

**Full thesis submitted in fulfilment of the requirements for the degree of  
Masters in Science Education.**

**Effects of Dialogical Argumentation Instruction on grade  
10 learners' understanding of concepts of chemical  
equations.**

**By**

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## DECLARATION

I declare that this thesis titled, “*Effects of Dialogical Argumentation Instruction on grade 10 learners’ understanding of concepts of chemical equations*” is my own work. This thesis was not submitted before in any other university for any examinations or degree purposes, and that I have indicated and acknowledged all sources of information by complete references.

**FRIKKIE GEORGE**

**SIGNED:** .....



**DATE:** .....

## ABSTRACT

Many learners struggle to learn physical science concepts. The conflict between how an individual understands a scientific term or phenomena and the commonly accepted scientific meaning may result in misconceptions. In an attempt to cover the content-laden science curriculum, teachers may tend to hastily cover important theoretical concepts within a unit, without rigorous conceptualisation of scientific terminologies. This study explored the Dialogical Argumentation Instruction (DAI) approach to determine whether it enhanced grade ten learners' understanding of the chemical equation concept.

Toulmin's Argumentation Pattern (TAP) and the Contiguity Argumentation Theory (CAT) underpin this study and was used to construct the Dialogical Argumentation Instruction (DAI) methodology, which was used as the intervention strategy. Information and Communication Technology (ICT) and Computer-Assisted Learning (CAL) were used as contextual environment for this study. This study is located in the interpretive paradigm and the data was collected and analysed using both qualitative and quantitative methods based on a quasi-experimental research design model. A survey questionnaire, open-end and fixed choice questionnaires and a chemistry achievement test was used to collect data from a High School in the Western Cape Province.

The analysis of the data showed a significant difference between the experimental group control group suggesting that Dialogical Argumentation Instruction was an effective and meaningful intervention and helped to eliminate misconceptions during the study. The findings also highlighted the important roles played by the teacher and information communication technology as the mediators and co-constructors of knowledge in the learning process. The findings may help to validate procedures for implementation of DAI in schools as well as suggest ways to ameliorating the misconceptions, thereby providing useful information about the effectiveness of using a DAI in teaching science concepts in general.

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This thesis is committed to the loving memory of my grandmother, Kate George (Nana) who unselfishly made my university career possible under trying circumstances.

## ABBREVIATIONS AND ACRONYMS

ANA	-	Analytical National Assessment
C2005	-	Curriculum 2005
CAL	-	Computer Assisted Learning
CAPS	-	Curriculum Assessment Policy Statements
CAT	-	Contiguity Argumentation Theory
CMC	-	Computer mediated communication
DAI	-	Dialogical Argumentation Instruction
DoBE	-	Department of Basic Education
FET	-	Further Education and Training
GET	-	General Education and Training
ICT	-	Information Communication Technology
INSET	-	In-service training
NCS	-	National Curriculum Statements
NOS	-	Nature of Science
NSC	-	National Senior Certificate
OBE	-	Outcome-Based Education
PRESET	-	Pre-service training

ROSE	-	Relevance of Science Education
SIKSP	-	Science and Indigenous Knowledge Systems Project
SPSS	-	Statistical Package for the Social Sciences
TAP	-	Toulmin's Argumentation Pattern
WCED	-	Western Cape Education Department
EMDC	-	Education Management and Development Centre



## KEY WORDS

Chemical equations

Computer Assisted Learning (CAL)

Critical thinking

Dialogical Argumentation Instruction (DAI)

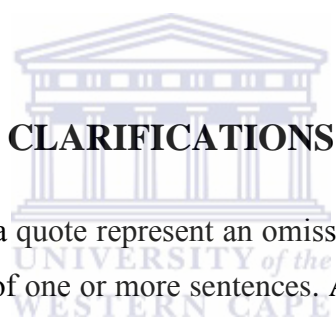
E-education

Information Communication Technology (ICT)

Learner achievement

Learner performance

Socio-cultural constructivism



## CLARIFICATIONