design. However, unlike the original design, the groups were not randomly constituted. Specifically, the design entails three treatment groups: one experimental group (E) and two control groups (C₁ and C₂). C₁, was the true control group that controlled for the treatment, namely, concept mapping while C₂ controlled for the possible effects of the pre-test.

The design is represented below:



O₁ and O₃ are the pre- tests and O₂, O₄ and O₅ are the post-tests while X stands for the treatment. According to Ogunniyi (1992) this design is tight enough to eliminate possible sources of extraneous variables, e.g. history, mortality of subjects, statistical regression, etc., which might affect the validity of the instrument and or the quality of the data obtained.

All the three groups were exposed to equal teaching hours, consisting of nine periods of 50 minutes each on chemical change and redox reaction. In consonance with Learning Outcome 3 of Curriculum 2005 for the Natural Sciences, effort was made to ensure that the students were “able to demonstrate an understanding of the relationship between science and society, and the impact of science on society” (Department of Education 2002:10). Learning Outcome 3 seems to be the most amenable to discussing socially related issues and problems like fluoridation of public water supply which is a good example of

chemical reactions. According to the same document, “Learning Outcome 3 calls for the student to become a scientific problem solver in the context of South African Society” (Department of Education; 2002:10).

The students of group E and C₂ were introduced to concept mapping while their counterparts in C₁ were only exposed to expository lecture approach. This method enabled me to determine the effectiveness of the intervention in the development of the students’ conceptual understanding of chemical reactions.

One may argue that since they are all my students and coming from the same school, they might communicate with each other and share this new method (including the use of concept mapping and other exemplary materials) the validity and reliability of the study will be greatly compromised. However, with the situation in my school, this problem is not likely to occur. First I teach a total of 141 students who do not move together as a group, but attend different subjects with different teachers at different times. Each cohort of students follows a particular schedule of class sessions, which do not overlap. Secondly, as stated in chapter 1, these students are “failures” from different schools and different provinces and are highly unmotivated to even care to share what has transpired in class as they are always eager to go to their respective homes and some to work after classes rather than stay at school and study.

Besides the moral argument and the professional argument seem to become stronger in terms of the potential of using a multiplicity of students. The desperate situation in my school demands a drastic approach that could reduce further chances of failure of these generally unmotivated students. Thirdly, for the topic of the study I have used redox reactions, which is part of the chemistry syllabus to be covered. In essence, the inclusion of fluoridation and other everyday life redox reactions included in the CAT, should help the students to see the application of the study in class to life outside the school.

The qualitative component of the study involved an analysis of the semi-structured student questionnaires and the semi-structured student interviews on both the use of concept mapping as well as fluoridation of drinking water. In each questionnaire sufficient space was provided for the students to write any extra comments. All these comments were also used in the qualitative analysis of the study to collaborate the quantitative data.

3.5 INSTRUMENTATION

Due to the different approaches used in conducting this study, a number of instruments were used to collect data. Altogether seven different types of instruments were used. They are:

1. The Chemistry Achievement Test (CAT), which was the pre- and post-test (see Appendix D) instrument for determining the students' conceptions of chemical reactions. The data collected through the CAT were analysed in terms of quantitative and qualitative descriptions.
2. A worksheet on experiments conducted to test the students' understanding of the concepts discussed (see Appendix C₁ and C₂).
3. Three questionnaires were used to explore:
 - (i) the students' perceptions of the lesson on redox reaction (Appendix E).
 - (ii) the students' perceptions of the experiment and the worksheet based on it (Appendix F).
 - (iii) the students' perceptions of the use of concept mapping (Appendix G).
4. The two student interviews included:
 - (i) A non-directive interview carried out to explore the students' perceptions of concept mapping and its effect on their understanding of the lesson.
 - (ii) An individual focused interview carried out to examine the students' understanding of fluoridation and their attitudes towards Government decision to add fluoride to public water as well as the effect of its introduction on their understanding of the lesson.

3.5.1 Validation and Reliability

All instruments were tested for validity and reliability to ensure that the study and the instruments measure what they purported to measure (Ogunniyi, 1992) and further what they would provide consistent results in two or more similar situations. To meet the requirements of these indices, all instruments were given to a panel consisting of ten teachers for scrutiny purposes. They were specifically required to assess: (i) the appropriateness of the level of language used to the target students; (ii) the clarity of the questions; (iii) whether or not there were any overlapping questions and (iv) whether or not the content was at the level of the students and measured what would be taught. Each question was rated by the panel from 1 – 5, i.e. 1 for a poor; 2, fair; 3, reasonable; 4, very good and 5, for an excellent item.

To improve the validity of each instrument the rating by the ten teachers on each item were randomly grouped into two groups the average score of one group was correlated with the other using the Spearman

Rank Difference formula (see Ogunniyi, 1992). For further validation of the study and instruments and also to test their consistency or reliability as well the time needed for the study, a pilot study was conducted on a neighbouring school. The data obtained from the pilot test formed the basis for the reliability values. The resulting correlation coefficients for the CAT and the three questionnaires based on perceptions of the concept mapping, the lesson (redox reactions) and experiments were 0.92, 0.82, 0.88 and 0.91 respectively.

During the pilot study all the teaching – learning tools and instruments developed for the study were administered over three weeks. These were the CAT, experiments, concept mapping, fluoridation and the questionnaires based on students' perceptions of the lesson, experiment and concept mapping and the interviews on fluoridation of public water supply. Likewise, the teacher kept journals of the classroom experience. This provided an insight into the shortcomings of the research design. For example, after the pilot study the items of the CAT and those of the questionnaire on students' perceptions of use of concept mapping were reduced due to the teacher complaining that they were too long and some statements not really relevant to the study. This also resulted in an increase in the number of members per group during experiments as three members meant having too many groups which were difficult to manage. This also afforded me the chance to practice teaching students how to develop their own concept maps as well as ability to manage the given time, which was not enough for the study. The validation of each instrument is further discussed below under the discussion of each instrument (section 3.5.2, 3.5.3, 3.5.4 and 3.5.5).

3.5.2 Chemistry Achievement Test (CAT)

The CAT was developed to measure the cognitive achievement of the students in the experimental and the control groups. An exemplary teaching-learning material was designed such that students negotiated meanings and constructed their own knowledge as they interacted with the learning material, (see Ramarogo, 1998). The CAT consisted of three parts, i.e. a multiple-choice question (MCQ) consisting of everyday life chemical reactions and two content -based questions derived from the syllabus. These questions were designed to elicit information about the students' chemical knowledge and reasoning.

In the first question, students were presented with a 12 item multiple-choice question on scientific phenomena well known in their everyday life. Students had to classify these phenomena by indicating the

nature of the reaction whether it was an acid-base (A), redox (B), precipitate (C) or dissociation (D). This type of question was chosen to reflect the new curriculum and forms about 25% of the final examination paper. Also, multiple-choice questions are a diagnostic tool for identifying students' conceptions about a given scientific subject (Soudani et. al., 2000). Treagust (1988) asserted that:

Such a test could be used as a diagnostic tool and helps the teacher to begin to address existing misconceptions based on earlier teaching and learning, prior to commencing the topic or that have occurred following teaching the topic.

The second question was a cloze test. Students were presented with a paragraph of how a chemical reaction occurs, transference of electrons and changes resulting from this. Ten spaces were left for the students to fill in from a list of 12 words provided for the purpose. The cloze test strategy enables students to focus on meaning and on how a text comes together (Puhl, 2000).

The third question consists of two parts. In part one, students were provided with four chemical reactions written in words. They were required to state what happens in each reaction and write the balanced chemical reaction. In part two, students were provided with two chemical reactions where they had to choose the redox reaction. Following this, they had to answer seven items based on the reaction chosen as the redox reaction. Unlike the first two questions the aim of this question was to provoke the students to explain the redox reaction.

As stated earlier, the CAT was administered by me as a pre-test and as a post-test (see Appendix D). This was meant to ensure that the students actually understood the questions. The students were told that the test was not for continuous assessment (CASS) purposes. This was to ensure that the students were relaxed while answering the test. This also eliminated the students' anxiety, which sometimes causes the students to fail the test even though they know the content.

To ascertain the face, content and construct validity of each instrument a panel consisting of ten experts was used. Their ratings were then subjected to Spearman Rank Difference Formula. The resulting correlation coefficient for the CAT was 0.87. Using results of the pilot study, the reliability of the final version of the CAT, was 0.81 using Kuder-Richardson 21 and based on Spearman-Brown split-half reliability, the reliability coefficient was 0.92.

3.5.3 Exemplary Instructional Material.

As indicated in chapter 1, the term “exemplary instructional material” should be construed in terms of its uniqueness not necessarily that it is excellent or better than other instructional material. To enhance students’ understanding of chemical reactions, exemplary instructional materials were used. These were (i) concept mapping for groups E and C₂, (ii) discussion of the debate on fluoridation of public water supply and (iii) experiments for all three groups. As mentioned earlier all the students involved in the study were introduced to the discussion on the controversial debate of the fluoridation of public water supply. After having been given information on the topic, group discussions followed by whole class discussions were held. The discussion focussed on (i) the students’ understanding of fluoridation; (ii) their opinions about fluoride in tooth paste preventing tooth decay; (iii) their perceptions of the effect of chewing or not chewing gum on tooth decay; (iv) the use or lack of use of calcium in tooth paste; (v) their perceptions of the logic of drinking fluoridated water to prevent tooth decay against their use of tooth paste and (vi) the relevance of fluoridation in the lesson.

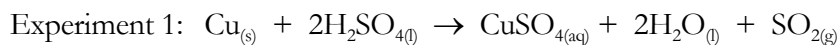
Concept mapping was used as an alternative teaching method, to teach redox reactions in groups E and C₂. Concept maps make clear to both the teacher and students the key ideas they must focus on for any specific learning task (Novak & Gowin, 1984). Thus students were also taught how to develop and read a concept map. They were introduced to the concept of mapping using the South African map. The students had to identify the different provinces, their capital towns as well the cities. They had to observe how these provinces, capital towns and cities were marked on the map. They also had to observe how the small towns were used as landmarks between the cities. The students had to also observe how the cities were connected by the national roads e.g. N1, N2, etc. After this exercise, in their groups, they had to develop a map of the route from their school through a township to the City of Cape Town. This exercise was meant for the students to be able to recognize the land marks (key concepts) as well as the connecting streets (linking words) thus be able to construct a concept map.

The students were then given notes on how to develop a concept map. They were also given three passages, which were later used to develop concept maps. Having chosen a passage on matter (see Appendix A₁) we used this information to develop a concept map of the passage. Later the students in groups had to develop concept maps of the other two passages (see Appendix A₂).

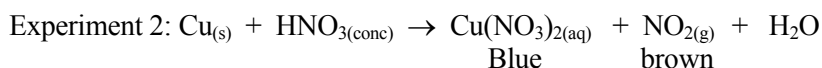
As mentioned earlier, in teaching redox reactions the key concepts and their meanings were written on the OHP as black board summary. From this summary, students had to develop concept maps in groups. These they presented to the other students who had to add or point out shortcomings of the map and eventually allocate the group marks. This later enabled students to develop concept maps for revision.

Two experiments were done by all the students, involved in the study before responding to a worksheet for each experiment. The use of experiments in this study was inspired by the fact that the grade 10, 11 and 12 Science Curriculum in South Africa places great emphasis on practical activities as tools of learning science. The worksheets developed were thought provoking and were meant to assess the students' understanding of chemical reactions. A Predict-Observe-Explain (POE) technique adopted by Mthembu (2001) was used in all the two experiments. The Predict, Observe and Explain (POE) method originated by White & Gunstone and described in details by Ebenezer & Connor (1998) was adopted in the hands-on experiments. In the POE method, students are confronted with an experimental task and then asked to predict, observe and explain what happens when experiment is carried out.

According to Mthembu (2001) this technique enables teachers to diagnose students' understanding of chemical concepts and promotes meaningful learning. Boo (1998) cited the studies of Frazer, Gabel, Gabel, Sherwood & Lythcott, which showed that students could produce correct answers to various kinds of problems, including those involving chemical reactions while lacking an adequate understanding of the underlying chemical concepts. He further argues that students can appear successful without achieving real understanding. This further emphasises the usefulness of the POE technique in conducting experiments. The use of the POE method should enable the teacher to have a clear understanding of the students' prior knowledge, their level of understanding of the concepts already taught as well as identifying their misconceptions if there are any. The students involved in this study had to answer all the prediction questions before doing the experiment. During the experiments, they had to write the observed events. Finally, they had to compare their predictions with the actual answers. The first experiment was a teacher demonstration of the reaction between copper and sulphuric acid.



The second experiment (based on the formula below) was done by students in groups of five, using the same method of predict, observe and explain used in experiment 1.



In experiments 1, before the reaction occurred, the students were asked to identify and note: (i) the colours of each element and the state in which it occurred in each reactant; (ii) the colours and state of each reactant. This enables them do easily identify the products formed, especially if there were any significant colour changes. After the reaction, they have to observe: (i) what happened in the reaction; (ii) any significant smell and gas produced and (iii) any colour changes of the products, i.e. solution. From these observations they had to identify the products formed and explain how they were formed with reference to two half reactions, oxidation and reduction reaction.

In experiment 2, before the reaction occurred the students had to do the same thing they did in experiment 1. After the reaction, the students had to observe if there were any colour changes of the products, i.e. solution as well as the iron and any other observable change. From these observations, they had to identify the products formed and explain how they were formed with reference to two half reactions, oxidation and reduction reaction.

In doing the experiments, the students had to work in groups. When the students worked in groups they were offered the opportunity to verbally interact, thus sharing their understandings and the knowledge they had acquired. Group work can improve the quality of students' responses to problems that require their ability to think. The group setting also affords one an opportunity to learn to contribute and receive ideas, defend his/her ideas and accept and go along with other people's ideas (Ramorogo, 1998). According to Reid and Yang (2002) letting the students work in groups gives them the opportunity for their previous knowledge and working memory space to be combined. Reid & Yang (2002) further asserts that the number of participants in a group should be determined. They cited Grant (1978) and Heller & Hollabaugh (1992) as suggesting three students per group as reasonable for optimal interaction. In a group of two members, a student might feel embarrassed with an uncooperative partner. At the same time, if the group is too big, some students might not participate. However, having worked with three students per group during the pilot study, for the main study, students were grouped into fives with specific roles to play. Working with three students per group, was time consuming as that meant having about 14 to 16 groups per class and thus being unable to observe and assist them all as effectively as one would have liked.

3.5.4 Students' Questionnaires (SQ)

A questionnaire is a more convenient and easy way of collecting data whereby a respondent is given a form with questions or statements, to be filled. Ndagi (1984) sees a questionnaire as similar to an interview as both attempt to get the feeling, attitudes, beliefs, experiences or activities of respondents. In this study,

four questionnaires were administered. Like the CAT, the questionnaires underwent the process of validation and reliability. To ascertain the face, content and construct validity of each questionnaire, a panel consisting of ten experts was used. Their ratings were then subjected to Spearman Rank Difference Formula. The resulting correlation coefficients for the three questionnaires based on perceptions of the concept mapping, the lesson (redox reactions) and experiments were 0.82, 0.88 and 0.91 respectively. At the end of the three weeks of the study, students were given the questionnaires and supervised by me while filling them up. This was to ensure that they understood them and I could clarify any statement they did not understand.

A plethora of classroom studies reported in the literature has been based on the perspectives of researchers and teachers without considering those of the students. In this study, students' perspectives have been taken into cognisance to provide a comprehensive picture of the classroom interactions. Thus, three questionnaires examining the students' perceptions of the lesson were administered to determine their viewpoints and experiences during the study.

The first student questionnaire sought to determine their perception of the lesson on redox reactions (see Appendix E). The questionnaire consists of three main items, ranging from how the lesson was presented to their understanding of the concepts involved. The students had to agree or disagree with each item. After every statement a space was provided for the students to explain why they agreed or disagreed with the statement. This was to ensure that they gave more input on how the lesson was conducted as well as express their own perspectives on the teaching – learning process.

The second student questionnaire was based on the experiment consisting of 12 items (see Appendix F), which they had to rank from three to one. A rank of 3 implies strongly agree, 2 for agree and 1 for disagree. The first three items were based on their attitude towards the worksheet. The language might have affected their attitudes, clarity of the items as well as their understanding of the concepts involved. Although I was there to assist the students with filling in of the questionnaire, some were shy to ask any questions. The second three items were based on doing the experiment and how it had affected or not their understanding of the lesson. The third three items were based on the effect of group work on their performance as well on their ability to answer the items on the worksheet. The last three statements were based on the advantages and disadvantages of using a worksheet. A space was provided for students to add any comments, which they felt should have been provided in the questionnaire.

The third student questionnaire had 12 items based on concept mapping (see Appendix G). To explore the students' perceptions of the use of concept mapping, an adapted version of a questionnaire on the level of agreement for selected students statements on learning developed by Roth (1994) was used. Roth's questionnaire had 14 statements. I initially chose all the 14 and included negative statements for others to make 22 statements. After the validation process, they were reduced to 15 as some of the experts felt some items were unnecessary, others too vague and some a repetition. These 15 items, after piloting, were further reduced to 12 as students find them vague and confusing. Roth had grouped these items into four, but only two of these groups were used in this study as others did not apply to the study, namely: (i) clarifying and simplifying and (ii) making sense. These items were rated 3 to 1 by the students. In other words, 3 stood for strongly agree (SA), 2 for agree (A) and 1 for disagree (D).

3.5.5 Interviews

The origins of the interview go back to the early Greek and Roman times. It was later perfected by Piaget and his colleagues in Switzerland (Novak & Gowin, 1984). Over the years a lot of researchers have criticised and have tried to perfect the interview technique. Interviews can be used for different purposes depending on the approach used. Irrespective of the approach, interviews are used to collect information in a face-to-face contact. According to Ndagi (1984) it is used when a researcher wants to obtain reliable and valid information in the form of verbal responses from respondents in order to confirm or reject hypotheses. To further probe the students' perceptions of exemplary teaching and learning, two interviews were conducted, one a non-directive based on students' perceptions of the concept mapping and the other a focussed interview based on the students' understanding and perceptions of the drinking water being fluoridated.

These interviews also went through a vigorous validation process. They were given to a panel of ten experts for face, content and construct validation. Using the Spearman-Brown correlation reliability formula, the reliability coefficient for the focus questions of the interview on students' perception and understanding of fluoridation of public water supply was 0.81. The interview on concept mapping had to focus and address three questions. For these focus questions, I had to explain to two of the panel members what my expectations were and what purpose they were going to serve.

Since students often talk so quickly, writing down their responses was impossible, so I used an audio tape recorder (ATR) to capture their responses. To put the students at ease, I explained why I was using the

ATR and that anything they were unhappy about will be removed from the tape. In starting each interview, I explained openly and clearly to the students what I hoped to achieve (Bell, Osborne & Tasker, 1997). This I found helpful in facilitating and steering the interview in the right direction.

3.5.5.1 Interview on Students' Perceptions of Concept Mapping (ISPCM)

The first interview was used to explore the students' perceptions of the use of concept mapping and how they thought it affected their conceptual understanding of chemical reactions. An in-depth non-directive interview was selected for the study as it gives respondents the opportunity to speak freely and fully. The students' argument had to focus and address the following questions:

- (i) Are you able to use it on your own, either in science or any other subject?
- (ii) Has its use made any difference to your understanding of this topic compared to previous topics?
- (iii) Will you recommend its use in other topics as well as to other teachers?

Students were encouraged to speak freely and even use their own mother tongue so that they could express themselves fully. This was a group interview, involving nine students, three from each class. I concur with Ramarogo (1998) when he asserts that using group interviews is :

... necessary because of not only the obvious cost of time and materials spent interviewing individuals, but also because interviewing students in a group helps recreate the ideas about classroom experiences better than when individuals are interviewed (p.135).

He further asserts that group interview reduces interview stress on the participants. The question imposed on the students was based on how they viewed the use of concept map during the lesson. I listened and only interjected occasionally to keep the respondents talking, redirect the interview as well as round off the interview.

3.5.5.2 Interview on Students' Understanding of Fluoridation (ISUF)

Fluoridation of public water supply was introduced to all the students in the study as an example of a chemical reaction. This was also meant to make the students aware of the ongoing controversial debate around fluoridation of public water supply. The advantages and disadvantages, as pointed out by both proponents and opponents of fluoridation, were discussed and all students received photocopied notes, internet material as well as news paper cutting on the topic. The aim was to ensure that each student had adequate information about the surrounding fluoridation. The six questions posed for the discussion relate to:

(i) the students' understanding of fluoridation; (ii) their opinions about fluoride in tooth paste preventing tooth decay; (iii) their perceptions of the effect of chewing or not chewing gum on tooth decay; (iv) the use or lack of use of calcium in tooth paste; (v) their perceptions of the logic of drinking fluoridated water to prevent tooth decay against their use of tooth paste and (vi) the relevance of fluoridation in the lesson.

The discussion was later followed by an interview aimed at exploring the students' understanding of fluoridation and how the discussion of the topic affected their understanding of chemical reactions. Initially, five students were to be interviewed but only two of these turned up for the interview. Since the study around fluoridation is a case study, I find interviewing two was justifiable as a case study can even be conducted on one student. A case study research lies on delimiting the object of study, the case. According to Merriam (1988) the case could be a person such as a student, a teacher, a principal, a programme, a group such as a class or a school.

The interview on fluoridation as an individual focussed interview, focused on the discussion about fluoridation only. The students were allowed to express themselves freely and completely using any language they were comfortable with but along the lines outlined by the interviewer.

3.6 DATA ANALYSIS

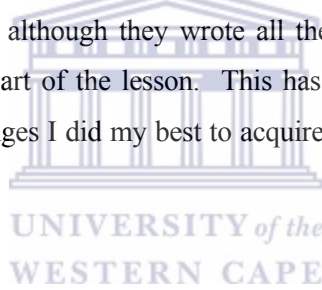
Due to the eclectic approach used in both the teaching of the lessons and the collection of the data, the data were analysed using both qualitative and quantitative descriptions (Ramorogo, 1998).

For quantitative data analysis, descriptive statistics used included mean, standard deviation and percentages. The inferential statistics used were t-test and the Analysis of Variance (ANOVA). According to Patton (1989) quantitative measures are succinct parsimonious and easily aggregated for analysis. Also, they are systematic, standardised and easily presented in a short space. It is for the same reasons that quantitative analysis was used to explore certain aspects of the data collected.

The qualitative data were obtained from listening to the students' responses at the interview, their responses and comments to the questionnaires and explanations given for responses on the CAT. The responses obtained from these two sources were analysed in terms of qualitative descriptions in form of excerpts derived from the students' statements on the issues relating to chemical reaction and the effectiveness or otherwise of concept mapping as well on fluoridation.

3.7 LIMITATIONS OF THE STUDY

This study was limited to one school which was more convenient for the researcher as she had to work with her own students and not ask for permission except the students, the head teacher and the head of department. Under normal circumstances this could pose a problem of contamination of treatment from the others, but due to the type of students I teach the chances of contamination of data are rare. For the pilot study having to analyse only 12 subjects makes it difficult to really generalise as the spread of these subjects does really represent that of the main study. The conducting of the study on grade 12s of a finishing school, who have only six months to finish the syllabus, left me with only three weeks to collect data. This meant having to try and short circuit other tools and minimise questions and statements. This might impact on the amount of data that could be collected. This has also led to the exclusion of some of the instruments, as they required more time. The timing for data collection which was in the third term was also a limitation in that the students were already anxious about writing their trial and final examinations. Some students were eager to start with the revision for their matric examination and did not come. Also, the time the study was conducted fell in the windy and raining winter season. Hence, students' attendance was generally poor. This implies that some of the students although they wrote all the tests and answered the questionnaires, might have been absent during a big part of the lesson. This has also caused a reduction on response of questionnaires. Despite all these challenges I did my best to acquire the necessary data to ensure the success of the study.



3.8 ETHICAL ISSUES

Obviously there are ethical issues on any research endeavour involving people or animals. The quasi-experimental design used in the study implies subjecting a certain group to a particular teaching strategy while another group is exposed to another strategy or denied one activity or the other. To achieve equity and fair play all the students in the three groups were exposed to the exemplary material. The only difference between the experimental (E) and the true control group (C_1) is that while the former was exposed to concept mapping the latter was taught the expository instructional approach. Besides, permission was sought from the Headmaster, the Head of Science Department and students themselves. All the students without exception willingly participated in the study, particularly as it related to their class work and their experiences in the impoverished Cape Flats where they came from. Also, for anonymity purposes the name of the school where the study was conducted and the students' names have not been disclosed in this report.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In line with Learning Outcome 3 (LO3) of the Revised National Curriculum Statement for the Natural Sciences to make science relevant to the students' life worlds (see Department of Education, 2002), the purpose of this study was to determine grade 12 students' conceptions of chemical reaction. As explained in chapter 3, the students involved in the study were matriculation (matric) failures attempting to improve their performance in preparation for work or further studies. Using fluoridation as a practical example of chemical reactions it was assumed that a controversial topic such as fluoridation might arouse the intellectual interest of these poorly motivated matric failures. Also, concept mapping was used as an instructional strategy to arouse the interest of the students in chemistry. The use of concept mapping an exemplary or contextualised materials along carefully conducted experiments have been found to: (1) enhance students' understanding of science and (2) motivate students' interest in socially relevant scientific topic (Hesse & Anderson, 1992; Novak & Gowin, 1984; Roth, 1994; Soudani et.al, 2000; Stavridou & Solomonidou, 1998).

The purpose of the study was to:

- Explored the students' knowledge of concepts related to chemical reactions.
- Examined the effectiveness or otherwise of concept mapping in creating the students' awareness about chemical reactions and in solving related problems.
- Find out if the exemplary materials (i.e. highly contextualised and relevant instructional material) helped to create the students' awareness about the concept of fluoridation, its benefits and risks to human kind.

As fluoridation and experiments were introduced to all the students, only concept mapping constituted the distinct treatment between the experimental (E) and the true control group (C₁). As indicated in chapter 3, C₂ was included to control for possible pre-test effect.

In pursuance of the purpose of the study, eight instruments, described in chapter three, were administered to collect the data. The data collected were then analysed quantitatively and qualitatively. The instruments used to gather the data are: the Chemical Achievement Test (CAT); a worksheet on two experiments; three questionnaires; and two student interviews. The focus of this chapter is to analyse the findings in terms of the research questions raised in chapter one and as depicted in the purpose above.

The data collected at the pre- and post-test stage were clustered around the students' gender and career interests. The statistical analysis was performed in order to determine the effect of the treatment, namely, concept mapping exemplary learning material and selected experiments on the students' understanding of chemical reactions. The qualitative data obtained from the questionnaires and interviews were carefully analysed and presented in form of excerpts to corroborate the quantitative data. The results based on this analytic procedure are presented in the following sections.

4.2 CHEMISTRY ACHIEVEMENT TEST (CAT)

As mentioned in chapter three, the CAT consisting of 33 items, were grouped into three major themes: everyday life reactions; chemical bonding and chemical reactions. Also, as explained in chapter three, the pre- and post-test CAT were administered to the Experimental Group (E) and Control Group 1 (C_1) while Control Group 2 (C_2) (controlling for the pre-test effect) received only the post-test. As can be seen in Table 4.1 each group, with the exception of C_2 , had an equal number of males and females to reflect the population of each group with respect to gender. As indicated earlier, the analysis of the data obtained from the CAT aimed at determining the effect of the treatment: concept mapping, exemplary materials and experiments on the students' conceptual understanding of chemical reactions.

Table 4.1: Frequency of Students Involved in Each of the Groups in the Study

Groups	Male	Female	Total
E	15	25	40
C_1	15	25	40
C_2	15	26	41
Total	45	76	121

4.3 Students' Conceptions of Chemical Reactions and Chemical Change.

4.3.1 Pre-test Results

The mean is a useful statistic for measuring the concept of average in a distribution. It measures the values of each score in a distribution and forms an important component in interpreting central tendency. However, it is very sensitive and can be easily affected by extreme scores in a distribution. Hence, for ease

of reference and to avoid interpretation errors, it is better to convert mean scores into percentages (Ogunniyi, 1984, 1992). Based on the percentages mean scores, it is evident that, with the exception of females in C_1 , less than one fifth of the students held valid conceptions of chemical reactions at the pre-test stage (Table 4.2).

Table 4.2: Pre-test Scores Obtained by Students on the CAT

Gender	Group	N	Mean	Mean %	SD
	E	40	6.40	19.4	2.55
	C_1	40	6.30	19.1	2.44
$t_{obs} (0.18) < t_{crit} (1.99)$					
Female	E	25	6.48	19.6	2.62
Male	E	15	6.33	19.2	2.41
$t_{obs} (0.03) < t_{crit} (2.02)$					
Female	C_1	25	6.76	20.5	2.41
Male	C_1	15	5.6	17.0	2.33
$t_{obs} (0.23) < t_{crit} (2.02)$					

Judging by the mean percentages of 19.4 % and 19.1 % for E and C_1 respectively, it is obvious that they are very low. However, the relatively low standard deviations of 2.55 and 2.44 for E and C_1 respectively, are indicative that the two groups were very much comparable. The t-test for the pre-test scores for both groups stood at 0.18. This value is less than the critical value required to reject the null hypothesis, namely, 1.99. Since the obtained value is less than the critical value, we cannot reject the null hypothesis suggesting no significant difference between the pre-tests of the E and the C_1 groups. This further reinforces the idea of comparability of the two groups at the pre-test stage. In this regard, and based on the rigours of the research design, any difference at the post-test stage, if any, can rightly be attributed to the treatment.

Based on the t-test scores for the pre-test, there was no significant difference between the girls and the boys. The mean percentages of both genders were very close, i.e. about 20 % and 19.2 % for the girls and boys respectively, thus indicating the comparability of the two gender groups. Also, the mean percentages for C_1 were 21 % and 17 % for the females and the males respectively. This suggests that the females had a slightly better understanding of the topic than the boys. However, when the score were subjected to t-test analysis, the difference between the males and the females for E and C_1 respectively were 0.03 and 0.23. These are less than the critical value of 2.02 needed to reject the null hypothesis at $p = 0.05$. Thus, the differences between the males and females in both groups are not statistically significant at the pre-test stage.

4.3.2 Students' Performance Based on Three Major Themes at the Pre-test Stage

The students' achievement in terms of percentage performance for the three themes (everyday life reactions, chemical bonding and chemical reactions) are depicted in Table 4.3. Further, for ease of interpretation and comparison, the percentages of responses were arranged in a descending order.

A close examination of this table reveals that the students' pre-test scores per item for the experimental group (E) and the control group 1 (C_1) range between 6 % to 36 % and 6 % to 39 % respectively. The overall average performance on the instrument was about 19 %. None of the items under chemical reactions, D, I, J and K for both groups as well as items F and G for group E were correctly answered by the students. Item A, under the Everyday Reactions Theme, i.e. the reaction between Hydrochloric acid (HCl) and Sodium Chloride (NaCl) attracted the lowest percentage of the correct responses, i.e. about 8 % for E and 3 % for C_1 . This is indicative of the students' poor conceptions of what happens when an acid reacts with a salt. One would have assumed that the students would be familiar with such reactions right from grade 8 but this has not been the case. Item F, from the theme chemical bonding, "what transference or acceptance of electrons depend on", also attracted a very low percentage of the correct responses, i.e. about 8 % for E and 5 % for C_1 . The students' responses to this item are indicative of their poor conception of how atoms bond. Most of the students gave responses which were far fetched e.g. valency, oxidised, electrons, protons, more positive, but mostly valency and electrons. The items, which attracted the highest percentage of correct responses of 50 %, under the theme chemical bonding were A, what are exchanged or shared during a reaction, for E and H, what the phenomenon electron exchange is, for C_1 . This suggests that the majority of the students have an idea of the mobility of electrons introduced in grade 10.

The overall students' performance per theme, for E and C_1 respectively at the pre-test stage, were as follows:

- everyday reactions were about 20 % and 18 %;
- chemical bonding were about 19 % and 23 %; and
- chemical reactions were about 9 % and 8 %.

This shows that while E performed slightly better than C_1 on the Everyday Life Reaction and the Chemical Reactions Theme, C_1 performed slightly better than E on the Chemical Bonding Theme at the pre-test stage. But as indicated earlier the differences were not statistically significant. Later on we shall see whether or not the intervention made any difference to their achievement. But before doing this, it is necessary to discuss the students' performance in greater details.

Table 4.3 Percentages of Correct Responses to Each Item of the CAT at the Pre-test

Stage					
Items	Summary of each item	E (%)	Items	Summary of each item	C ₁ (%)
EVERYDAY LIFE REACTIONS					
C	Rust of iron blade	33	C	Rust of iron blade	33
D	Petroleum burning	30	B	Zinc blade in hydrochloric acid solution	30
I	Rubbed ebonite rod	28	E	Metal corrosion	25
E	Metal corrosion	25	G	Nail in a bleach	23
B	Zinc blade in hydrochloric acid solution	23	I	Rubbed ebonite rod	23
K	Respiration	20	K	Respiration	23
H	Sodium chloride in water	18	D	Petroleum burning	18
F	Apple discolouring	15	J	Cleaning of brass with brasso	13
J	Cleaning of brass with brasso	15	L	Photosynthesis	13
G	Nail in a bleach	13	F	Apple discolouring	10
L	Photosynthesis	13	H	Sodium chloride in water	10
A	Hydrochloric acid and sodium chloride	8	A	Hydrochloric acid and sodium chloride	3
Subtotal	Average %	20		Average %	18
CHEMICAL BONDING					
A	What are exchanged or shared during a reaction?	50	H	What the phenomenon electron exchange is?	50
H	What phenomenon electron exchange is?	33	A	What are exchanged or shared during a reaction?	45
C	Which ion is formed when a + ve ion loses electrons?	25	G	The ratio with which reactants combine depends on...	30
G	The ratio with which reactants combine depends on...	25	E	Which ion is formed when a – ve ion loses electrons?	28
B	Which ion is formed when an atom loses electrons?	15	I	Reactant transferring electrons is ...?	18
D	Which ion is formed when an atom gains electrons	10	J	Reactant accepting electrons is ...?	18
E	Which ion is formed when a – ve ion loses electrons?	10	B	Which ion is formed when an atom loses electrons?	15
I	Reactant transferring electrons is ...?	8	C	Which ion is formed when a + ve ion loses electrons?	28
J	Reactant accepting electrons is ...?	8	D	Which ion is formed when an atom gains electrons	13
F	What does the transference/acceptance of electrons depend on?	8	F	What does the transference/acceptance of electrons depend on?	8
Subtotal	Average %	19		Average %	23

Table 4.3 continues

CHEMICAL REACTIONS					
B	Zinc in hydrochloric acid?	28	B	Zinc in hydrochloric acid?	35
E	Identify redox reaction from the following reactions: (a) $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$; (b) $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$	18	E	Identify redox reaction from the following reactions: (a) $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$; (b) $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$	15
H	Write chemical equation for the following word reaction: Copper and conc. nitric acid making copper nitrate, water and nitrogen dioxide		H	Write chemical equation for the following word reaction: Copper and conc. nitric acid making copper nitrate, water and nitrogen dioxide	15
A	Iron in copper sulphate?		A	Iron in copper sulphate?	13
C	Copper in silver nitrate?		C	Copper in silver nitrate?	8
F	From the reactions in E, identify oxidizing the agent	-	F	From the reactions in E, identify the oxidizing agent	3
G	From the reactions in E, identify the reducing agent	-	G	From the reactions in E, identify the reducing agent	3
D	Copper in sodium chloride?	-	D	Copper in sodium chloride?	-
I	From the reactions in H, identify and write oxidation 1/2 reaction	18	I	From the reactions in H, identify and write oxidation 1/2 reaction	-
J	From the reactions in H, identify and write reduction 1/2 reaction	18	J	From the reactions in H, identify and write reduction 1/2 reaction	-
K	From the reactions in I and J, write net-reaction	15	K	From the reactions in I and J, write net-reaction	-
Subtotal	Average %	9		Average %	8

NB: Percentages have been rounded off

4.3.2.1 Everyday Life Reactions

Chemical reactions do not occur only in science laboratory. They also occur in everyday life although they are not generally comprehended as such. If science teaching aims at helping students conceive the natural world and phenomena in a more scientific way, the teacher needs to find out if his/her students really use the knowledge gained at school to explain the physical and chemical phenomena that occur in everyday life (Hesse & Anderson, 1992; Saudani et al., 2000; Stavridou & Solomonidou, 1998).

In the Everyday life Reaction Theme, the students were presented with a multiple-choice question with 12 reactions that happened around them in their everyday life. They were required to classify these reactions as either, acid-base, redox, precipitation or dissociation reactions. These included reactions in both chemistry and biology. The multiple-choice question (MCQ) was administered to assist me clarify the nature of the students' understanding and the difficulties they encountered not only with redox reactions, but also with

other interrelated concepts. The results on the Everyday Life Reactions Theme, per item, are represented in Table 4.3. The students' performance on these items indicates that the two groups have very little understanding of these commonly encountered reactions in their homes. Their correct responses range between 7 % and 33 % for E and 3 % and 30 % for C₁.

As mentioned earlier, students were required to identify these reactions as: A: acid-base; B: redox; C: precipitation and D: dissociation reaction. The sequence of the correct scores on the Everyday Life Reaction Theme is as follows:

- Item C, deals with rust on iron blade. Here, students in both E and C₁ obtained the highest score of 33 %. Almost two thirds of the students identified the item as the acid-base reaction, probably because of the presence of the acid.
- Item D, which is concerned with petroleum burning, ranked as 2 and 7 for E and C₁ i.e. 30 % and 18 % respectively. This could be due to oxidation reaction learnt in organic chemistry. Quite a number of the students identified this reaction as D, a dissociation reaction, probably because of their prior organic chemistry knowledge where this reaction results in the formation of carbon dioxide (CO₂) and water (H₂O). To the students (designated as S₁, S₂, S₃ etc) petroleum splits into CO₂ and H₂O. The following responses might illustrate their thinking trends:

S₁: Petrol in a car splits up into CO₂ and steam, so it dissociates (E)

S₁: Petroleum burning dissociates into gas and steam (C₁)

- Item I, dealing with a rubbed ebonite rod, ranked three for E and five for C₁ i.e., 28 % and 23 % respectively. During the discussions some of the students recognised the removal of electrons from the ebonite rod thus guessing it to be redox reactions, probably based on their prior knowledge from previous grades.

S₂: When ebonite rod is rubbed, electrons are removed into the cloth, that can be redox or something but not A, C or D (E).

- Item E, dealing with metal corrosion, ranked four and three for E and for C₁ respectively. Both groups scored 25 % in this item. Many students identified this reaction as a precipitation. Students believed that during rusting a deposit is formed, thus opting for C, precipitation. For instance according to

S₂: Metal corrosion forms an extra layer on the metal, this layer is precipitation (C₁)

- Item B, dealing with zinc blade put in hydrochloric acid solution, ranked five and two for E and for C₁ respectively, attracting 23 % and 30 % of the correct response. Students might have deduced their

answers from the presence of metal as redox reactions are always introduced to students using reactions between metal and acid, (see Saudani et al., 2000). But some of the students regarded this reaction as A, acid-base reaction.

- Item K, dealing with respiration, ranked six for both E and C₁. The scores are 20 % and 23 % respectively. Several students identified this reaction as dissociation. To

S₃: Respiration means breathing in oxygen, thinking about it, it can't be A there is no acid, not C no solid is formed, not redox there is no chemical, so dissociation (E).

- Item H, dealing with sodium chloride in water, ranking seven and 11 for E and C₁, i.e. 18 % and 10 % respectively. For the NaCl in H₂O, many of the students identified it as an acid-base reaction. Students erroneously identified NaCl as a base and H₂O as an acid.
- Item F, dealing with the apple discolouration, ranked eight and 10 for E and C₁, i.e. 15 % and 10 % of E and C₁ gave the correct responses. Several students identified this as a precipitation, probably because they thought that the discolouring was a deposit, in which case precipitation seemed the correct answer. An example in this regard was made by S₃ below:

S₃: Bacteria form a deposit, precipitate, on the apple when cut changing its colour to brown and old (C₁).

- Item J, dealing with the cleaning of brass with brasso, ranked nine and eight for E and C₁, i.e. 15 % and 13 % respectively. To a number of students cleaning of brasso is dissociation.
- Item G, dealing with a nail in water bleach, ranked 10 and four for E and for C₁, i.e. 13 % and 23 % respectively. Although this is a common household oxidant, many students classified it as an acid-base reaction, probably because of the presence of a metal.
- Item L, a biological concept dealing with photosynthesis, ranked 11 and nine for E and C₁ respectively, attracting 13 % of correct responses for both groups. Many students were unable to classify this item, claiming that it is not a reaction. For example:

S₄: It is not all of these. It is not a reaction, not a chemical (E).

S₄: Photosynthesis is biology not physics and A, B, C and D are physics, none of the above (C₁).

- Item A, dealing with hydrochloric acid and sodium chloride, attracted the lowest score of the correct response, 8 % and 3 % respectively from E and C₁. The majority of the students selected option A, namely acid-base reaction. They argued that HCl is an acid and NaCl a base.

S₅: This is a reaction of an acid, HCl and a base salt, NaCl, so it is A (E).

S₅: Most sodium salts are bases and HCl is an acid, and the reaction is acid and base (C₁).

Students' responses to items H and A clearly indicate that they gave quick answers without paying too much attention to the question (see Gil-perez & Carrascosa, 1990). Since these reactions have HCl and the other one has Na they probably assumed that the two substances represent acid-base reactions.

4.3.2.2 Chemical Bonding

Chemistry educators, (i.e. teachers and lecturers) would generally agree that understanding the concept of chemical bonding is fundamental in the learning of chemistry. Such understanding is essential to the learning of chemical reactions. Poor understanding of this concept will impede further learning of any other chemistry concept. Thus the inclusion of chemical bonding adds value to this study. The students' understanding of chemical bonding was further explored through a cloze test. The use of a cloze test was meant to test the students' reading ability as well as their understanding of the concepts summarised in the text. The readability analysis for this theme based on Bormuth's (1968) readability index is presented on Table 4.4 below.

Table 4.4: Students' Pre-test Performance on Chemical Bonding Theme Using the Cloze Test

Scores %	E n (%)	C ₁ n (%)	Description
90-100	-	-	Independent Level
80-89	-	-	Instructional Level
75-79	-	-	
60-74	1 (2.5 %)	2 (5 %)	Frustrational Level
50-59	2 (5 %)	2 (5 %)	
40-49	9 (22.5 %)	4 (10 %)	
30-39	4 (10 %)	13 (52 %)	
16-29	10 (25 %)	8 (32 %)	
0-15	14(35 %)	11 (44 %)	
Total	40	40	

n : number of students; (%) : percentage of students

N.B: Independent Level = students can read and comprehend;

Instructional Level = students can only read and comprehend if assisted by the teacher;

Frustrational Level = students cannot read or comprehend and might fail to show progress even with the teachers' assistance.

Using Bormuth's readability category (see Tesfai, 2001), all the students from both groups, E and C₁, at pre-test stage fall in the frustrational level. A close examination of this table shows that the students' performance ranges from 0 % to 74 % for both groups. This suggests that all the students at pre-test stage were at the lower scale of the readability index and are comparable and that they all had difficulty reading and comprehending the text. This implies that all the students exposed to the pre-test, have a poor understanding of the concept, chemical bonding and hence, chemical reactions. This also implies that these students might fail to show progress even with the teacher's help (see Tewolde, 2001). Reading ability of the students will be explored further at post-test stage.

For further comparison of the two groups in the Chemical Bonding Theme, the results obtained by the students in this theme presented in Table 4.3 are examined. This table reveals that group C₁ outperformed group E in all the items except items A, C and F. Group E's and C₁'s overall performances on this theme were 19 % and 23 % respectively. The low scores obtained by the students in this theme further suggest that they had a poor understanding of the concept. Since they were given words to fill in, one would have expected them to achieve better results. This further confirms the results obtained from the Bormuth's (1968) readability scale as shown in Table 4.4 above. Items in this theme were further analysed using the scores obtained per item as shown in Table 4.3. The sequence of correct responses on the Chemical Bonding Theme in a descending order is as follows:

- Item A, dealing with finding out if the students knew what are exchanged or shared during a reaction, attracted the highest correct responses, ranking one and two i.e. 50 % and 45 % for E and C₁ respectively. This could be attributed to their prior knowledge based on what they learnt in the lower grades chemical bonding stresses the mobility of electrons. One would assume that all the students would make the correct responses to this item but that was not the case. The students displayed all forms of erroneous conceptions such as redox, reduced, negative, etc, as answers instead of electrons. The excerpts below vividly reflect their conceptions:

S₁: During a reaction redox is shared or exchanged (E).

S₁: during a reaction reduced is shared or exchanged (C₁).

- Item A is followed by item H. Item H is concerned with finding out if the students knew what the phenomenon of electron exchange is. Their responses ranked two and one for E and C₁, i.e. 33 % and 50 % respectively. The students, who gave incorrect responses to item A, got this item wrong as well. The irrelevant responses include among others, proton, more negative, valency, electronegativity and so on. These type of responses indicate the students' lack of understanding of redox reactions. The excerpts below are representative:

S₂: This phenomenon is known as electronegativity (E).

S₂: This phenomenon is known as valency (C₁).

- Item C, which comes after H, is concerned with finding out which ion is formed when a positive ion loses electrons. The correct responses made by E and C₁, ranking three and eight were 25 % and 13 % respectively. Some of the erroneous responses given by students included the following:

S₃: If the reactant that transfers electrons was a positive ion, it will become a proton ion (E).

S₃: If the reactant that transfers electrons was a positive ion, it will become a oxidising ion (C₁).

- Item G coming next to C, is concerned with finding out whether the students knew what the ratio with which reactants combine depend upon. The correct responses, ranked four and three for E and C₁ i.e., 25 % and 30 % respectively. In assessing the students' responses there was a lack of understanding and very few responses can be classified as misconceptions. The following excerpts attempt to illustrate this point:

S₄: The ratio with which reactants combine depends on their redox (E).

S₄: The ratio with which reactants combine depends on their protons (C₁).

- Item B, ranking next to G, attempts to find out whether students knew which ion is formed when an atom loses electrons. The correct responses ranking five and seven for E and C₁ were 15 % for both groups. The students' poor conception of this reaction is exemplified as follows:

S₅: If the reactant that transferred electrons was an atom, it will become a redox ion (E).

S₅: If the reactant that transferred electrons was an atom, it will become a negative ion (C₁).

- Item D, attempting to assess whether students knew which ion is formed when an atom gains electrons, ranked six and nine for E and C₁ i.e., 10 % and 13 % respectively. Some of their erroneous responses are:

S₆: If the reactant that accepted electrons was an atom, it will become a reduced ion (E).

S₆: If the reactant that accepted electrons was an atom, it will become a proton ion (C₁).

- Item E, dealing with finding out whether students knew which ion is formed when a negative ion loses electrons, ranked seven and four for E and C₁ i.e., 10 % and 28 % respectively. The following excerpts illustrate some of the erroneous responses given by the students:

S₇: If the reactant that accepted electrons was a negative ion, it will become a electronegative ion (E).

S₇: If the reactant that accepted electrons was a negative ion, it will become a oxidised ion (C₁).

- Items I and J, are concerned with finding out whether students knew what happens to the reactant that transfers or accepts electron respectively. Students scored 8 % and 18 % for both E and C₁ respectively ranking eight and five. These are some of the students' erroneous responses:

S₈: The reactant that transfers electrons is proton (E).

S₈: The reactant that accepts electrons is electronegativity (C₁).

- Item F, dealing with finding out whether students knew what transference or acceptance of electrons by a reactant, depend on, ranking the lowest for both E and C₁, attracted 8 % and 5 % of the correct responses respectively. The following excerpts reflect their erroneous conception of this reaction:

S₉: Which reactant will transfer or accept electrons, depends on their redox (E).

S₉: Which reactant will transfer or accept electrons, depends on their electron (C₁).

An assessment of the students' responses to various items seems to show that in most cases the students were guessing or just filling in the blank spaces whether or not their responses made sense. This is a further indication of their poor reading skills and understanding of the concepts. On items F, I and J, dealing specifically with redox reactions, they obtained the lowest scores. Since the redox reactions are first introduced in grade 10, one would expect the students to have developed a better understanding of the concept. With further enquiry about their poor performance on these items, it became clear that the students were not adequately introduced to the topic in grade 10. In fact, many of them claimed that they were doing redox reactions for the first time. Considering their low morale in general, it might well be that they had actually forgotten what they learned two or three years earlier.

4.3.2.3 Chemical Reactions

The theme Chemical Reactions was further divided into two sections. In the first section the students were given four-word chemical reactions. They had to describe and explain observable changes occur during these reactions and then write a balanced chemical equation of the reaction. In the second section, they were given seven items based on redox reaction. The aim was to establish the students' prior knowledge and understanding about chemical reactions. Further, this theme had been inspired by studies conducted by Hesse & Anderson (1992) and by Ahtee & Varjola (1998), on Students' Conceptions of Change and Students' Understanding of Chemical Reaction. According to Hesse & Anderson (1992), "When students learn about even the most common chemical changes, they must acquire understanding in three areas: chemical knowledge, conservation reasoning, and explanatory ideals." They also point out that students should be helped to understand why some explanations are preferred to others. From the observations and explanations given by the students, I was able to identify which explanations were to be emphasised or abandoned. The students' responses to this theme are arranged in a descending order in Table 4.3.

A close examination of Table 4.3 reveals that the students possess very little understanding of the concept of chemical reaction. Their correct responses range between 0 to 28 % and 0 to 35 % for E and for C₁ respectively. Of the eleven items, forming this theme, the students in E responded to only five while those in C₁ responded to seven. The overall percentage of correct responses for E and C₁ respectively were 9 % and 8 %. Although the students responded to some of the items, they failed to explain their responses, as required and only one chemical equation, i.e. $Zn + HCl \rightarrow ZnCl_2 + H_2$, was correct for both groups. The sequence of correct scores on the Chemical Reaction Theme is as follows:

- Item B, dealing with the zinc dropped into a solution of hydrochloric acid attracted the highest percentage of correct responses, i.e. 28 % and 35 % for E and C₁ respectively. One would assume that the majority of the students would be familiar with this reaction as it is normally one of the first reactions introduced in grade 10. A number of students were able to give correct responses but incorrect equation or explanation of how the reaction occurs. Some of the responses to the item are:

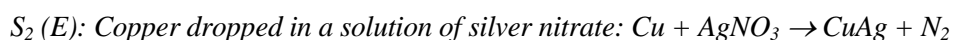
S₁ (E): Elimination of hydrogen gas; $Zn + HCL \rightarrow ZnCL + H$

S₁ (C₁): There will be bubbles and smell and heat; $Zn + HCl \rightarrow ZnCl + H$

- This was followed by items E, where students were required to identify a redox reaction from (a) $2 Mg + O_2 \rightarrow 2MgO$ and (b) $H^+ + OH^- \rightarrow H_2O$, and H, where students were

required to write a chemical equation for a reaction: Copper and concentrated Nitric Acid making Copper Nitrate, Water and Nitrogen Dioxide. Both items ranked two attracting about 18 % and 15 % correct responses for E and C₁ respectively.

- Item A, concerned with the students writing a chemical equation, observable changes and explaining how the word reaction of iron in copper solution occurs. This item ranked four for both groups attracting 18 % and 13 % correct responses for E and C₁ respectively.
- Item C, where students were required to write a chemical equation, observable changes and explain how the word reaction of copper in silver nitrate occurs. This item ranked five for both groups attracting 15 % and 8 % for E and C₁ respectively. For example:



- Items F and G, where students were required to identify the oxidizing and reducing agents respectively from the reaction, many chose in E. These items ranked six scoring 1 % for C₁ and no responses for E.

In this theme more than 50 % of the students for both groups did not give any responses to the various items. This is a clear indication of poor understanding of how chemical reactions occur. The students also displayed a poor understanding of how to write chemical formulae and symbols. These are some of the formulae they wrote:



One would have expected that grade 12 students would be able to write simple equations on chemical reactions but this has not been the case with these students.

4.4 CAREER INTEREST

The students indicated thirty-six careers. However, for ease of analysis these careers were grouped into six main categories: medical field; engineering; technology; sciences; business and services (Table 4.5). An examination of Table 4.5 indicates that the mean scores obtained in terms of career interests range between 15 % and 21 % while the standard deviations range between 0.82 and 2.92. The relatively low standard deviations are indicative of the comparability of the six groups at the pre-test stage. This is further buttressed by the low F-value of 0.87 at $p < 0.05$ compared to 2.34 needed to reject the notion on non-comparability.

Table 4.5 Performance in Pre-test According to Career Choices.

Career	n	Mean	Mean %	S.D
Medical field	29	6.86	20.8	2.37
Engineering	22	6.09	18.5	2.92
Technology	11	7.00	21.2	2.09
Sciences	07	5.89	17.7	2.30
Business	5	5.8	17.6	2.84
Service	6	5.00	15.2	0.82
Total	80	6.38	19.3	2.3
$F_{(5,74)} = 0.87$ at $P = 0.05$ $F_{crit} = 2.34$				

4.5 RELATIVE EFFECTIVENESS OF THE TREATMENT

The second and the third research questions stated in chapter 1 are concerned with finding out the effect of the treatment, i.e. exemplary instructional materials (including concept mapping) on the students' understanding of chemical reactions, particularly redox reactions. The purpose of the pre-test was to determine the nature of the students' conceptions of chemical reactions as well as areas where they had poor understanding of the concept. This was necessary to know what treatment (i.e. the exemplary teaching - learning material) might prove useful in overcoming their misconceptions of the concept. In this regard, both E and C₂ (i.e. the group which was not pre-tested) were exposed to a three-week treatment involving the use of concept mapping. Also, all the three groups were exposed to the discussions sessions on the current debate regarding the proposed fluoridation of drinking water as well as experiments. Introduction of the discussions as well as experiments to all the students and not E and C₂ only, was based on ethical reasons. All these students had to write the same final examination by so doing it was to ensure that none of the students were deprived of teaching and learning material, which I felt was vital to prepare them for the examinations.

4.5.1 The Effect of Concept Mapping

Research question 2 is concerned with determining the relative influence of concept mapping on the students' understanding of chemical reactions, particularly redox reactions. The use of concept mapping was influenced by the fact that students' knowledge of science is often characterized by lack of coherence. Instead of having well structured and integrated domain-specific knowledge structures, students tend to consider the different concepts as isolated elements of knowledge (Brandt et al., 2001). In this study concept mapping was used to help the students to learn the concept of chemical reactions as meaningfully as possible

It was also used as a method used to explicitly show the links or relations between concepts and as a technique to study the coherence between concepts in students' knowledge structures (Novak & Gowin, 1984). After the learning task had been completed, concept mapping was again used to provide a schematic summary of the lesson (Novak & Gowin, 1984).

Generally, the use of concept mapping seemed to have achieved the desired effect as many of the students mentioned that it helped them in the understanding of the concepts of the chapter. This is illustrated by the data presented in Table 4.6 and subsequent comments.

Table 4.6: Students' Perceptions of the Use of Concept Mapping

Rank		A (%)	D (%)	NO (%)
1	Concept mapping helps me to make sense of the many terms in a chapter and organise them in a meaningful whole	79	19	1
2	Concept mapping is a good way of reviewing a chapter	77	19	4
3	Concept mapping helps me to express complicated concepts in a simple way.	77	19	4
4	Concept mapping helps to clarify the relationships between concepts	76	18	6
5	Concept mapping helps me in understanding the concepts much better	74	18	9
6	Cross links help me to get the bigger picture	63	32	5
7	Concept mapping helps in clarifying confusing and complicated concepts.	58	35	8
	MEAN %	72	23	5
8	Cross links makes getting the bigger picture more difficult	49	41	10
9	Concept mapping makes expressing complicated concepts more difficult.	46	50	4
10	Concept mapping makes me to confuse the relationship between concepts	46	47	6
11	Concept mapping makes the complicated concepts more confusing	41	51	8
12	Concept mapping is not a good way of reviewing a chapter.	37	57	6
	AVERAGE %	44	49	7

A = Agrees; D = Disagrees; NO = No opinion; N.B: The percentages are rounded off

The questionnaire on concept mapping consists of 12 items, i.e. seven positive and five negative statements about the use and effectiveness of the concept map. Table 4.6 above summarises the responses given by the students for each of the 12 items in the questionnaire. For analysis purposes I have rearranged these items putting the positive statements together and the negative ones together. The average agreement, disagreement and no opinion percentages for the seven positive items are 71 %, 25 % and 5 % respectively and 44 %, 49 % and 7 % respectively for the five negative statements. Overall, the students seem to be more favourably disposed towards the positive statements about concept mapping than towards the negative

statements. The majority of the students (72 %) viewed the use of concept mapping as effective as teaching/learning tool while a minority (23 %) thought otherwise.

A further analysis of Table 4.7 and the excerpts below provide some insight into how the students perceived the effectiveness or otherwise of concept mapping. e.g. 79 % of the students claimed that concept mapping helped them to make sense of the many terms in a chapter and organise them in a meaningful whole, 19 % did not think so while 1 % offered no opinion. These are some of the comments they made in regard to this opinion:

S₁: Concept mapping helps make sense of many terms, they make you to understand a little bit of the chapter and express them (E).

S₁: Concept map give us more understanding (C₂).

To 77% of the students, concept mapping is a good way of reviewing a chapter, 19% thought otherwise while 4% was undecided. Seventy seven percent of the students claimed that concept mapping helped them to express complicated concepts in a simple way, 19% disagreed while 4% was undecided. 76 % of the students found concept mapping helpful in clarifying the relationship between concepts, 18% did not think so while 6% offered no opinion. The following excerpt illustrates this:

S₂: Concept mapping help me to know better the relationships between concepts (C₂).

About 74% of the students viewed concept mapping as helpful for the understanding of concepts, 18% disagrees and 9% offered no opinion. These are some of their comments:

S₂: I think to use concept mapping is a good idea it can help the students to understand better everything included in the chapter they read (E).

S₃: Concept mapping uses the short words and sentences so it is easier for us to understand the concepts better (C₂).

Sixty three percent of the students found cross-links helpful in getting the bigger picture, 32% felt otherwise while 5% did not offer any opinion.

S₃: Concept map is easy to understand and cross links help give us the picture of what we talking about (E).

About 58% of the students claimed that concept mapping helped them in clarifying confusing and complicated concepts, 35 % disagreed while 8% offered no opinion.

S₄: I think concept mapping helps me to understand the concepts much better. Especially to express complicated concepts in simple way (E).

Items eight to twelve are the opposites of items one to seven. One would have expected agreement percentages on the negative items to be below 30%. However, to my surprise these range between 37% and 49%. To 49% of the students cross links makes getting the bigger picture more difficult while 41% thought otherwise and 10% were undecided. Looking at the students' comments, there is a high probability that they did not have a clear understanding of what cross-links are. The following are some of the students' comments:

S₅: Concept mapping is much difficult to me because I don't even understand concept making and cross-links (E).

S₄: I don't understand concept mapping and cross-links (C₂).

Forty six percent claimed that concept mapping made expressing complicated concepts more difficult, 50% disagreed while 4% gave no opinion. To 46 % of the students, concept mapping made them to confuse the relationship between concepts, 47% did not think so and 6% offered no opinion. About 41 % felt that concept mapping made the complicated concepts more confusing, 50% felt the opposite while 8% offered no opinion. The following comment made by S₅ is indicative of a negative perception of a concept map:

S₅: Mapping is not a good way of many terms in an organise, it is confusing (C₂)

Also, 37% of the students view concept mapping as not being a good way of reviewing a chapter, 56% thought it was and 6% offered no opinion.

Some students were intrigued by how they could work with concept maps while others felt it helped them in understanding their shortfalls in the chapter. Some of the students felt that concept mapping was useless without the understanding of the concepts in the chapter concerned. The following are some of the comments made by the students to illustrate their perceptions of the use of concept mapping:

S₆: Concept mapping is the very easy way to study it help you to understand easier by writing the key words (E).

S₇: According to my understanding it helps me to have a better idea were I am lacking (E).

S₆: I think it is better if you know the chapter first. Redox reaction is easy then it is easy to understand redox reaction and to understand concept mapping and to do it (C₂).

S₇: Concept mapping is a very easy to understand because you can do it on one double page filled with all the important necessary topics and sub headings (C₂).

S₈: Concept mapping are little bit difficult but you have to stick and ask everything so that you can understand, but it was just easy (C₂).

Some students related their not understanding concept mapping to time and felt they needed extra lessons.

S₈: May be I need time to study therefore I can see that there is a lot that I need to concentrate on concept mapping and chapter (E).

S₉: These concept mapping we don't understand well. If Mrs we can do same (some) extra classwork for this lesson. This concept mapping is hard to do on your own is better if we do in group (C₂).

To obtain more insight into the students' perceptions about the effectiveness or otherwise of concept mapping on their understanding, eight students, four from E and four from C₂, were interviewed. For anonymity purposes, these students were given pseudonyms. Also, as mentioned in chapter three, this was a group interview. During the interview, seven out of the eight interviewees felt that concept mapping helped them to understand the underlying concepts of chemical reactions better. The students' arguments had to be based on three focus questions. The interviewer simply interjected to direct the argument or to probe the students to elaborate on their opinions.

Interviewer (I): During your argument about the effectiveness or otherwise of concept mapping you have to focus and address the following questions:

- (i) Are you able to use concept mapping on your own, either in science or any other subject?
- (ii) Has its use made any difference to your understanding of this topic compared to previous topics?
- (iii) Will you recommend its use in other topics as well as to other teachers?

The excerpts below reflect the responses of the interviewees:

I: How did you find the use of concept mapping?

Sibongile: I enjoyed this mapping because it is easy to answer this question

Odwa: I think concept mapping helps me to understand the concepts much better especially to express complicated concepts in simple way

Ayanda: concept mapping makes your chapter to be much easy to study. It is short and its easy to remembering.

Nomsa: From my point of view concept mapping is an eye opener, and I absolutely recommend it.

I: Nomsa, would you explain what you mean by concept mapping being an eye opener.

Nomsa: It makes or made me understand much better, it give us the picture of what we talking about. It uses the short words and not sentences so it is easy for us to understand.

The comments above seem to suggest that the interviewees found concept mapping to facilitate their understanding of chemical reactions. It also helped them to develop a positive attitude towards the study of chemical reactions. However, some of the students felt that without the understanding of the concepts first, concept mapping is useless. Here, are some examples of such viewpoints:

Zandi: use of concept mapping is a very good idea it can help the students to understand better, but it is important to understand the lesson than to do things wrong. I understand the lesson.

Sipho: I agree with Zandi, it is easy to learn or read if you have an understanding than you have no understanding. Using concept mapping is easy if you have understanding of the chapter, otherwise is waste of time.

I: Sipho, why do you agree with Zandi?

Sipho: I have to know the chapter, the important concepts so that I can do mapping. If I don't know, I don't know what concept to write and what linking words to use. So teach a piece, then do its mapping, then another piece and later we can bring the pieces together. Then we understand better this way.

Luvo: You need to first teach mapping clearly, not for just few lessons. Some of us did not really understand how to use concept mapping. When you teach with it we understand. When we do it all, we understand but when I do it, it is difficult but except when you know the chapter.

Odwa, the more I see pictures the more understanding of what is asked.

I: Odwa, what do you mean?

Odwa: when doing concept mapping it uses key words and when you need the thing you have been highlighted it not take time to get it. You can see what you want on the map. Reading a map is easy than reading lines and lines of work like notes and textbook.

Nomsa: yes of course when we use the map it gives more understanding. It uses short words and sentences so it is easier for us to understand.

Sibongile: you can get more information because you can see what you want on the map. Sometimes map confuses and more simple. But if you know the map, you cannot be confused and the lesson be even easier.

Vuyolwethu was the only one of the interviewees who had something totally negative about concept mapping.

Vuyolwethu: concept mapping is much difficult and confusing to me, because I do not understand concept mapping and cross-links.

I: What do you think might be the reason, Vuyo?

Vuyolwethu: both I do not understand especially this chapter. I am poor in science especially chemistry side. May be I need time to study I can see there is a lot I need to study on. May be my problem is not mapping, I don't know.

Zandi: I understand science and redox reactions is easy, maybe that's why I understand concept map easily, I recommend it be used to other topics and other subjects like biology it has many difficult topics.

Sibongile: I recommend it especially for biology with many difficult words and stuff. The more I see pictures the more I get more understanding of what is talking about.

(Students continued agreeing with each other on their recommendation of concept mapping except for Siphon, who had this to say)

Siphon: I agree with all of you, but I feel we have to first understand how to use concept map better, then use in other subjects. Biology is very difficult it's not like science, it's not easy to study and understand, it's problem.

I: What do you mean you first need to understand how to use concept mapping?

Siphon: I think you need to teach concept map more in other difficult topics like equilibrium, then we can understand even better.

Ayanda: I agree with everyone. Concept mapping helps make sense of many terms they make you understand the chapter. It can also confuse someone who do not understand. I think you need to understand chapter, then do the concept map, it will now be easy to understand even better.

Although a number of the students mentioned that they enjoyed working with the concept map and found it easy. Judging by some of both positive and negative responses, however, it became clear to me that

I needed to have spent more time teaching them how to develop a concept map before using it as a teaching tool as well as expect them to use it as a learning tool. Out of the eight students I interviewed, only one found concept mapping confusing. She further explained her inability to understand might stem from the fact that she is generally not strong in chemistry.

The students seem to have a narrow view of concept mapping. All the comments above suggest that the students construe concept mapping mainly as a tool to reinforce their understanding of a topic. They do not see concept mapping as a means to: (1) reveal their own understanding or prior knowledge of the topic; (2) help them to know how to relate isolated concepts together, i.e. how concepts are inter-related; (3) help them understand the structure or meaning underlying a topic; (4) revise what they have learned in preparation for a test or examination; (5) see a bigger picture of a topic in the context of their life worlds; (6) reveal their misconceptions or alternative conceptions; (7) facilitate collaborative relationships or social interactions among students or between students and their teachers in the process of constructing concept maps; etc. The students were correct in stating that they had not mastered concept mapping thoroughly enough before they were assessed or confronted with the task of problem solving using concept maps. The place to begin perhaps is to see concept mapping as an exploratory tool, which reveals the present status of the students' knowledge of a topic. As Ebenezer & Connor (1998) have observed, teachers ought to examine their first attempts at providing concept maps, to be better informed about where to begin instruction or the direction they should follow.

4.5.2 Discussion on Fluoridation

Research question 3 is concerned with determining the relative influence of the discussions on the students' understanding of the issues surrounding fluoridation. As indicated in chapter 2, fluoridation of public water supply is an on going controversy in South Africa. As indicated before, the Government has proposed to introduce fluoridation of drinking water as a preventive measure of tooth decay. Although the students were unaware of the debates, their lives would be affected by the decision reached on the matter, and hence by introducing all the students to the issue of fluoridation. Based on the class discussions the students were asked to express their views about fluoridation. The students gave a variety of responses. The majority of the students seemed to understand what fluoridation is as well as its implications for their lives. Although this was generally the case, some students did have misconceptions about fluoridation, describing it as either calcinations or chlorination. The group of each respondent is indicated in brackets. The excerpts below are representative of the students' notions of fluoridation:

S₁: Fluoride is a natural substance needed for the development of bone (E).

S₁: It is important to use fluoridation because bacteria in water can cause epidemic of diseases like typhoid and cholera (C₁).

S₁: Fluoride purifies water and stored in storage reservoirs, then flows by gravity to the homes and factories when it is needed (C₂).

The misconceptions above led to a further argument, whereby some students gave the correct definition of fluoridation while others equated fluoridation to medicine. The following statements were made by some of the students:

S₂: Fluoridation is the medicine that can clean the water. Fluoride may be added to the water if there is not enough naturally present (E).

S₃: Is the process of adding fluoride to water supply (E).

S₂: It is the additions of chemicals called fluorides to water supplies to help teeth resist decay (C₁).

S₂: A fluoride is a chemical, which prevents tooth decay it is usually added to toothpastes (C₂).

R: In place of fluoridated drinking water, the use of other fluoridated products have been suggested e.g. toothpaste, chewing gum, etc. What do you think of the use of these products?

Some of the statements made by the students regarding fluoridated toothpaste and other products, e.g. chewing gum, beside, water as a preventive measure for tooth decay include:

S₃: Fluoride in toothpaste makes teeth white and strong and no holes. The toothpaste must be used every morning and at night, to clean teeth and use fluoride to prevent teeth from decay. Causes less tooth ache but expensive (C₁).

S₃: Chewing gum can prevent teeth decay for the whole day and toothpaste only morning and night. Chewing gum is cheap and easy to buy we eat all day not morning only like toothpaste (C₂).

Some students objected outright to the use of chewing gum explaining how irritating it is. Also, some indicated that it is expensive in the sense that one would have to eat at least four a day, thus being more expensive than toothpaste.

S₄: Chewing gum is not good. It is irritating all people chewing all the time. I don't like chewing gum it makes you look stupid. It is expensive, you can't eat one at least four gums a day. Imagine how much money wasted instead of toothpaste. 50 cents chewing gum, R2 a day, R60 a month, that's 12 toothpastes all for six months. It's a waste of time and you get tired from chewing (E).

R: Does toothpaste have calcium added to it? If so what is its use? Is there a need to add fluoride if there is calcium? If not is it necessary that it be added?

Some of the students had the tendency to think that fluoride and calcium have the same use, some for economic reasons perhaps, saw no need to add calcium to toothpaste if there is fluoride and vice versa. They also felt the presence of both substances would inflate the price of toothpaste. The following statements are representatives of their viewpoints:

S₄: Because fluoride is added there is no need for calcium, already fluorine makes teeth strong, white and clean. Why add calcium and fluorine and not add one it is waste of money. If toothpaste has fluorine or calcium only, it is going to be cheaper. Yes, you can add calcium then your teeth can be extra strong, not decay and very white (C₂).

Some of the students who knew that the two substances do not serve the same purpose and had this to say:

S₄: Yes, calcium has to add as it makes teeth strong but does not prevent tooth decay like fluorine. Without calcium, even fluorine is useless, as you teeth will continue to break because they are weak (C₁).

S₅: Calcium makes tooth strong and fluoride makes it not to rot. We need them both (E).

R: If you were the Government, what would you recommend, drinking fluoridated water or using toothpaste or any other fluoridated products as a measure to prevent tooth decay?

The students' were able to make an informed decision about the use of fluoridated water proposed by the government. In making this decision they also weighed the use of fluoridated drinking water against the use of toothpaste. The majority of the students favoured fluoridation of drinking water. To them this will benefit everybody including the poor people who cannot afford toothpaste, as they do not have money. The excerpts below reflect this view:

S₆: Adding fluoride to all water will help poor people who can't buy toothpaste (E).

S₇: Adding to water is more effective way of reaching population worst affected by tooth decay (E).

S₅: Adding fluoride in water is surest way for everyone in the community to benefit (C₁).

S₆: Supporters argue that fluoridation gives the whole community fluoride protection supply effectively and a small expense compared with costs of treating tooth decay and buying toothpaste (C₁).

S₅: On the other hand, if water is not fluoridated, people will suffer from tooth decay (C₂).

S₆: Fluoride in toothpaste only helps teeth but in water develops healthy teeth and bones (C₂).

Other students, who highly recommended fluoridation of public water supply highlighted the harmfulness of using other fluoridated products. According to these students:

S₇: Fluoride toothpaste and tablets produce a variety of intolerance effects, including skin eruptions, gastric upsets, headaches, increased desire to urinate and in the case of toothpaste, mouth ulcers (C₁).

S₇: All what he says we've read in a number of books, so water fluoride is the best as there is no proof of it being harmful like toothpaste (C₂).

Some students felt both the use of fluoridated drinking water and toothpaste should be used so as to further reduce dental bills for those who can afford dental treatments and also for those who cannot afford toothpaste. One student also quoted from a book that toothpaste is sufficient for the prevention of tooth decay.

S₈: Adding it to drinking water will reduce the needs for and the costs of dental treatment (E).

S₈: According to the book rates of tooth decay also have declined in areas without fluoridated water, perhaps chiefly because of the widespread use of toothpaste (she was reading directly from something she had written) (C₁).

S₈: Fluoride in water is a life saving because it prevents the need for treatment (C₂).

Some of the students highlighted the harmful effects of the use of fluoridated water. These students felt that although it is a good idea, especially for people who cannot afford toothpaste, the risks concerned are more harmful than losing teeth. These students preferred the use of toothpaste to fluoridated drinking water. The excerpts below are reflective of this view:

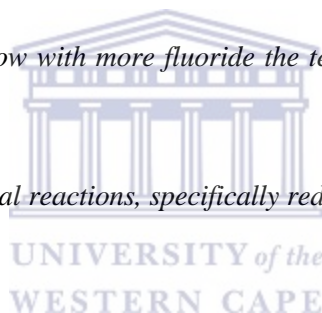
S₉: Fluoride interferes with the action of a number of enzymes in the human body causing them not to do their work. Then cancer, skeleton fluorosis and other bad diseases (E).

S₉: Fluoridation is dangerous for people with kidney problems, now with all water with it means these people have to buy spring water, and that is expensive. If a person doesn't have money, he drinks water and die (C₁).

S₉: Excessive fluoride intake can be harmful especially to the bones and teeth, and drinking fluorine water means excessive intake (C₂).

S₁₀: Water has natural fluoride, now with more fluoride the teeth becomes more common and easy to break and decay (C₂).

R: Since our lesson is about chemical reactions, specifically redox reactions, do you think fluoridation is relevant to this lesson?



The students explained the relevance of fluoridation based on the fact that fluorine is a chemical element, a halogen. Also, the fact that it is a strong oxidising agent makes it fluoridation a good example for the lesson. The following excerpts are illustrative of the students' comments:

S₁₀: Fluorine is a chemical element with symbol F and ordinary temperature is a plain yellow gas and compounds that contain fluorine are called fluoride. It is a strong oxidising agent (E).

S₁₀: Fluorine is an element of group seven, a halogen (C₁).

S₁₁: Fluoride reacts with something on the teeth and makes a coating that prevent tooth decay. Therefore fluoride as a chemical reaction and you teaching chemical reaction (C₁).

S₁₁: Fluoride prevents erosion of enamel, like it is like iron in acid (C₂).

Although the students had different views about fluoridation of public water supply, they agreed that the government should leave it to the communities to decide on whether or not they wanted fluoridated or unfluoridated water.

4.5.3 Interview on Students' Understanding of Fluoridation.

To obtain an in-depth perception of the students regarding fluoridation, two students were interviewed. As a case study, conducting an interview with two students was considered adequate (e.g. see Merriam 1998). These students were student 1 (S₁) and student 2 (S₂) from group E and C₂ respectively.

Following the fluoridation discussion, the students seemed to have a clearer understanding of fluoridation. They seemed to have read extensively about it. Some of their responses seemed to be a repetition of what was said in the class discussions. Here are some of their responses:

Interviewer (I): What do you understand fluoridation means?

S₁: Fluoridation is the addition of chemicals called fluoride to water supplies.

S₂: Fluoridation means addition of fluoride to drinking water.

I: In your opinion, what is the function of fluorine added to drinking water.

S₁: Its function is to help teeth resist decay and make the strong ad healthy

S₂: It helps to prevent tooth decay.

I: Is addition of fluoride to drinking water the only method used for tooth decay prevention?

S₁: No, toothpaste is the most common thing with fluoride. Also books say salt and pills in other countries are used.

S₂: The use of fluoride salt, tablets and toothpaste and the application of strong fluoride solution to the teeth by dentist can also help prevent tooth.

I: Toothpaste has been used for a number of years to prevent tooth decay. In your opinion is toothpaste or fluoridated drinking water the most effective way?

S₁ felt that, although toothpaste has been used for a long time to prevent tooth decay, not all people could afford it. She also indicated that in some rural areas they still use ash and brick. This has been one of the traditional ways of cleaning teeth. These excerpts reflect her view:

S₁: Using toothpaste is good, but not everyone has money to buy it.

I: Those who do not have money, how do they keep their teeth clean?

S₁: Some grannies in the Transkei use ashes and powder brick. It cleans teeth good. Now adding fluoride to water gives everybody fluoride to prevent tooth decay and tooth ache.

In his argument, S₂ highlighted the cost effectiveness of using fluoridated water compared to the treatment of tooth decay. This is what he had to say:

I: Toothpaste has been used for a number of years to prevent tooth decay. In your opinion is toothpaste or fluoridated drinking water the most effective way?

S₂: Scientists and dentists argue that fluoridation of water protects the whole community and at low cost compared to tooth decay and tooth lost.

I: What is your opinion, do you agree with them or not?

S₂: I think, yes. When your tooth are rotten they are painful and frustrating. You can't laugh with rotten teeth. Then you have to go to a doctor. Doctors are expensive, you pay R90 but with fluoridation you pay nothing it is government problem. This also means, less fear and anxiety about visits to the dentist as treatment would be less complicated, with less anaesthesia.

With the risks proposed by the opponents of fluoridations some of the students felt they were not quite proven, thus cannot really argue them. The fact that a lot of dental and health organisations including the Department of Health, support fluoridation, had a big influence on their decision.

I: A lot of opponents to fluoridation of drinking water have highlighted a number of risks, e.g. cancer, etc. What is your opinion in this regard?

S₁: Yes there are claims that fluoridated water could be linked to "mass medication", that it was toxic and that it would not really help the people who need it most. The problem there is no proof of risk.

S₂: Yes, but also they say there is no proof, but there is proof for preventing tooth decay. In the Cape Argus Dr Nkosazana Dlamini-Zuma the Minister of Health, Johan Smit also from Department of Health and others, supports fluoridation of drinking water. So it is proof that it is good for preventing tooth decay.

For the closing argument the students made the following statements to the interviewer:

I: What would you say to sum up your argument to convince me to go with your opinion?

S₁: It is important to remember that while fluoridation benefit everyone with natural teeth, the greatest benefit of all goes to those least able to help themselves, the children. This is more especially the children from impoverished and increasingly urbanised communities who will benefit the most. Also fluoride combines with enamel before tooth eruption, benefits the tooth more for its whole life.

S₂: For most people in South Africa, the cost of toothpaste and toothbrushes takes up a large part of their incomes. Fluoridation will help so as all benefit and have healthy strong teeth. Everybody, especially children will have same beautiful teeth even if she is poor.

Although most of the students favoured fluoridation of drinking water, they were of the view that the decision to implement the programme should be left to their respective communities. They seemed more aware of the merits and demerits of fluoridation and hence felt that larger communities should be involved in the process of decision-making.

The students' views based on the class discussions and the interview can be summarised as follows:

- Fluoridation is the least expensive and most effective way to reduce tooth decay.
- Fluoridation, besides the unproven risks by opponents, is by far the safest way to prevent tooth decay.
- Fluoridation benefits children and adults. The drinking of fluoridated water by children prevents caries primarily after tooth eruption.
- Fluoridation provides life long benefits i.e. incorporation of fluorides into the enamel even before tooth eruption lasts for the life of the tooth.

- Fluoridation reduces the need for and cost of dental treatment.

Although the students' opinions expressed above seem well informed, their concern for the prevention of tooth decay should not overshadow other health risks. One proponent's argument is that fluoridation of drinking water, will benefit everybody especially children and people who cannot afford toothpastes and dental treatment. Although this might be true, one cannot rule out the opponents' claims that it is even more toxic than lead. The risks involved may outweigh its benefits. Taking into consideration the fact that the Government as well as other health organisations and the private sector are promoting the use of unleaded petrol due to the toxicity of the leaded one, it comes as a surprise that the same Government will promote the use of something more toxic as fluoride. Also, the fact that fluoridation has been associated with cancer of the oral cavity, pharynx, colon, rectum, hepato-biliary and urinary organs and bone (Takahashi, 2001) is enough to scare any one away from its use. I think the Government should investigate what is in the best interest of South Africans in respect of fluoride before they decide whether or not they should implement fluoridation. The South African conditions differ from those of the first world countries, and relying on research from these countries might lead to committing type one error, i.e. implementing a harmful programme with irreversible consequences (e.g. Ogunniyi, 1992).

Many proponents of fluoridation have argued that it prevents tooth decay and oral diseases, which have been associated with a number of health problems including cardiovascular disease and diabetes (Maddox, 2000). On the other hand opponents equate fluoridation to mass medication and is toxic and causes many health problems, cancer (William, 1992) and reduces fertility (Freni, 1994). These opponents also argue that regardless of any benefits, the process violates the principle of freedom of choice.

Besides all these arguments fluoridation is accost-effective means of improving the oral health of children and adults. The lifetime cost of receiving fluoridated water is typically less than the cost of one dental filling or any dental treatment. This is more so in our country as the majority of people live beneath the poverty line and cannot afford dentists or, with some, toothpaste or any other fluoridated product. The students' argument and final decision on the issue, reflects the trend of thinking of our communities and what the results of public participation on the debate might be. On the other hand fluoridation will ensure that few people will have a need for dental treatment, thus affecting the dentistry industry in a negative way

as they will lose a lot of money and people working there will lose jobs. Also this will also ensure that we have a “healthy working force”. Also manufacturers will rather push for the fluoridation of public water supply as they will benefit a lot from it. Since the majority of South Africans live beneath the poverty line, they cannot afford things like toothpaste, thus if fluoridation of public water debate were to be open to public participation, the majority will opt for it irrespective of the health hazards. Thus manufacturers will support the fact that the debate be open for public comment.

4.5.4 The Effect of the Experiment

In an effort to further enhance the students’ understanding of chemical reactions, all the students performed two hands-on experiments. Since all the students were to write the final examinations and these experiments were crucial for their understanding of redox reactions, I felt it was necessary for all of them to perform the experiments. Hands-on experience is integral to familiarising students with difficult scientific concepts. According to Abraham et al. (2000) many students find it difficult to visualise concepts without at least a practical demonstration. They stated further that lack of practical work in school science could have been one of the reasons why students tend to perceive science as an abstract subject matter. These hands-on experiments as described in chapter 3 have been designed therefore, to try and correct this negative perception.

Generally, the students did well in the experiment. With respect to the teacher demonstration experiment: $\text{Cu} + \text{H}_2\text{SO}_4$, most of the students predicted that Cu would turn white while others said white CuSO_4 would be formed. This was based on the fact that they had done the experiment: $\text{CuSO}_4 + \text{H}_2\text{SO}_4$, where H_2SO_4 acted as a dehydrating agent changing the blue $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ into a white anhydrous CuSO_4 .

The following excerpts are illustrative of their responses:

S₁: A white copper sulphate will be formed (E).

S₂: Sulphuric acid sucks water from the reaction leaving dry white copper sulphate (E).

S₁: Copper will change colour to white (C₁).

S₁: Copper will turn white (C₂).

S₂: I think its white copper sulphate no copper. Copper is always brown (C₂).

On which of the reactants was an oxidising agent, the students mostly agreed it was Cu. Their view was based on the fact that the example done earlier of the $\text{Fe} + \text{CuSO}_4$, where Cu^{2+} acted as the oxidising agent. It became clear that the students had the tendency to compare their current work with the previously familiar one without really looking or thinking critically about the one asked. After the demonstration and seeing the blue solution formed, they were able to know that Cu^{2+} was formed. Based on this, they could see where they went wrong and were able to identify the oxidising agent with ease. They were also able to identify SO_2 by recognising its pungent smell. These are some of their responses:

S₃: The air bubbles mean a gas is formed (E).

S₂: The gas has a choking smell, therefore, it must be sulphur dioxide (C₁).

S₃: The smell is sulphur dioxide gas (C₂).

For the group experiment, which they had to perform, they did quite well. With regard to the products for the reaction: $\text{Cu} + \text{HNO}_3$, all the groups agreed that a blue $\text{Cu}(\text{NO}_3)_2$ and H_2O would be formed and that Cu is a reducing agent. Only two groups, G₁ and G₂ for E and C₂ respectively, mentioned the formation of NO_2 and not all of them agreed on its formation in both groups. Their reasoning was all the reactants have been used up where was the N and O_2 to form NO_2 going to come from? The excerpts below are some of their arguments:

For group E the discussion went on as follows:

S₄: A blue copper nitrate and water will be formed.

R: Are those the only products formed during the reaction?

S₅: Yes, if you look at the reactants, you have Cu, N, O_2 and H_2 and for products you have the same.

S₆: I know in rates of reactions nitrogen dioxide gas is made from Cu and HNO_3 acid.

S₇: There is a problem there, where are you going to get another N and O_2 ?

S₈: I also remember, but where they come from, well. Let's add the two and see.

For group C₁ the discussion did not involve much argument. This is how the discussion went:

S₃: Copper nitrate is formed.

R: What do you think will be the colour of this copper nitrate?

S₄: copper nitrate is blue.

R: Are there any other products formed?

S₅: Yes, water or H_2O .

R: Any other products?

S₆: I don't think so. All the elements in the reaction are used up.

For group C₂ the discussion went as follows:

S₄: A blue copper nitrate and H₂O will be formed.

R: Are those the only products formed during the reaction?

S₅: I think there is nitrogen dioxide.

R: What do others in your group think?

S₆: Well the two of them say there is NO₂, but we think all the elements are finished. Where is he getting other N and O₂?

This pattern of reasoning is what Ben-Zvi et al. (1986) call the additive conception of chemical reaction. From the above discussions, it became clear that some of the students consider a compound as an additive of conglomeration of atoms. After having done the experiment and have seen the formation of the brown gas, most of them were able to identify it as NO₂, perhaps recalling it from grade 11 work of Nitrogen and Compounds and perhaps earlier in the year from the topic “Equilibrium and Le Chatelier’s principle.” The students’ arguments also served as an indication that doing experiments do not always guarantee that students will understand or remember it. It also indicates that as teachers we need to reconsider the methods we use in teaching experiments. Although the experiments were demonstrated in grade 11 and in grade 12 earlier, it was probably not explained how the products were formed. This probably was one of the reasons they easily forgot the reaction. Also the fact that they isolate instances (Osborne & Freyburg, 1997) might have contributed on them not seeing the connection between the experiment in the three different topics, i.e. Nitrogen and Compounds, Chemical Equilibrium and Redox Reactions. Besides performing the experiment and filling a worksheet, all the students were also given a questionnaire to test their perceptions on the experiment. Their perceptions are discussed below.

The need for students to know and understand the concepts involved in redox reactions and how reactions occur has been one of the key objectives of this study. In doing the experiments, the students had to fill in a worksheet instead of a long report on the experiments. This was an attempt to facilitate the above objective. Looking at the comments they wrote in their questionnaires seems to show that this objective to some degree has been achieved. Some of the students indicated that the group discussions and their performing of the experiment helped them to understand chemical reaction better. The following excerpts illustrate the students’ perceptions of the discussions and the experiments in their respective groups:

About the discussions involved in their groups, they had this to say:

S₉: I like discussion because I am gaining another knowledge for other learners (E).

S₇: I understand if more and more discussion and if I have done an experiment (C₁).

S₇: I want discussion and do experiment for helpful (C₂).

Some of the students indicated that answering the questionnaire (worksheet) was easier and preferable to the long questions, and that this approach had enhanced their understanding of chemical reactions. Some of the statements in this regard are as follows:

S₁₀: According to my understanding this questionnaire is helping me to understand where I am in my study (E).

S₁₁: It was easy for me to understand the chapter by asking questions and also answering questions. It was an easy way for me to understand any chapter (E).

S₈: To fill in the questionnaire is most easier than to answering a question, which need a long answers (C₁).

S₉: I like straight forward questions which needs an answer not more than two sentences (C₁).

S₁₀: Answering the questionnaire was a great joy to me. It gave me motivation to the way I use to read my books (C₁).

S₈: To answer questions I think is so enjoyable 100%, because it helps me to understand the topic better. Experiments help me to answer the questions ease, especially when I do with my views. I like challenges like questionnaire because it helps me to have a better idea of were I am lacking (C₂).

S₉: The questionnaire on experiment are not difficult if you lesson (listen) and look very well during the experiment and the teacher advice you to concentrate and write answer on the experiment so cannot have a problem when answering a question (C₂).

S₁₀: It opens our minds more to answer the questions with our own, and according to do so we learn to our mistakes and to know how to correct them. Also to answer into the class we learn to our mistakes (C₂).

Quite a number of the students found the experiments to be helpful in enhancing their knowledge as they could now refer to the reactions they had seen. Some of their statements in this regard are as follows:

S₁₂: It was very helpful to do that experiment but after the teacher teaches we forgot the colour of the chemicals but after we done experiment, we remember all colours and smells (E).

S₁₁: To answer question is very easy if you enjoy it. And when you use an experiment it is easy because you can see what we are talking about or what is happening (C₁).

S₁₁: This experiment is very good to help their knowledge and obtain reflections (C₂).

S₁₂: Well, I myself have found answering the questionnaire helpful, although I had difficulty here and there but it really helped me, doing experiment this way is really preferable to me (C₂).

Some of the students found the whole exercise to be a model for test and examination. This can be attributed to the stance taken by the curriculum, government, teachers, and society at large, of putting more emphasis on the examinations. Parents too are very keen on the results of schooling, especially the examination marks of their children (Gao, 1998). This has been demonstrated by some of the students' comments:

S₁₃: This questionnaire makes me understand the way the test questions were set and how I am answer them in test (E).

S₁₂: I enjoyed answering this questionnaire and it made the insight of what is expected out of us on exams. I can see also that the teachers do care about young hopefuls like us (C₁).

S₁₃: Experiments make easy to answer the questions in test especially in exam many questions are experiment (C₂).

Whenever students are given work, they always look for clues to help them understand and do well on examinations (Gao, 1998). For these students, the questionnaire is a means to understanding the questioning style of the examinations as well as tests. This prepares them to answer examination and tests correctly thus enabling them to do well in examinations and tests.

There were a few negative comments such as:

S₁₄: We don't understand the question (E).

S₁₃: Answering this questionnaire didn't help me to understand the experiment (C₁).

S₁₄: The reactions are not easy to understand you do not know which reduce and which oxidation (C₁).

S₁₄: The question were not that much easy but the experiment help me not that much because I didn't understand (C₂).

Generally, the experiments had a positive effect on the students' understanding of how chemical reactions occur, especially redox reactions.

To further explore the students' perceptions about the effect of the experiment on their own they had to answer a questionnaire (see Table 4.7). The responses have been further arranged in a descending order.

Table 4.7: Students' Perceptions of the Experiment and the Questionnaire

Rank	ITEMS	A (%)	D (%)	NO (%)
1	Questionnaire helps me to have a better idea of where I am lacking	82	5	14
2	Doing the experiment helped me to answer the questionnaire with ease.	75	8	17
3	I found group discussion helpful.	71	12	17
4	Answering the questionnaire helped me to understand the topic better	71	14	15
5	Answering the questionnaire on my own helped to understand better	68	19	14
6	Answering the questionnaire was enjoyable	66	28	6
7	Questionnaire is useful for reviewing a lesson	60	26	14
8	Answering the questionnaire was very easy.	54	32	14
9	I prefer answering a questionnaire to long questions, which need a long answer.	54	40	6
10	Answering a question can be deceiving.	43	22	35
11	I learned nothing from answering the questionnaire.	31	59	11
12	I could not have answered the questionnaire by myself	26	40	34

A = Agreements; D = Disagree; NO: No Opinion; N.B: The percentages are rounded off

A close examination of Table 4.7 indicates that 82% of the students felt that filling the questionnaire helped them to have a better understanding of where they were lacking while 5% felt otherwise and 14% expressed no opinion. Seventy five percent of the students claimed that experiments helped them to answer the questionnaire with relative ease, 8% did not agree and 17% offered no opinion. Overall, the comments suggest that the experiments generally benefited the students.

Although 71% of the students found group discussion helpful, 12% felt the opposite and 17% offered no opinion. Specifically 43% strongly agree while 28% agree. The high percentage of students who strongly agree with this statement is an indication of the effectiveness of group discussions. Again 17% not offering any opinion is relatively high and a cause for concern. Probably these students were not really participating in the group discussions. However, as Ogunniyi (1992) points out, as a rule of the thumb "no opinion" percentages below 33% are indicative that the respondents are neither guessing nor unclear about the item in question.

Seventy one percent of the students claimed that answering the questionnaire helped them to understand chemical reaction better, 14 % had a different opinion while 15 % did not offer any opinion. While 66% of the students claimed to have enjoyed answering the questionnaire, 28% did not and 6% up-stayed. In a close comparison of item 6 with 12, one would see that the percentage of students who did not enjoy answering

the questionnaire (28 %) is about the same percentage of students (26%) who claimed they could not answer it. Sixty percent (60 %) of the students found the questionnaire useful for reviewing the lesson, 26% felt otherwise and 14% expressed no opinion. In comparing item 7 and 11, which have opposing statements, one would see that in both items the same percentage (60 %) of students found the answering of the questionnaire useful.

Although 54% of the students found answering the questionnaire very easy, a whopping 32% felt otherwise while 14% offered no response. Looking at the next item one would find that the same number of students, 54% preferred the questionnaire to long questions while the 40% preferred otherwise and 6% offered no opinion. For science students one would expect that a high percentage would prefer a questionnaire to long questions, as there are less writing and hence less language mistakes.

About 43% of the students found that answering a questionnaire could be deceiving, 22% disagreed while 35% offered no opinion. This could be that the students did not understand the statement, which could be a problem with language. Quite disappointing was the 31% of students who claimed they learnt nothing from answering the questionnaire while 59% had a different opinion and 11% did not offer any opinion.

Sixty eight percent of the students felt that answering the questionnaire on their own (item 5) helped them to understand better, 19% felt the opposite and 14% offered no opinion. It came as a surprise that 26% of these students claimed they could not answer the questionnaire on their own, 40% had no problem answering the questionnaire while 34% had no opinion. Looking at the number of students who did not offer any opinion makes one wonder whether the students understood the statements in the first place. The students were probably unclear of what the item was all about. A closer examination of the items shows that it is a rather vague statement. It is either “I could not have answered this item without clarification” or I could not have answered this item by myself unless clarification was made of what “the questionnaire on myself” means.

4.6 POST TEST

At the end of the implementation period, all the three groups were subjected to the CAT as a post-test. In a study where the post-test differs from the pre-test, it is dubitable whether the measuring instrument reflects the same underlying conceptualisation and thought processes in the post-test as in the pre-test. Thus the use of the same CAT for both pre- and post-test. As stated earlier, groups E and C₁ wrote a pre test and

group C₂ acted as a control for the pre-test. Group E and C₂ were exposed to the treatment, i.e. concept mapping, and group C₁ acted as a control for concept mapping. The students' performances were then analysed in terms of gender and career interest.

4.6.1 Data Collected at the Post-test Stage

Judging by the means of the pre-test of about 19 % for both E and C₁ and the post-test mean scores of about 47 % (E) and 28 % (C₁), one can see there is a big difference between the means of the two tests for both groups at the post-test stage.

Table 4.8: Students' Understanding of Chemical Reactions at the Pre-and Post-test Stages

	GROUP E		GROUP C ₁	
	Pre-test	Post- test	Pre-test	Post-test
N	40	40	40	40
Mean	6.4	15.5	6.3	9.2
Mean %	19.39	47.1	19.09	27.9
SD	2.55	5.1	2.44	3.5
t-test	$t_{\text{obs}} (10.00)^* > t_{\text{crit}} (1.68)$		$t_{\text{obs}} (4.27)^* > t_{\text{crit}} (1.68)$	

***significant at p = 0.05**

Obtaining a t- value of 10.00 and 4.27 for the E and the C₁ groups respectively for the pre- and post-test scores against a critical value of 1.68 are indicative of significance differences between the pre- and post-test mean scores. This implies that the null hypothesis has to be rejected, as there is a significant difference between the two tests. However, the difference between the pre- and post-test for E is more noticeable than for C₁. Since both groups were exposed to the same exemplary teaching and learning materials, (except for the inclusion of concept maps for E), the higher t-value for E was probably as a result of the concept map to which the students in that group were exposed.

Table 4.9: Students' Understanding of Chemical Interactions at the Post- test Stage

Group	N	Mean	Mean %	SD
E	40	15.2	45.9	5.1
C ₁	40	9.2	27.9	3.5
C ₂	41	12.1	35.6	3.5
$F_{(2,118)} = 23.79$ at $p = 0.05$ $F_{\text{crit}} = 3.07$				

All the three groups having written the post-test obtained scores ranging between 5 and 29 out of 31. A close examination of Table 4.9 reveals that the means scores obtained were about 46 % (E), 28 % (C₁) and 36 % (C₂). Looking at these three groups' standard deviations (SD), the E has the highest disparity of scores compared to C₁ and C₂. This again may not be unrelated to the impact of the treatment i.e., concept mapping on E. The treatment seems to have created disparity of scores within the E group. Certainly, this warrants a closer investigation in future studies. In terms of percentage performance, E performed better than C₂ while C₂ in turn performed better than C₁. This is probably due to the fact that groups E and C₂ were exposed to the treatment, concept mapping, which might have had an extra effect on the students' understanding of chemical reaction. As one of E students commented:

“Concept mapping is the very easy way to study it helps you to understand easier.”

It is apposite to mention that C₁ group was not left to its own devices in that it was exposed to some treatment (i.e. exemplary instructional materials and the experiments) and hence the significant difference between its pre- and post-test mean scores ($t = 4.27$ at $p = 0.05 > t_{cr} = 1.68$). However, the addition of concept mapping to E and C₂ is instructive for future studies. The statistics represented in Table 4.9 above, show that the F ratio obtained for the post-test is 23.79. This value exceeds the critical value of 3.07, i.e. $F_{(2,118)} = 3.07$ at $p < 0.05$ needed to falsify the null hypothesis expecting no significant difference among the three groups.

Table 4.10: Pair-wise Comparison of the Students' Scores at the Post-test Stage

Pair groups	t – test values at p = 0.05
E and C ₁	$t_{obs} (6.09) > t_{crit} (1.68)$
E and C ₂	$t_{obs} (3.90) > t_{crit} (1.68)$
C ₁ and C ₂	$t_{obs} (3.35) > t_{crit} (1.68)$

To further explore the differences and similarities of the students' performances between groups, a t-test per pair was performed (see Table 4.10). The t-test values obtained were for: E and C₁ (6.09); E and C₂ (3.09) and groups C₁ and C₂ (3.35) at $p < 0.05$, all which are higher than the critical value of 1.68. This suggests that there is a significant difference between E and C₂, E and C₁ and C₁ and C₂. The difference observed between groups E and C₁ and groups C₁ and C₂ could probably be attributed to the fact that groups E and C₂ were exposed to the exemplary instructional materials, experiments and concept mapping, while C₁ was exposed only to the exemplary materials and experiments. This probably made these students to have a better understanding of the concept. As Bongiwe commented in the interview:

“I think concept mapping helps me to understand the concepts much better and it makes the chapter much easy to study. It is short and it’s easy to remembering.”

The difference observed between group E and C₂, which were both subjected to the exemplary instructional method, concept mapping, could probably be due to many factors. One of them could probably be the exposure of group E to the pre-test. Since group E wrote the same CAT twice and had the benefit of the discussion during intervention, it should not be a surprise that E outperformed C₂ group in all the items of the CAT (see Table 4.11) although the treatment was supposed to correct the pre-test effect. Also, this could probably be because C₂ was assumed to be comparable to E and C₁. This assumption might in fact not be valid, especially as no two classes are ever the same. For instance, variables related to the classroom culture which was not the focus of this study could have contributed to the differences between E and C₂. Another factor that was not considered is that some of these students are working. The number of working students per class might affect the overall performance of that particular class.

The statistical differences observed in tables 4.8, 4.9 and 4.10, suggest that:

- (i) The pre-test administered in the experimental group (E) and the control group (C₁) did not seem to have given the students in the control group C₁ a leading edge above their counterparts in the control group (C₂) who were not exposed to the pre-test.
- (ii) The use of the concept mapping in the experimental group (E) and the control group (C₂) seems to have enhanced the performances of the students in these two groups and given both groups some advantages over C₁.

4.6.2 Data collected from the CAT at the Post-test Stage

As stated earlier, the study involved 121 students, 76 girls and 45 boys. The CAT consisted of 31 items, which were divided into three themes, Everyday Life Reactions, Chemical Bonding and Chemical Reactions. As expected, there was a great improvement in the performance of the three groups compared to the performance of E and C₁ at pre-test stage. The theme Chemical Reactions, which had attracted the least correct responses during the pre-test stage had the most correct responses at the post-test stage followed by Chemical Bonding then the Everyday Life Reactions. For ease of reference and comparison, the post-test for the three groups were analysed item by item using the percentage of correct responses, which were arranged in a descending order.

In Table 4.11 above, the students' performances per item range between 18 % and 88 %, 3 % and 68 % and 2 % to 81 % for E, C₁ and C₂ respectively at the post-test stage. Item A, dealing with hydrochloric acid in sodium chloride, from the theme "Everyday Life Reactions", attracted the least correct responses, i.e. 18 %, 3 % and 2 % for E, C₁ and C₂ respectively. Item B, dealing with zinc in hydrochloric acid from the theme "Chemical Reactions", attracted the most correct responses, 88 %, 68 % and 73 % for E, C₁ and C₂ respectively. Looking at the overall performances of the three groups per item, one can see that group E outperformed the other two groups followed by group C₂ and lastly group C₁.

4.6.2.1 Everyday Life Reactions

During the post-test stage there was an improvement in most of the items compared to the pre-test stage. Although this was the case, item A, dealing with hydrochloric acid in sodium chloride, still attracted the least correct responses 18 %, 3 % and 2 % for E, C₁ and C₂ respectively. The students still harboured the same misconception of identifying HCl solution in NaCl as an acid-base reaction. Item A, dealing with rubbed ebonite stick, attracted the most correct responses 88 %, 53 % and 66 % for E, C₁ and C₂ respectively. The sequence of the correct scores on this theme is as follows:

- Item E, dealing with metal corrosion, ranked two, three and two for E, C₁ and C₂ respectively, showing an improvement in performance from 25% to 50% and 25 % to 42.5 % for E and C₁ respectively while C₂ attracted 51 % of the correct responses.
- Item B, dealing with zinc blade put in hydrochloric reaction, the performance improved from 23 % to 35 % and 30 % to 50 % for E and C₁ respectively, while C₂ attracted 39 % of the correct responses. This item ranked five, two and three for E, C₁ and C₂ respectively.
- Item C, dealing with the formation of rust on iron blade, ranked three for E and four for C₁ and C₂, showing an improvement from 33 % to 40 % for E and 23 % to 35% for C₁ while C₂ obtained 34 % of the correct response. There was a clear lack of conceptual change in this item as even in the post-test students regarded this reaction as precipitate.
- Item K, dealing with respiration, ranked six for all three groups, showed an improvement from 20 % to 33 % for E and no improvement for C₁ attracting 23 % while C₂ attracted 24 % of the correct responses.
- Item L, dealing with photosynthesis, ranked seven for E and C₂ and five for C₁, showed an improvement from 13 % to 30 % and 25 % for E and C₁ respectively while C₂ attracted 20 % of the correct responses.

Table 4.11: Percentages of the Correct Responses to Each Item of the CAT at the Post-test Stage.

Item	Summary of each item	E (%)	Item	Summary of each item	C ₁ (%)	Item	Summary of each item	C ₂ (%)
EVERYDAY LIFE REACTIONS								
I	Rubbed ebonite rod	88	I	Rubbed ebonite rod	53	I	Rubbed ebonite rod	66
E	Metal corrosion	50	B	Zinc blade in hydrochloric acid solution	50	E	Metal corrosion	52
C	Rust of iron blade	40	E	Metal corrosion	43	B	Zinc blade in hydrochloric acid solution	39
J	Cleaning of brass with brasso	38	C	Rust of iron blade	35	C	Rust of iron blade	34
B	Zinc blade in hydrochloric acid solution	35	L	Photosynthesis	25	F	Apple discolouring	24
K	Respiration	33	K	Respiration	23	K	Respiration	24
L	Photosynthesis	30	G	Nail in a bleach	15	L	Photosynthesis	20
F	Apple discolouring	25	H	Sodium chloride in water	15	D	Petroleum burning	17
G	Nail in a bleach	20	D	Petroleum burning	13	J	Cleaning of brass with brasso	17
H	Sodium chloride in water	20	F	Apple discolouring	8	G	Nail in a bleach	10
D	Petroleum burning	18	J	Cleaning of brass with brasso	8	H	Sodium chloride in water	5
A	Hydrochloric acid and sodium chloride	18	A	Hydrochloric acid and sodium chloride	3	A	Hydrochloric acid and sodium chloride	2
	Average %	34		Average %	24		Average %	25
CHEMICAL BONDING								
F	What the phenomenon electron exchange is?	83	A	What are exchange or shared during a reaction?	48	F	What the phenomenon electron exchange is?	56
A	What are exchange or shared during a reaction?	68	B	Which ion is formed when an atom loses electrons?	43	A	What are exchange or shared during a reaction?	54
B	Which ion is formed when an atom loses electrons?	40	F	What the phenomenon electron exchange is?	43	B	Which ion is formed when an atom loses electrons?	49
C	Which ion is formed when an atom gains electrons	40	C	Ion formed when an atom gains electrons	30	C	Ion formed when an atom gains electrons	46
G	Reactant transferring electrons is ...	35	G	Reactant transferring electrons is ...?	28	G	Reactant transferring electrons is ...?	27
H	Reactant accepting electrons is ...?	35	H	Reactant accepting electrons is ...?	18	H	Reactant accepting electrons is ...?	27
E	The ratio with which reactants combine depends on...	23	E	The ratio with which reactants combine depends on...	13	E	The ratio with which reactants combine depends on...	24
D	What does the transference / acceptance electrons depend on?	18	D	What does the transference / acceptance electrons depend on?	8	D	What does the transference / acceptance electrons depend on?	10
	Average %	43		Average %	29		Average %	37

Table 4.11: continues

Item	Summary of each item	E (%)	Item	Summary of each item	C ₁ (%)	Item	Summary of each item	C ₂ (%)
CHEMICAL REACTIONS								
B	Zinc in hydrochloric acid?	88	B	Zinc in hydrochloric acid?	68	H	Write chemical equation for the following reaction: Cu and conc. HNO ₃ making CuNO ₃ , H ₂ O and NO ₂ .	81
H	Write chemical equation for the following reaction: Cu and conc. HNO ₃ making CuNO ₃ , H ₂ O and NO ₂ .	83	H	Write chemical equation for the following reaction: Cu and conc. HNO ₃ making CuNO ₃ , H ₂ O and NO ₂ .	50	B	Zinc in hydrochloric acid?	73
A	Iron in copper sulphate?	83	A	Iron in copper sulphate	43	A	Iron in copper sulphate	59
C	Copper in silver nitrate?	80	E	Identify redox reaction from the following reactions: (a) 2Mg + O ₂ → 2HgO; (b) H ⁺ + OH ⁻ → H ₂ O	43	E	Identify redox reaction from the following reactions: (a) 2Mg + O ₂ → 2HgO; (b) H ⁺ + OH ⁻ → H ₂ O	59
E	Identify redox reaction from the following reactions: (a) 2Mg + O ₂ → 2HgO; (b) H ⁺ + OH ⁻ → H ₂ O	70	C	Copper in silver nitrate?	33	I	From the reactions in H, identify and write the oxidation 1/2 reaction	49
I	From the reactions in H, identify and write the oxidation 1/2 reaction	60	I	From the reactions in H, identify and write the oxidation 1/2 reaction	20	C	Copper in silver nitrate?	46
F	From the reactions in E, identify the oxidizing agent	55	F	From the reactions in E, identify the oxidizing agent	20	J	From the reactions in H, identify and write reduction 1/2 reaction	42
D	Copper in sodium chloride?	53	F	Copper in sodium chloride?	18	F	From the reactions in E, identify the oxidizing agent	27
J	From the reactions in H, identify and write the reduction 1/2 reaction	53	K	From the reactions in I and J, write net- reaction	18	K	From the reactions in I and J, write net- reaction	27
K	From the reactions in I and J, write net- reaction	35	G	From the reactions in E, identify the reducing agent	15	D	Copper in sodium chloride?	24
G	From the reactions in E, identify reducing agent	25	J	From the reactions in H, identify and write reduction 1/2 reaction	10	G	From the reactions in E, identify reducing agent	5
	Average %	62		Average %	31		Average %	45

Note: E group (n = 40); C₁ group (n = 40); C₂ group (n = 41); Percentages have been rounded off.

- Item J, dealing with cleaning of brass with brasso, ranked four, eleven and nine for E, C₁ and C₂ respectively, improved from 15 % to 37.5 % for E and C₁ declined from 13 % to 8 % while C₂ attracted 17 % of the correct responses.
- Item F, dealing with the apple discolouring, ranked ten for E and C₁ and five for C₂, obtained 15 % E and 10 % of the correct sores. The students' slightly improved from 15 % to 25 % for E, declined for C₁ from 10 % to 8 % while C₂ attracted 25 % of the correct responses. There was no change in their conceptions as they still regarded this reaction as a precipitate.

- Item D, dealing with petroleum burning, ranked eleven, nine and eight for E, C₁ and C₂ respectively showing a decline from 30 % to 18 % and 18 % to 13 % for E and C₁ respectively while C₂ attracted 18% of the correct responses.
- Item G, dealing with a nail in water bleach, ranked eight, seven and ten for E, C₁ and C₂ respectively showed an improvement from 13% to 20 % for E and a decline declined from 23 % to 15 % for C₁ while C₂ attracted 10 % of the correct responses.
- Item H, dealing with sodium chloride in water, showed a slight improvement from 18 % to 20 % and 10 % to 15 % for E and C₁ respectively while C₂ attracted 5 % of the correct responses, ranking eight, seven and eleven.

Looking at the overall performance of these groups, 35 %, 24 % 26 % for E, C₁ and C₂ respectively, E outperformed C₂ and C₂ in turn outperformed C₁.

Clearly, even though an example of an Everyday Life Reactions, fluoridation, had been used during the intervention, and most of the reactions on this theme were used as examples, students were still holding on to their misconceptions such as discolouring of an apple being caused by bacteria which sits on a cut apple causing it to be brown and old. In a similar study, Soudani et al. (2000), came up with similar findings, i.e. students held to their misconceptions. According to Soudani et al. (2000):

- (i) Students have probably never been required to make chemical interpretations of everyday phenomenon, nor to consider the relationship between biological phenomenon (respiration and photosynthesis) studied during biology courses... (ii) Curricula, textbooks and exams tend to concentrate on moving students up into higher classes, rather than training the scientific mind (p. 70).

According to Stavridou & Solomonidou (1998):

If chemistry teaching is to improve the way pupils comprehend common-sense conceptions, it is important to confront common-sense conceptions, and to encourage pupils to apply and use scientific concepts to describe and explain everyday life phenomena and situations in a more systematic way.

4.6.2.2 Chemical Bonding

This theme consisted of 10 items. Two of these items had to be removed after the pre-test as the students found them vague and confusing. These were (i) item C, “if the reactant, which had transferred electrons, was a positive ion it will become a ...”. (ii) Item E, “if the reactant, which has accepted electrons, was a negative ion it will become a ...”. This caused a change in item numbering, i.e. item D became C, F (D), G (E), H (F), I (G), and J (H).

As mentioned in section 4.3.4, the students’ understanding of chemical bonding was explored through the use of a cloze test. The use of a cloze test was meant to test the students’ reading and comprehension abilities. The reading ability of the students was analysed using the Bormuth’s readability category (see Tesfai, 2001) in terms of independent, instructional and frustrational readability levels. As stated earlier independent readability level is when students can read and comprehend, instructional readability level is when students can only read and comprehend if assisted by the teacher and frustrational readability level is when students cannot read or comprehend and might fail to show progress even with the teacher’s assistance. The readability analysis for this theme is presented on Table 4.12.

A close examination of Table 4.12 shows that 2.5% of the students from group E fall within the independent reading level. However, none in C₁ and C₂ belong to this category. This implies that only 3 % of the students in E could read and comprehend without the assistance of the teacher. About 3 % and 2 % for E and C₂ respectively fall within the instructional level. This implies that only a small percentage in E and C₂ was able to comprehend the passage with some assistance from the teacher. About 94 %, 100 %, and 98 % for E, C₁ and C₂ respectively fall within the frustrational reading level.

On average, about 97 % of the students fall within the frustrational level. This implies that the majority of the students in each group probably experienced difficulties in understanding the concept of chemical bonding. This also implies that despite the intervention, only a small percentage in each group improved their reading and comprehension abilities. This is further confirmation of earlier studies that deficits in reading and comprehension cannot easily be ameliorated within a short instructional intervention (e.g. see Tesfai, 2001; Tewolde, 2001). For further comparison of the three groups in the Chemical Bonding Theme, the results obtained by the students presented in Table 4.11 are examined below.

Table 4.12: The Mean Close Test for the Chemical Bonding Theme at the Post-test Stage

Scores	E n (%)	C ₁ n (%)	C ₂ n (%)	Description
90-100	1 (3 %)	-	-	Independent Level
80-89	1 (3 %)	-	1 (2 %)	Instructional Level
75-79	-	-	-	
60-74	4 (10 %)	2 (5 %)	2 (5 %)	Frustrational Level
50-59	3 (8 %)	2 (5 %)	1 (2 %)	
40-49	5 (13 %)	4 (10 %)	5 (12 %)	
30-39	6 (15 %)	14 (35 %)	9 (22 %)	
16-29	15 (38 %)	8 (20 %)	18 (44 %)	
0-15	5 (13 %)	11 (27.5 %)	5 (12 %)	
Total	40	40	41	

N.B: Percentages were rounded off;

Table 4.11 shows that there has been an overall improvement on the students' performances from pre- to post-test, i.e. from 19 % to 43 % and 23 % to 29 % for E and C₁ respectively while C₂ obtained 37 %. Group E outperformed the other groups followed by C₂ and lastly C₁. The students' performance in this theme during post-test ranged between 18 % to 83 %, 8 % to 48 % and 10 % to 54 % for E, C₁ and C₂ respectively. Item D, dealing with finding out whether students knew what transference or acceptance of electrons depends on, as in the pre-test stage, attracted the least correct responses, 18%, 8 % and 10 % for E, C₁ and C₂ respectively. Item F, assessing whether students knew what the phenomenon of the transference of electrons is, attracted the most responses, 83 %, 43 % and 56 % for E, C₁ and C₂ respectively ranked one, three and one. This was followed by item A, concerned with whether students knew what is transferred or exchanged during a reaction, which attracted 68 %, 48% and 54 % for E, C₁ and C₂ respectively raking two, one and two. The other items followed in the following sequence:

- Item B, concerned with finding out if students knew which ion is formed when an atom loses electrons, improved from 15 % to 40% and to 43 % for E and C₁ respectively while C₂ obtained 49 % of the correct responses ranking three, two and three respectively.
- Item C, attempting to assess whether or not students knew which ion is formed when an atom gains electrons, improved from 25 % to 40% and 13 to 30 % for E and C₁ respectively while C₂ obtained 47 % of the correct responses ranking four.

- Item G, dealing with finding out whether students knew what the reactant transferring electrons is, improved from 8 % to 35 % and 18% to 28 % for E and C₁ respectively while C₂ obtained 27 % of the correct responses ranking five.
- Item H, dealing with finding out whether students knew what the reactant accepting electrons is, improved from 8 % to 35 % for E, C₁ remained at 18% while C₂ obtained 27 % of the correct responses ranking six.
- Item E, dealing with finding out whether students knew the ratio with which reactants combine depends on, ranked seven showing a decline from 25 % to 23 % and 30 % to 13 % for E and C₁ respectively while C₂ attracted 25 % of the correct responses.

The concepts of items D and E (valency and electronegativity) are introduced in grade ten after which there is no mention of them again. One would expect the students to understand and be able to apply them. Knowing that most students tend to compartmentise their studies, (see Aikenhead & Jegede, 1999) this could be the reason for their poor performance on these two concepts. Although these two concepts, valency and electronegativity, were revised during the lessons, it is obvious from their responses that the students did not seem to find the information meaningful enough for them to grasp, probably because they lacked underlying sub-concepts.

4.6.2.3 Chemical Reactions

A close examination of Table 4.11 indicates that in this theme, students' performances improved exceptionally well. During the pre-test stage five items had no correct responses. The overall performance improved from 9 % to 62 % and 8 % to 31 % for E and C₁ respectively while C₂ scored 45 %. The students' performance at the post- stage ranged between 25 % to 88%, 10 % to 68% and 5 % to 81 % for E, C₁ and C₂ respectively. Item G, dealing with assessing whether or not students could identify an oxidizing agent from a reaction presented in item E, attracted the least correct responses of 25 %, 15 % and 5 % for E, C₁ and C₂ respectively, at the post-test stage ranking eleven for E and C₂ and ten for C₁. Item B, assessing whether students could write a chemical equation, complete and balance the word reaction of zinc dropped in a solution of HCl acid giving an explanation for the products, attracted the most correct responses, 88 %, 68 % and 73 % for E, C₁ and C₂ respectively ranking one for E and C₁ and two for C₂. Although improvement was shown on this item, some students still showed an inability to write formulae, i.e. they wrote the products as ZnCl + H, instead of ZnCl₂ + H₂. Ogunniyi (1999) found that when students were required to complete the reaction of Z + HCl, they obtained 9 % of the correct responses. This is an indication that students generally

have a problem of writing chemical equations. This can be attributed to their inability to read a periodic table, as well as not knowing valence electrons and their use in the way compounds are formed. The other items were in the following sequence:

- In item H, students had to write the chemical equation for a word reaction of $\text{Cu} + \text{HNO}_3$. Groups E, C_1 and C_2 obtained 83 %, 50 % and 81 % respectively, ranking two for E and C_1 and one for C_2 .
- Item A, requires that the students write a chemical equation, complete and balance the word reaction of iron dropped in CuSO_4 solution. Groups E, C_1 and C_2 obtained 83 %, 43 % and 59 % respectively ranking three.
- Item E, demands that the students identify redox reaction from the following reactions: (a) $2\text{Mg} + \text{O}_2 \rightarrow 2\text{HgO}$; (b) $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$. In this item groups E, C_1 and C_2 obtained 70 %, 43 % and 59 % respectively, E, C_1 and C_2 obtained ranking five for E and three for C_1 and C_2 .
- Item C, attempts to determine whether or not students could write a chemical equation, complete and balance the word reaction of Cu in AgNO_3 . In this item groups E, C_1 and C_2 exhibited 80 %, 33 % and 46 % of the correct responses, ranking four, five and six.
- Item I, required the students to identify and write the oxidation half reaction from the reaction in H. This item attracted about 60 %, 20 % and 49 % of the correct responses by E, C_1 and C_2 respectively, ranking six for both E and C_1 and five for C_2 .
- Then item J, where students were required to identify and write the reduction half reaction from the reaction in H attracted about 53 %, 10 % and 42 % of the correct responses for E, C_1 and C_2 respectively ranking eight, eleven and seven.
- Item F, dealing with assessing whether or not students could identify the reducing agent from a reaction presented in item E, attracted the least correct responses of 55 %, 20 % and 27 % of the correct responses for E, C_1 and C_2 respectively ranking seven for E and eight for both C_1 and C_2 .
- Item D assessing whether students could write a chemical equation, complete and balance the word reaction of Cu in NaCl , attracted 53 %, 18 % and 25 % of the correct responses from E, C_1 and C_2 respectively, ranking eight for E and C_1 and ten for C_2 .
- Item K, where students were required to use reactions in item I and J to write the net reaction, was the second last, attracting 35 %, 18 % and 27 % correct responses from E, C_1 and C_2 respectively, ranking ten for E and nine for C_1 and C_2 .

The outstanding performance of the students in items B, H, A and C come as no surprise as these reactions have a hissing, bubbling or colour change. Such reactions seem to be more recognisable and remembered by the students than concepts that do not exhibit concrete referents. This further confirms the findings by Driver, Asoko, Leach, Motimer & Scott (1994) that students tend to recognise that a chemical reaction has occurred if there is a hissing, bubbling, blowing or colour change.

In examining the overall performances of the three groups (see Table 4.11), group E outperformed the other two groups obtaining 62 % of the correct responses followed by group C₂ with 45 % then group C₁ with 31 %. In all the items, Group E outperformed group C₁ and C₂. With the exception of items B and G (where C₁ outperformed C₂) C₂ outperformed group C₁ in all items.

Two problems emerged on this theme. They are: (i) the students' inability to write formulae of compounds accompanied by ignoring the laws and theories that give meaning to chemical symbols (Yarroch, 1995). (ii) the students' inability to explain their observation though some used analogies in explaining the phenomenon in question (Hesse & Anderson, 1992). With regard to their observations on the reaction of Zn + HCl solution, here are some of their explanations:

S₁: Gas is released from this reaction all the time doing it.

S₂: Since gas is given off it is given that its hydrogen as it is only gas in reactants.

The students who did not give any explanation for their observations might have memorised the observations based on the fact that they had done the reactions either as experiments in class or as part of homework. Also, it seems that the students could not find the connection between their observations and the explanation given by the teacher in class or by the textbook and hence could not offer the correct responses to the tasks in question. Ahtee & Varjola (1998) pointed out that in the case of chemical reactions, students tend to have a cognitive conflict between the observations made in the real macroscopic world and the theoretical explanations of the microscopic world.

The students' performance on the theme on Chemical Reactions confirms what Hesse & Anderson (1992) have found. Hesse & Anderson asserted that:

We found that students have great difficulty in changing their thinking when they are asked to jump from the phenomenological level of chemistry (i.e. observable changes in substances) to the atomic molecular level, which explains observable changes in terms of the interactions between

individual atoms and molecules. This lack of mobility across the levels of chemistry created other problems for students as well (Ben Zvi et. Al. p.279).

4.7 CAREER

With respect to career interest, the performances of the students varied from career to career (see Table 4.13 below). For ease of reference, the careers indicated by the students have been arranged in a descending order. The percentages range between 40 % and 54 % while SD range between 2.60 and 6.64. A close examination of Table 4.13 reveals that the students wanting to pursue scientific careers performed best (54 %). They were followed in a descending order by those aspiring to pursue careers in social services (53 %), medicine (48 %), business (45 %), technology (42 %) and lastly engineering (40 %). This finding is different from those found in earlier studies where the technology group outperformed the other career groups (e.g. Ogunniyi, 1999; Ogunniyi & Fakudze, 2003). This could also be due to the fact that the students involved in this study are quite different to others in other studies. As pointed out earlier these student are repeaters of grade 12, they are poorly motivated and regard themselves as failures.

Table 4.13 Students' Performance at the Post-test According to Career Interests.

Career	N	N %	Mean	Mean %	S.D
Sciences	12	10	17.8	53.8	4.90
Service	10	8	17.4	52.7	6.64
Medical field	47	39	15.9	48.2	5.51
Business	5	4	14.8	44.8	3.66
Technology	16	13	13.9	42.0	2.60
Engineering	32	27	13.1	39.7	4.50
Total	121	100	15.16	45.9	4.69
F _(5,115) = 2.50 at P = 0.05			F _{crit} = 2.22		

As can be observed in Table 4.13 the F-ratio of 2.50 for the six career groups at post-test stage exceeds F-critical of 2.22 needed to reject the null hypothesis. This suggests slight significant differences among the six career groups.

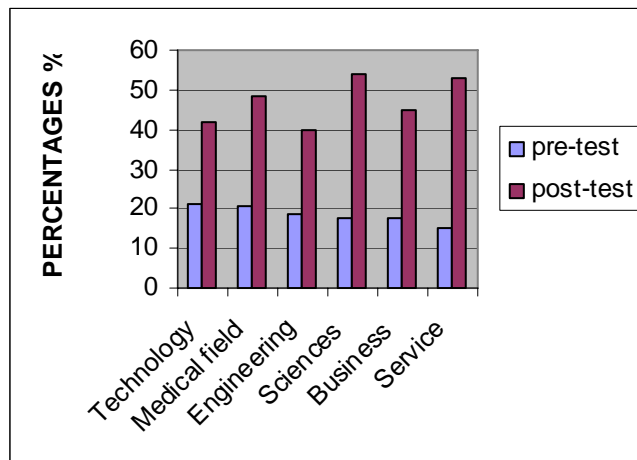


Fig. 4.1 Students' Performances at the Pre- and Post-test Stage According to Career Interests

Looking at Fig.4.1, it seems that there is a great difference between the students' performances at pre- and post- stage in terms of career interest. At the pre-test stage the students interested in technology and the medical fields outperformed the others and while those interested in business, science and services obtained the lowest scores. But at the post-test stage, it was the opposite with students interested in the sciences and services (including teaching) obtaining the highest scores and those interested in technology and engineering obtaining the lowest scores.

4.8 GENDER

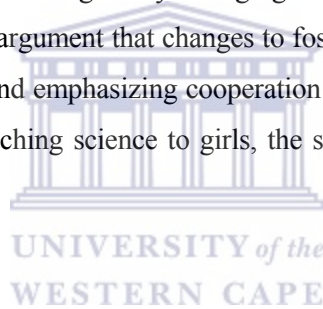
Based on a series of studies related to gender and science/technology, Sjoberg (1996) suggests that:

If we think that girls and boys are brought up to hold different values and beliefs, or even stronger, that they constitute different sub – cultures and hold on to their 'world – views', then it would be very important to add the gender perspective to this area of research (p. 239).

Women come to know and perceive reality in ways different to boys. Viewing knowledge from the perspective of women is helpful to an understanding of girls' beliefs and decisions regarding science. According to Woolfolk cited by Chiappetta, Koballa & Collette (1998), from a very young age, children begin to form general schemas or organised networks of knowledge about what it means to be male or female. Parents tend to give boys technological toys like cars, aeroplanes, guns, and so on while girls are given dolls, tea-sets and so on. As children grow older these schemas develop and they also influence students' interests and preferences for school subjects. Girls tend to chose less demanding, less challenging

and less complex subjects which do not enhance their potential for science and related fields, whilst boys tend to go for the demanding, challenging and complex ones like science (Chamdimba, 1994).

Gender schemas indicate that science has a masculine image. Harvey & Edwards, Rennie, Parker & Kahle cited by Chiappetta et al. (1998) claimed that girls are usually, but not always, more interested in biological sciences and not in physical science than boys. This is further supported by Sjoberg (1996) who asserts that biology is more popular among girls, chemistry is more neutral, and physics is the most problematic from a gender perspective, enjoying little popularity from both boys and girls. Kelly (1987) suggests that girls are more turned off by the physical sciences because of lack of self-confidence and fear of failure associated with the difficult nature of physical science. According to Chiappetta (1996) if credence is given to women's ways of knowing, then fundamental changes are needed in the way in which science is presented in schools. Science should be presented in such a way that students see it as a human construction and that what is written in textbooks and recorded in videos is not to be accepted as truth. The traditional sciences need to be made more attractive to girls by changing the image of science presented in science classrooms. I concur with Chiappetta's argument that changes to foster feminine science include attending to the social and moral issues of science and emphasizing cooperation and caring rather than competition in all school science activities. In science teaching science to girls, the social, personal, and creative aims of the individual should be taken into account.



With the Governments' emphasis on girls doing science and technology and the need for girls and women in science projects advocated, there has been a growth in the number of girls doing science. This has resulted in the current situation where science classes are female dominated, and a lot of women are venturing into the scientific fields. In this study 62.8% of the participants were girls and 37.2% were boys. The statistics may reflect the current school population or may well show that in the so called "Finishing School" for the matric failures (as was the case in the present study) the girls were the most dominant or the Government may be succeeding in its advocacy for girls to follow science and technology fields. Whatever the case may be one would expect that the emphasis should not be only on the quantity but quality as well.

To encourage girls to do science without providing the necessary support systems would only result in mass failure of girls in science. Census figures show that there are more women than men in South Africa, it seems reasonable that an increase in women scientists will result in an increased skilled scientific and technological human power critically needed in modern economy. It is also worth noting that though the

differences in performance between the girls and the boys are not statistically significant, the former seem to obtain higher mean scores at the pre- and post-test stage (see Table 4.14 below). This finding is similar to what was found earlier (Ogunniyi, 1999). But this positive picture on account of the girls may not go beyond the secondary school level in that even the girls who perform well in science for one reason or the other might not pursue scientific careers at the tertiary levels. According to Ogunniyi (1999) the smart girls tend to pursue the softer sciences or change their career paths by pursuing business fields rather than science.

Table 4.14: Students' Performance at the Pre-and the Post-test Stages According to Gender

Gender		N	Mean	Mean %	SD	t-test
Female	Pre-test	50	6.62	20.1 %	2.52	$t_{\text{obs}} = 0.13 < t_{\text{crit}} = 1.99$
Male		30	5.97	18.1 %	2.40	
Female	Post-test	76	12.3	37.2 %	4.92	$t_{\text{obs}} = 0.64 < t_{\text{crit}} = 1.98$
Male		45	12.0	36.2 %	4.65	

4.9 STUDENTS' PERCEPTIONS OF THE LESSON ON REDOX REACTIONS

Studies done specifically to determine students' perceptions of science lessons are relatively few (Mbajoorju, 1999) compared to those concerned with determining students' understanding of certain scientific concepts (Gallant, 2003; Ogunniyi & Mikalsen, 2003; Ogunniyi & Taale, 2003) or students' attitudes towards science (Taiwo, 1996). For the students' perceptions of the lesson on redox reactions, three statements were provided and the students had to either agree (A) or disagree (DA) and give an explanation for their choices. Of the 142 students given this questionnaire, 66 students returned them. The responses of the 66 students are tabulated in Table 4.15 below and are ranked according to the students' preferences.

A close examination of Table 4.15 indicates that 86 % of the students found the experiments helpful in their understanding of the concept, while 8 % disagree and 6 % gave no opinion. Of the statement, "the way the first lesson was presented was interesting, and has made me to understand how reactions occur much better", 83 % of the students agree, 14 % disagree whilst 3 % offered no opinion. For the statement, "I can identify a redox reaction, oxidation half reaction and reduction half reaction with ease", 82 % of the students agree, 14 % disagree whilst 4 % did not respond. Looking at these results one can deduce that the students were satisfied with the manner in which the lesson was presented. Although they were required to provide an explanation for their responses, very few did.

Table 4.15: Students' Perceptions of the Lesson on Redox Reactions

STATEMENTS	A (%)	DA (%)	NO (%)
Experiments helped me to have a better understanding of the concept.	86	8	6
The way the first lesson was presented was interesting, and has made me to understand how reactions occur much better.	83	14	3
I can identify a redox reaction and the oxidation half reaction and reduction half reaction with ease.	82	14	4
SUBTOTAL	84	12	4

N B: Percentages have been rounded off; NO = No Opinion

Quite a number of the students' primary concern was passing the test or the examinations. It is doubtful whether they would still remember the experiments performed during the lesson after they had finished writing the test or examination. This can be attributed to the fact that the grade 12 syllabus is examination driven and emphasis is on whether or not they pass the examination. The following excerpts corroborate this opinion:

- *S₁: Because when with your own the experience is easy to understand and easy to remember when writing exams (E).*
- *S₁: Because when you do it practical, when you write it not need to read because you remember every thing that you have been done (C₁).*
- *S₁: Because when you do oxidation it is always easy to understand and it is easy to remember when you writing test (C₂).*

Some students stand a better chance of retaining the knowledge gained by doing the experiments as their primary concern is based on having a better understanding of the concepts taught. These students see experiments as a tool to enhance and supplement the knowledge gained in the lesson. The following reasons were given by the students:

- *S₂: Because experiments gives me idea or more understanding about this lesson or concept about it. It helped me to have a better understanding of concept and know things (E).*
- *S₂: Yes because I see the colours and the masses maybe mass decrease or increase also a positive colour (C₁).*

- *S₃: Because I know how to identify which is an oxidising agent or which is a reducing agent. I know the donation of electrons (C₁).*
- *S₂: It's practical work for me there is no need for study or go over the book after the experiment. It is very easy to recall what you did practically than what you heard (C₂).*
- *S₃: Because I know to explain about experiment that I've done, when I'm doing it is not easy to forget it (C₂).*

Few students disagreed with the statement giving the following reasons to support their opinions.

- *S₃: Find it difficult to do it (E).*
- *S₄: Because I don't understand clearly the experiment and it is not is to remember when you are writing (C₁).*
- *S₄: Because I didn't understand the experiment of redox reaction (C₂).*

The statement, "The way the first lesson was presented has made me to understand how reactions occur much better" ranked two. The majority of students agreed with the statement as they found the lesson to be easy, interesting and easy to understand as well as made them to understand how reactions occur much better. Here are what some of them said:

- *S₁: This lesson is easy to me that is why I'm so interested and has made to understand the reactions occur much more better (E).*
- *S₂: Because was more interesting of the lesson (C₁).*
- *S₁: Because the first lesson it easy to understand (C₂).*

This group of students felt that the lesson gave them more knowledge and thus helped them to understand the next and other related topics better.

- *S₂: Because if you don't understand the first lesson, you can't understand the whole lesson. It is giving us a knowledge (E).*
- *S₄: Because it helped me to have a better idea of were I am lacking (E).*
- *S₃: At first I was confused about the electrons that donate and accept by another solution. But as we go along the chapter it interest me and I understand it very well (C₁).*
- *S₂: It was a bit easy and you get to expand your knowledge much easier. You also get to know how to measure voltmeter reading. You differentiate solutions (C₂).*

A small number of students involved in the study attributed their improved understanding of the lesson to the manner in which the lesson was presented to them as well as a change in their attitude.

- *S₅: It is better presented and interesting and made me to understand because can be remember the solution of reaction and changes (E).*
- *S₅: Presentation of the lesson kept me interested to have an eager of what will follow and collaborating these types of reaction with other reactions (C₁).*
- *S₅: Because the teacher who thought me was nice and she has a patience to the students so she makes me always interested in her subject (C₂).*

Some of the students disagreed with the statement reasons being that they did not understand the lesson and thus did not find it interesting. Some felt they need more lessons on the topic.

- *S₃: Even in the start I don't understand whats going on in this chapter (E).*
- *S₆: Didn't understand the lesson (C₁).*
- *S₇: I was not interested because on that time I was not understand but as the lesson continues I understand a little bit (C₁).*
- *S₄: I don't know how reactions occur I just don't understand them. I want more lesson of the reaction (C₂).*

Two students (3 %) felt that more time should have been allocated for the topic. They also felt that it did not accommodate the so-called 'slow learners'.

- *S₆: The chapter was conducted in a short phase and I'm not that good at catching things in such short time (E).*
- *S₆: The lesson was interesting but to me some of the lesson I didn't understand as I'm a slow leaner (C₂).*

The statement, "I can identify a redox reaction and the oxidation half reaction and reduction with ease" was ranked last. The reasons for the students' choices on this item were the as follows:

- *S₄: It is ease to me, because I know what is a redox reaction and also know to identify oxidation and reduction half reaction (E).*
- *S₁: Because of my book it is differentiating what is redox reaction, oxidation half reaction and reduction half reaction I can differentiate between the reaction (C₂).*

These students seem to have developed a positive attitude towards the topic, which could be a contributing factor to their finding the lesson easy, thus having a better understanding of the concepts involved as shown below:

- *S₁: Yes I can because I understand it now better than before. It's easier for me to differentiate between them (E).*
- *S₁: It was the chapter that I like because I understand better than before. It is easy to differentiate them than others (C₁).*

As can be seen in the following comments, one can deduce that the knowledge gained by the students in the lesson was meaningful to them:

- *S₂: I can spot when the reaction is oxidation or reduction, and can write nett reaction of equation. My difficulty is when I'm suppose to pick the half reaction on the standard redox table (E).*
- *S₃: Because I know how to differentiate the redox reaction and oxidation half reaction I can also know how to do other reactions (C₁).*
- *S₂: Because it helps to make sense of the many terms in a chapter and organise them in a meaningful way (C₂).*

Also from the statements listed below it seems obvious that the students were able to identify the reactions by using the Standard Electrode Potential Table. Whether or not they understood how these reactions occurred so as to be able to apply the information on other related topics is quite another matter. The following statements reflect their views:

- *S₇: I understand redox reaction. I know in my table where is oxidation and reduction and I know oxidation loss electrons and reduction accept electrons (E).*
- *S₅: It's very easy to identify redox reaction and the oxidation half reaction and reduction half reaction with ease according to the electrochemical cell and standard redox potential table (C₁).*
- *S₃: They are much easier understandable when you use a table 4 (C₂).*

With this group of students, it seems that they liked the way the teacher presented the lesson because it facilitated their conceptual understanding of the topics in question:

- *S₅: The way she teaches me know I have got a clear understanding in her subject (E).*
- *S₅: It is easy to understand and identify redox reactions, oxidation and reduction half reaction. The teacher was interesting and good in teaching them (C₂).*

One cannot be sure whether these students are just verbalising their responses or really understand these terms. Instead of addressing the question, they wrote definitions, which were in their notes (e.g. see Duran et. Al., 1998).

- *S₈: Because I know the oxidation loose electrons reducing gain electrons and redox reaction is about reduction agent and oxidation agent (E).*
- *S₂: I can identify them quite easily by gaining and loss of electrons to generate energy (C₁).*
- *S₄: Reducing agent is loses electron by substances. Redox reaction in term of electron transferring reaction (C₂).*

The few learners who disagreed with this statement seemed to be confused not knowing what reaction was what. Probably they would understand better when doing remediation, as they claim they need more explanation.

- *S₉: Not yet I am still confused may be if our teacher can explain it to me once more then I think I can have a better understanding (E).*
- *S₆: Because I didn't understand clearly the time we do it in the classroom (C₁).*
- *S₇: I have a little confusion. I take reduction as oxidation so I am trying very hard to differentiate the two of them (C₂).*

From the analysis of Table 4.15, it seemed clear that the majority of the students agreed with all the three statements about the lesson to which they were exposed. To be precise, 83.4% of the students unanimously agreed that the lesson was presented in a very interesting way and made them to have a better understanding of how the reactions occurred. They claimed that they could now identify the reactions involved in the lesson and would be able to apply the information in other related topics. To them, the experiments conducted helped to enhance their understanding of redox reactions and the oxidation and reduction half-reactions. The explanations given by these students, further confirm the success of the lesson. However, looking at some of the CAT responses, some of these students seemed to confuse reducing or oxidising agent with reduction and oxidation. These are some of the excerpts:

Oxidation occurs on the oxidising agent.

The reactant that transfers electrons is oxidising and the one that accepts them is reducing.

This was also one of the findings of a study conducted by Schmidt & Volke (2003) among senior high school students.

However one cannot rule out the 11.6 % that disagreed with these statements. Some of the students especially the “slow learners” complained about the time being insufficient. This fact has been acknowledged as one of the limitations of the study. It is hoped that the remediation lessons would address these limitations so that no student would be disadvantaged on the long run. A further discussion of the data will be done in chapter five.

4.10 SUMMARY OF THE RESULTS

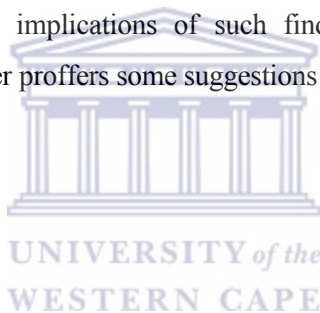
1. At pre-test stage there was no significant difference between the scores of the experimental (E) students and control one (C_1) students.
2. At post-test stage there was a significant difference between students exposed to the treatment, i.e. concept mapping (E and C_2) and those exposed to expository method (C_1).
3. The experimental group students performed better than the control group students whilst the C_2 students performed better than C_1 students.
4. The experimental group students tended to achieve higher scores than the control group students on multiple-choice questions based on the theme everyday life reactions but the control group students (C_2) slightly outperformed those of C_1 .
5. On the theme “chemical bonding”, the E group outperformed the control group students followed (i.e. C_2 and C_1 respectively).
6. On the theme “chemical reactions”, the experimental group, E, tended to perform better followed by C_2 and lastly C_1 .
7. In examining the students’ reading and comprehension ability, the E group students seemed to have a better reading ability than those in C_2 then C_1 respectively. Although the majority of the students fell under the frustrational level, 3 % of E fell under the independent level while 3 % of E and 2 % of C_2 fell under the instructional level.
8. There was no significant difference between the scores achieved by the boys and by the girls, although performance seemed to favour the girls.
9. There was a slight significant difference in the performance of the students relative to career interests with the science group achieving the highest score, followed by those interested on services (including teaching), medical field, businesses, technology and lastly engineering.
10. Most of the students claimed that concept mapping enhances their understanding of chemical reactions, especially redox reactions.
11. On the fluoridation debate, as much as the students understood the health risks accompanied by use of fluoridated water, for economical reasons they still preferred its use.

CHAPTER 5

SUMMARY, CONCLUSION AND IMPLICATIONS

5.1 INTRODUCTION

The main goal of this study was to explore grade 12 students' conceptual understanding of chemical reactions, using concept mapping as a teaching tool. Also, discussion on fluoridation, a currently controversial subject was used as a catalyst to foster the students' understanding of, and interest in studying chemical reactions. In addition the effects of gender and career interest on the students' conceptual understanding of chemical reactions were examined. In chapter one, the questions pertaining to this study were raised. In chapter two, the theoretical framework in which the study was situated was discussed in detail while in chapter three the methodology used in collecting the data are described. In chapter four, the results based on the quantitative and qualitative data are analysed and discussed. This chapter summarises the major findings and examines the implications of such findings for curriculum development and instructional practice. Finally, the chapter proffers some suggestions for various stakeholders.



5.2 SUMMARY OF FINDINGS

As outlined in chapter three, three groups of grade 12 students consisting of the experimental group (E), the control groups 1 (C_1) and control group 2 (C_2) participated in the study. Groups E and C_1 wrote a pre-test while C_2 (controlling the pre-test effect) did not write the pre-test. Both E and C_2 were exposed to concept mapping while C_1 , the true control group was not so exposed. The major findings of the study are presented below:

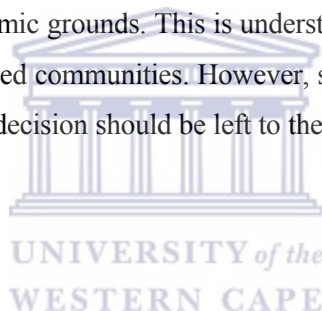
- Based on the pre-test data, there was no significant difference between the performances of groups E and C_1 , i.e. they were quite comparable.
- At the post-test level, however though there was an improvement in the performance in both E and C_1 , the former clearly outperformed the latter in most of the items. This was probably due to the fact that E was exposed to a combination of exemplary instructional materials, (including concept mapping) while

C_1 was exposed to the exemplary instructional materials only. The significant difference between E and C_1 were therefore attributed to concept mapping to which the former was exposed.

- Group E also outperformed group C_2 in 32 of the 33 items although they were both exposed to the treatment. Since they were exposed to the same treatment, one would expect not to find any significant difference between their performances. This difference might partly be due to the residual effect of the pre-test on E, which C_2 was supposed to nullify. However this awaits a closer scrutiny. Also, the assumption that both groups were comparable, might not actually be valid. One also cannot rule out the differences in the culture of learning and class related factors between the two groups. The enthusiasm shown by students towards their work has a great effect on how they learn as well as their performance. A further study on the students from these groups might show a difference in their culture of learning or classroom environment which might have had an effect on their performances. However, this issue is beyond the scope of this study.
- In the case of C_1 and C_2 , the former outperformed the latter in 31 of the 33 items. This probably was due the fact that group C_2 was exposed to the full treatment while C_1 was not so exposed.
- Although generally, concept mapping seems to have had a positive effect on the understanding and learning of the students, judging by the few negative comments made by some of the students, concept mapping can sometimes complicate rather than facilitate knowledge acquisition (Brandt et al., 2001).
- From the analysis of the questionnaires as well as the interviews, it seems clear that the methods (i.e. concept mapping for E and C_2 , the Prediction-Observation-Explanation method during experiments as well as the use of fluoridation for all three groups) employed during intervention in this study seems to have had a significantly positive impact on the students' understanding of the concept of chemical reactions.
- Many of the students found the use of concept mapping to be useful in helping them to understand not only the concept in question, but also other related concepts as well as in the study of other subjects. They found concept mapping to be a useful tool for revision.
- Looking at the students' reading abilities, at the pre-test stage it was obvious that most of the students could not read nor comprehend well even with the assistance of the teacher. However, at the post-stage there was a slight improvement, where a very small percentage of students from E could read and

comprehend without the teachers' assistance. Also, a small percentage of students from E and C₂ were able to read and comprehend with some assistance from the teacher. The majority of the students in E and C₂ and all the students in C₁ still experienced difficulties in reading and comprehending the passages given to them. This finding implies that the students will have difficulties in understanding chemical reactions, as they are likely to experience difficulties reading or comprehending the textbook.

- In both the pre-test and post-test, there was no significant difference between the performances of the girls and the boys involved in this study.
- The students' career interests (perhaps a reflection of their abilities) seemed to influence their performance at the pre- and post-test stages.
- From the discussions and interview on fluoridation it appeared that the students understood the benefits and the risk of drinking fluoridated water. But most of them preferred fluoridated water for the prevention of tooth decay on economic grounds. This is understandable considering the fact that most of the students came from disadvantaged communities. However, some cautioned that in view of the health risks of fluoridated water, the final decision should be left to the communities concerned and the national government.



5.3 INSTRUCTIONAL AND CURRICULAR IMPLICATIONS OF THE FINDINGS

Looking at the data provided in chapter four, one could see that students seemed to have made a significant attempt to make sense of the concepts involved in this study. They even did their best in debating and trying to understand fluoridation as well as attempting to use concept mapping as a learning tool. While the constructivist perspective focuses primarily on actions of the student in constructing or developing information, teachers, curriculum developers and textbook writers also influence learning outcomes (Garnet & Tregust, 1992). These professionals need to select and organise learning materials in such a way that students can easily access such materials. The significant role of textbooks in the teaching-learning process has been well attested to in the extant literature (e.g. Ogunniyi, 1999; Ogunniyi & Taale, 2004; Ogunniyi & Mikalson, 2004; etc).

The foregoing results suggest that there is a need for teachers to consider using a combination of instructional strategies (including concept mapping) in their teaching. Also, the results of this study suggest that traditional expository method is not as effective as the alternative method in which concept mapping plays a significant role in helping students learn the concept of chemical interactions (e.g. see Hesse & Anderson, 1992). At the beginning of this study the students had a poor understanding of chemical interactions and associated concepts. For the main reason that they were matriculation (matric) failures, they lacked the necessary motivation for their study. However, in view of the outcomes of this study, it is apposite to suggest that the instructional approach adopted in the study could serve as a useful means to motivate them in developing a positive attitude towards their studies. As their achievement improves as a result of their conceptual understanding, they might become more confident to find their study a meaningful learning experience (e.g. see Horton et al., 1993).

As has been confirmed in a plethora of studies, concept mapping (a pedagogy built in Ausubel's meaningful learning theory e.g. Novak & Gowin, 1984; Ebenezer & Conor, 1998; Tesfai, 2001; Tewolde, 2001) enhanced the students' understanding of chemical reactions. The potential of this instructional tool for enhancing students' understanding of other science concepts is worthy of further consideration.

As a practice based on constructivist epistemology, the construction of concept mapping by students could help them interrogate their prior knowledge and to seek for ways to make necessary adjustment in their own understanding of a given phenomenon. The process whereby students seek for a meaningful integration or incorporating the new conceptual understanding into their overall cognitive structure is what Ogunniyi (1995, 2002, 2004) calls contiguity learning or what Aikenhead & Jegede (1999) call smooth border crossing and/or secured collateral learning process. However, relevant as these are, the focus of this study and space limitation (as indicated in chapter 2) would not permit any further elaboration on these learning theories at this stage of this report.

In teaching any concept the teacher should not only consider the students' prior knowledge of the concept in question but should also integrate what is taught in class to their everyday lives. This will enable the students to know that science is not only what is taught in class but a part of their everyday experiences. If students are made aware of this, their attitude towards science as a subject might improve and consequently, their performance might also improve. The inclusion of relevant controversial issues, like fluoridation, pesticides and the like that are affecting the students' lives could also be used to arouse their interest in the lesson. Although this approach in some cases may be problematic, particularly for students

from traditional societies who are not used to open formal confrontation or argumentation. There is also the danger of shifting the students' focus from the real scientific concepts to social issues. However, this approach should be introduced into the lesson in such a way that they form part of the class discussion. As Huibregtse, Korthagen & Wubbes (1994) assert the inclusion of everyday life and realistic contexts in school learning situations may be very important for retaining attention, for facilitating later application of the conceptions, thus breaking down the possible division between school science and everyday knowledge.

The integration of the everyday science in teaching should not only end in class but should be accommodated in the test and examinations. The emphasis of the newly revised Curriculum 2005, particularly Learning Outcome 3 (LO3) expects students to develop and be able "to demonstrate an understanding of the interrelationships between science and technology, society and the environment" (Department of Education, 2002, p.10). Hence, what appears in the examination papers seems to have a great influence on what students learn and how they learn. There is no doubt that LO3 is not only challenging to the teacher and his/her students but also the curriculum planners as well. Considering the fact that the previous curriculum was examination driven and all the students did was largely to regurgitate facts, C2005 is a significant departure from the former. The latter is obviously more demanding in that it requires the need to design new tasks and assessment protocols. Also, in view of the generally low readability level of Second Language Students (Rollnick & Rutherford, 1996), it is necessary for textbook writers to simplify their reading materials. However, in the spirit of constructivism and current debates about fluoridation of drinking water, HIV/AIDS, genetic engineering, etc., the inclusion of socio-scientific issues or the application of science to social issues seems long overdue.

5.4 RECOMMENDATIONS

A further research needs to be carried out on whether concept mapping does really have an effect on students' attitudes to science as well as on their performance on other concepts. This should be coupled with an investigation of what other alternative methods can be used. This needs to be done on a bigger scale involving several schools from different background. Also the duration of the study should be much longer than was the case in this study.

A further study also needs to be done on the effect of integrating everyday science with school science. I believe this could be an answer to a lot of problems facing the teaching of science in general and chemistry

in particular. One of these problems is the phobia that science is a difficult subject meant only for individuals with a high intellect. It is hoped that as more data about students' conceptual development become available, new and effective strategies would be designed to cater for their needs. It is also hoped that the approach used in this study, especially the inclusion of a controversial topic – fluoridation, and the findings would stimulate further studies in the area.

The topic chemical reaction is one that deserves additional attention from the curriculum designers, textbook authors and teachers (Hesse & Anderson, 1992). These experts need to take into consideration the deeper issue of misconceptions that affect students' thinking and learning about chemical reactions and related topics. Hesse & Anderson (1992) have further asserted that these misconceptions form the basis for explanations which focus analogies to everyday events. Thus, it is important that they be highlighted in textbooks for the teachers to be aware of them. Teachers should incorporate these misconceptions into the lessons in such a way that the students are able to identify and deal with them and link valid prior concepts with the newly taught scientifically correct concepts. This will enable them to build a more scientifically interconnected conceptual framework (Soudani et al. (2000).

As indicated above, most science second language students have a low reading and comprehensive ability (Dinnie, 2000, Tesfai, 2001; Tewolde, 2001). For the same reason, students tend not to read their text books. 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.

5.5 CONCLUSION

In this study, the students' conceptions of chemical reactions were examined. While the majority of the students seemed to have made some progress in their conceptual development as a result of their exposure to concept mapping, others struggled with the approach. This finding corroborates earlier findings in the area that concept mapping does enhance students' conceptual development (e.g. Abraham et al., 1992; Ben-Zvi, 1986; Heinze-Fry & Novak, 1990; Hesse & Anderson, Stravidou & Solomonidou, 1998; Ogunniyi & Taale, 2004; Tewolde, 2001). The teaching of chemistry should give students 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 contextualised. Students 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 be reflected in science textbooks, the curriculum as well as the examinations. Science teachers should examine their conceptions of how students learn and what teaching methods can best facilitate learning. This will not only improve students' conceptual understanding of chemical reactions but their performance in science in general.



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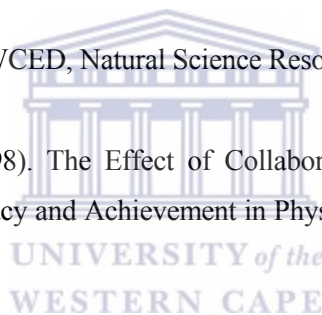
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APPENDIX A

Matter is anything that has mass and takes up mass. It consists of three phases, solid, liquid and gas. A solid melts into a liquid. Solids have a definite shape e.g. a ball. a liquid can solidify to form a solid as well as change into a gas by boiling. Liquids take up the shape of a container, e.g. milk in a jug. Gases change into a liquid by condensing. They take any shape, e.g. air in a balloon.

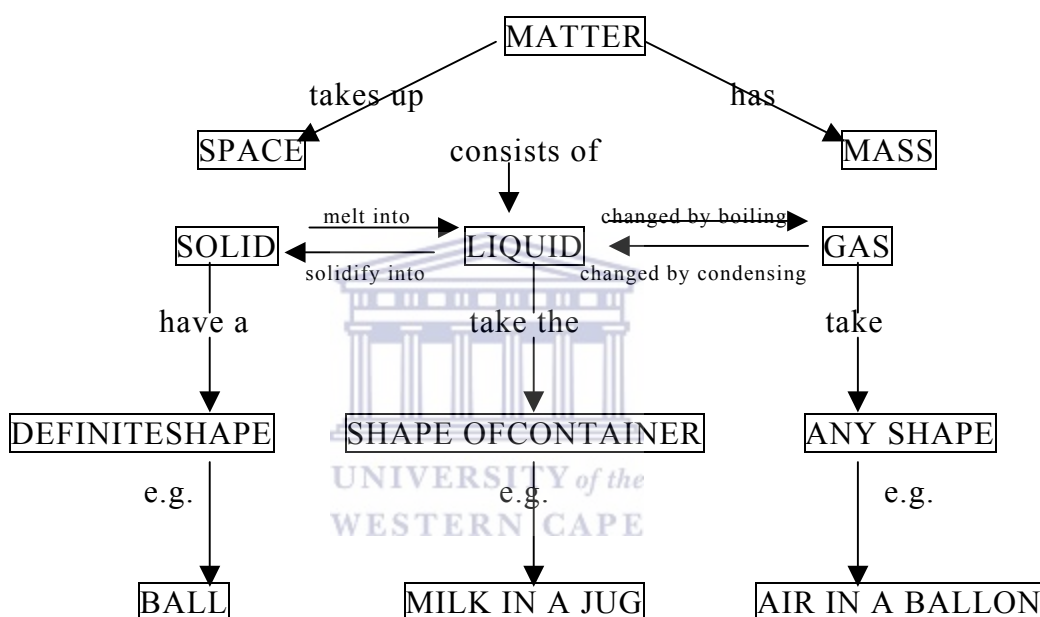


FIGURE 2: A Concept Map on Matter Developed by the Teacher and Her Students

An atom is the smallest particle of an element. It consists of three particles, the protons, neutrons and electrons. Protons and neutrons are found in the nucleus in the centre of the atom and known as nucleons and their sum is the same as the atomic mass of that element. The protons are positively charged and their number is the same as the atomic number of that particular element. The neutrons are neutral. A Concept Map on Matter Developed by the Teacher and Her Students Electrons are found in energy levels around the nucleus and are positively charged.

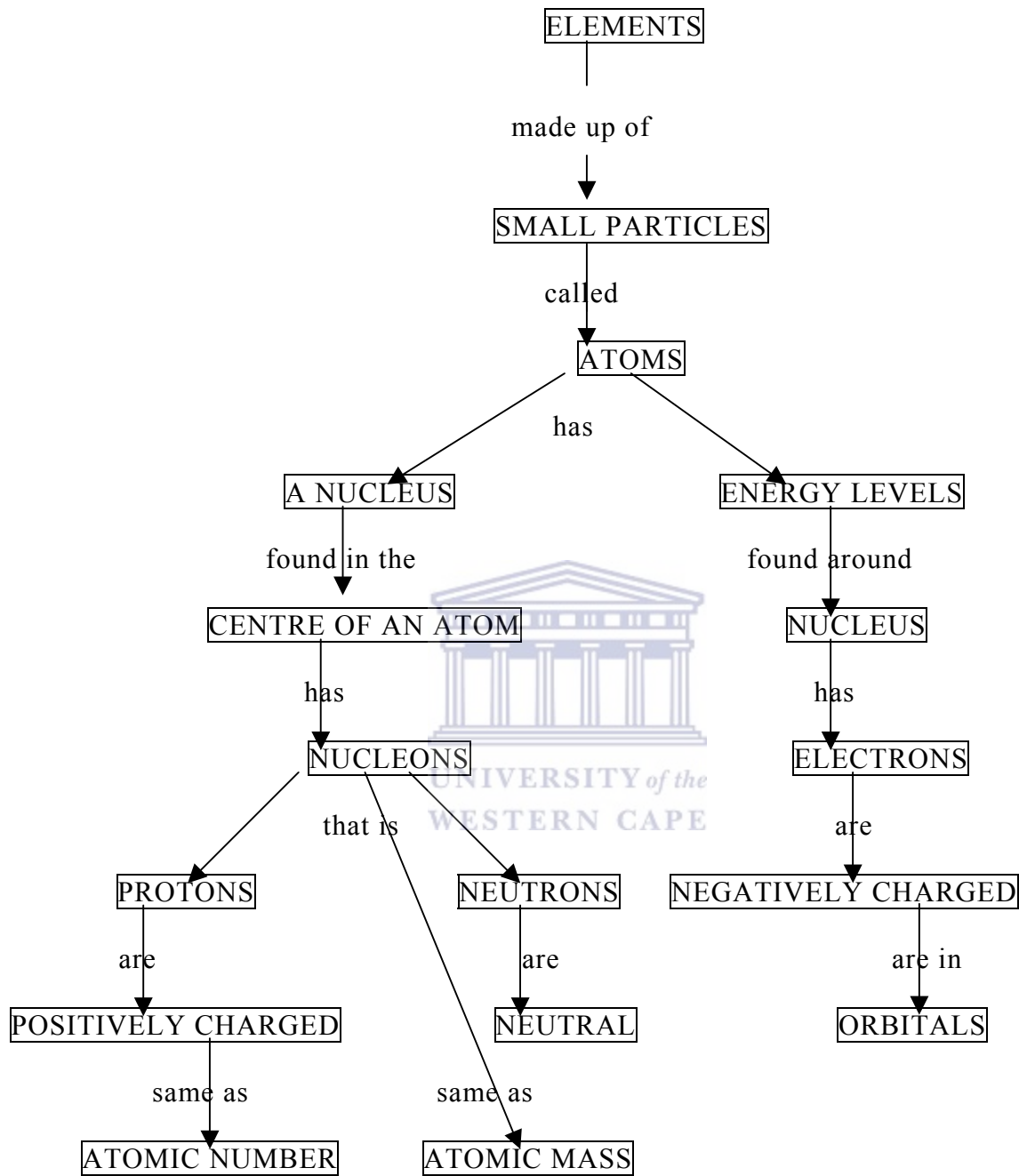


FIGURE 3: A Concept Map on Elements Developed by Group E Students

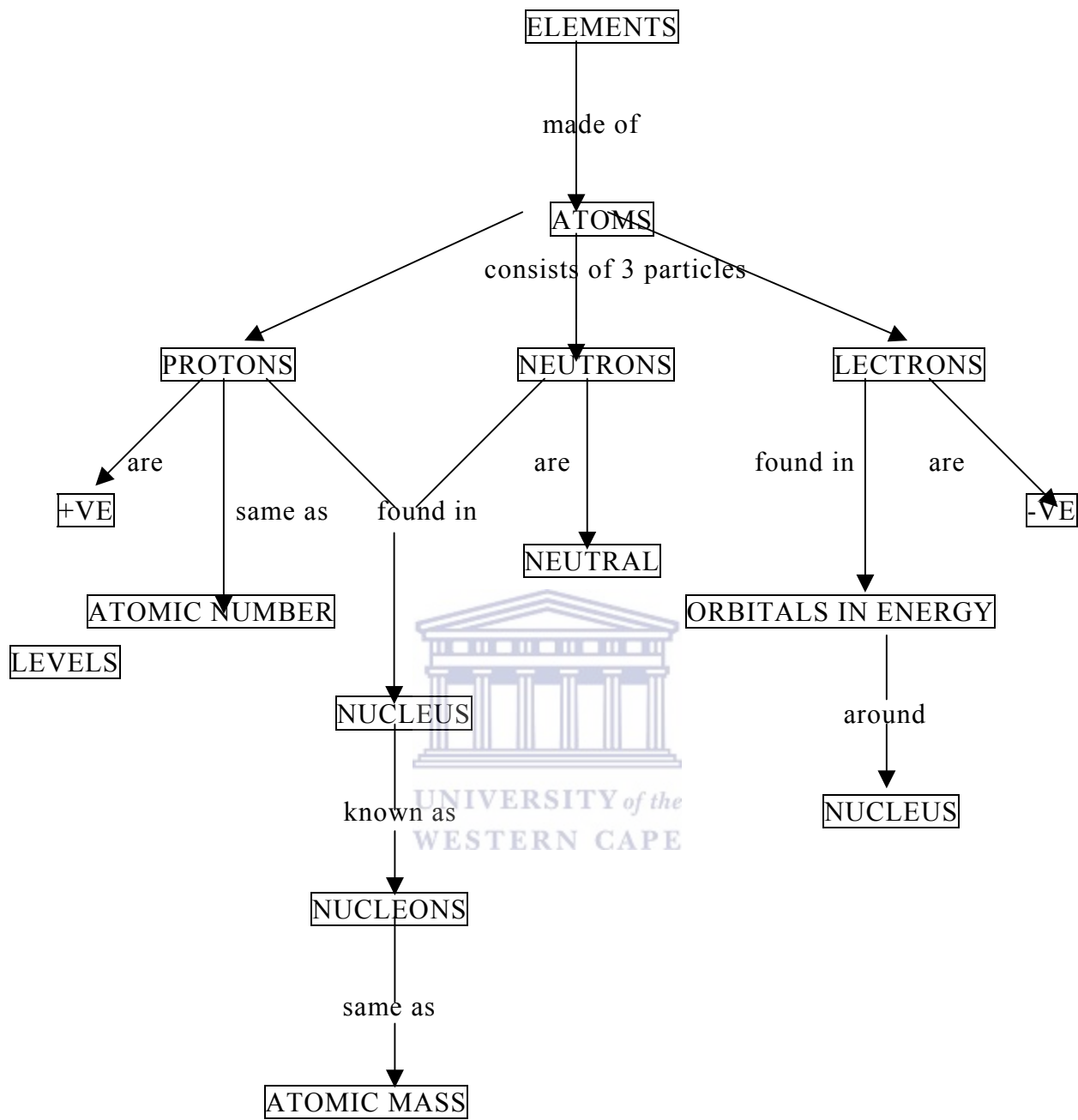


FIGURE 4: A Concept Map on Elements Developed by Group C Students

APPENDIX B

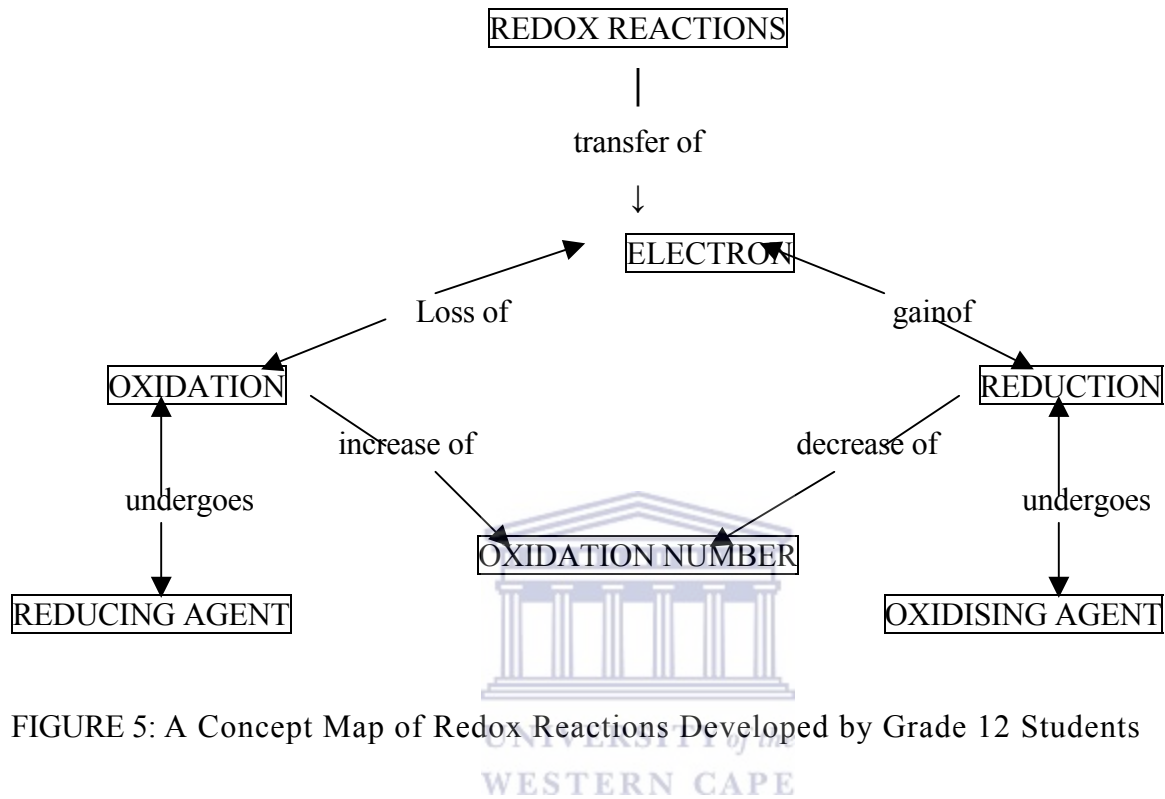


FIGURE 5: A Concept Map of Redox Reactions Developed by Grade 12 Students

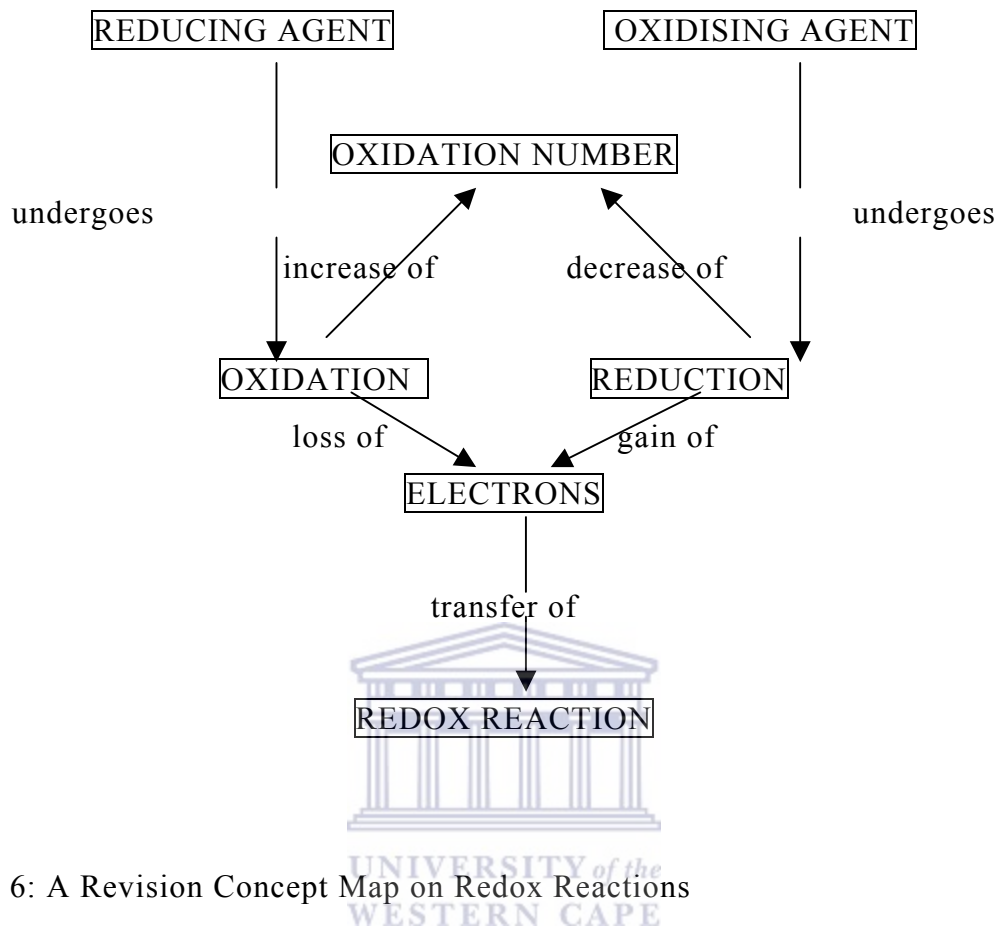


FIGURE 6: A Revision Concept Map on Redox Reactions

APPENDIX C

TEACHER DEMONSTRATION EXPERIMENT

Worksheet 1: C₁

Answer the following questions based on the experiment demonstrated.

Experiment 1: $\text{Cu} + \text{H}_2\text{SO}_4 \rightarrow$

1. What are the colours and phases of the following elements?

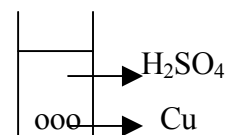
- (i) copper: _____
- (ii) hydrogen: _____
- (iii) sulphur: _____
- (iv) oxygen: _____

2. What is the colour and state of the following?

- (i) Copper (Cu): _____
- (ii) Sulphuric acid (H_2SO_4): _____

3. What do you think will happen if I add the copper shavings to the sulphuric acid and why?

I am now putting the copper shaving into the test tube with sulphuric acid.



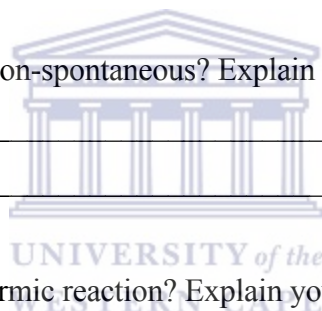
4. Are there any significant changes, i.e. any significant smell, gas produced, colour changes?

Lets heat the reaction and see if there will be any significant changes. Are there any?

5. If yes, what are they?

6. Looking at your reaction now, what do you think we have now, i.e the new products formed?

7. Is this reaction spontaneous or non-spontaneous? Explain your answer.



8. Is this an endothermic or exothermic reaction? Explain your answer.

9. Complete and balance the above chemical equation include the phases.

STUDENT PRACTICAL EXPERIMENT IN GROUPS

Worksheet 1: C₁

Do the following experiment and answer the following questions based on this experiment.

Experiment 2: $\text{Cu} + \text{HNO}_3 \rightarrow$

1. What are the colours and phases of the following elements?

(v) copper (Cu): _____

(vi) hydrogen (H): _____

(vii) nitrogen (N): _____

(viii) oxygen (O): _____

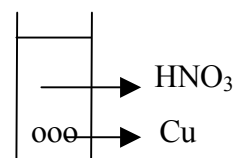
2. What is the colour and state of the following?

a. copper (Cu): _____

b. nitric acid (HNO_3): _____

3. What do you think will happen if you add the copper shavings to the nitric acid and why?

Now put the copper shaving into the test tube with nitric acid.

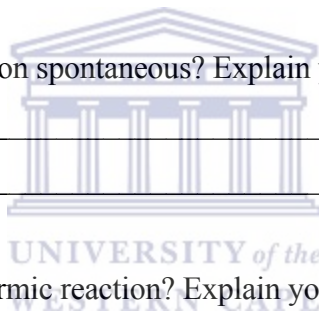


4. Are there any significant changes, i.e. any significant smell, gas produced, colour changes?

5. If yes, what are they?

6. Looking at your reaction now, what do you think we have now, i.e the new products formed?

7. Is this reaction spontaneous or non spontaneous? Explain your answer.



8. Is this an endothermic or exothermic reaction? Explain your answer.

9. Complete and balance the above chemical equation, include the phases.

APPENDIX D

THE CHEMISTRY ACHIEVEMENT TEST

NAME	
GENDER	
CARREER CHOICE	

Question 1

1.1 For each of the following phenomena listed, indicate the nature the nature of the reaction by writing: A: acid-base; B: redox; C: precipitation; D: dissociation

- (a) Hydrochloric acid solution in sodium chloride. _____
- (b) Zinc blade put in hydrochloric acid solution _____
- (c) Formation of rust on iron blade _____
- (d) Petroleum burning _____
- (e) Metal corrosion _____
- (f) The colour change of a cut apple _____
- (g) A nail in water bleach _____
- (h) Sodium chloride in water _____
- (i) A rubbed ebonite stick _____
- (j) Cleaning of brass with Brasso _____
- (k) Respiration _____
- (l) Photosynthesis _____



/12/

Question 2

Use the words provided to complete this extract: electro-negativity; positive; proton; reducing; oxidized; electrons; redox; negative; valency; oxidizing; reduced;

During a reaction _____ are either exchanged or shared. If the reactant that transferred them was an atom, it will become a _____ ion. If the reactant that accepted them was an atom, it will become a _____ ion. Which reactant transfers or accepts them depends on their _____ and the ratio with which these reactants combine depends on their _____. This phenomenon is known as _____.

reaction. The reactant that transfers them is _____ and the one that accepts them is _____. Oxidation occurs on the _____ agent resulting in a _____ in oxidation number. In a redox reaction, the higher the electrode potential the higher is the _____ strength. /11/

Question 3

3.1 Describe what you would see happening in the following situations, and write a chemical equation where appropriate.

(a) Iron (steel wool) is dropped into a solution of copper sulphate? (3)

(b) Zinc is dropped into a solution of hydrochloric acid? (3)

(c) Copper is dropped in a solution of silver nitrate? (3)

(d) Copper is dropped in a solution of sodium chloride? (3)

/12/

3.2.1 Which of the following equations represent oxidation-reduction reactions? (3)

Explain your answer: (a) $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$ (b) $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$

(c) $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ (d) $\text{CO}_3^{2-} + 2\text{H}^+ \rightarrow \text{H}_2\text{O} + \text{CO}_2$

3.2.2 From the equation you have chosen in 2.1, identify the

(a) oxidising agent: _____ (2)

(b) reducing agent: _____ (2)

3.2.3 Write the following word equations in formulae.

Copper and conc. nitric acid making copper nitrate, water and nitrogen dioxide

_____ (5)

3.2.3.1 Identify and write the following half reactions:

(a) oxidation: _____ (2)

(b) reduction: _____ (2)

(c) nett: _____ (3)

/19/



APPENDIX E

Students' Perception of the Lesson on Redox Reaction.

Please tick the relevant box according to your opinion, give a brief explanation of it.

- (i) The way the first lesson was presented was interesting, and has made me to understand how reactions occur much more better.

AGREE	<input type="checkbox"/>	DISAGREE	<input type="checkbox"/>
-------	--------------------------	----------	--------------------------

- (ii) I can identify a redox reaction and the oxidation half reaction and reduction half reaction with quite ease.

AGREE	<input type="checkbox"/>	DISAGREE	<input type="checkbox"/>
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- (iii) Experiments helps me to have a better understanding of concepts.

AGREE	<input type="checkbox"/>	DISAGREE	<input type="checkbox"/>
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APPENDIX F

Students' Perceptions of Questionnaire Based on an Experiment.

Please tick the relevant box according to your opinion, give a brief explanation of it.

3 = STRONGLY AGREE; 2 = AGREE; 1 = DISAGREE

Answering the questionnaire was enjoyable			
Answering the questionnaire was very easy.			
Answering the questionnaire helped me to understand the topic better			
Doing the experiment helped me to answer the questionnaire with ease.			
I learned nothing from answering the questionnaire.			
Answering the questionnaire on my own helped to understand better			
I found group discussion helpful.			
I could not have answered the questionnaire on myself			
I prefer answering a questionnaire to long questions which need a long answer.			
Answering a question can be deceiving.			
Questionnaire helps me to have a better idea of where I am lacking			
Questionnaire is useful for reviewing a lesson			

Comment:

APPENDIX G

Students' Perceptions of the Use of Concept Mapping Questionnaire

Your answers should be arranged according to levels of agreement with the statement

3 = STRONGLY AGREE; 2 = AGREE; 1 = DISAGREE, tick the relevant box according to your opinion

	3	2	1
Concept mapping helps to clarify the relationships between concepts			
Concept mapping makes me to confuse the relationship between concepts			
Concept mapping helps me in understanding the concepts much better			
Concept mapping helps in clarifying confusing and complicated concepts.			
Concept mapping makes the complicated concepts more confusing			
Concept mapping helps to express complicated concepts in simple way.			
Concept mapping makes expressing complicated concepts more difficult.			
Concept mapping is a good way of reviewing a chapter			
Concept mapping is not a good way of reviewing a chapter.			
Concept mapping helps to make sense of the many terms in a chapter and organise them in a meaningful whole			
Cross links help me to get the bigger picture			
Cross links makes getting the bigger picture more difficult			

Comment:



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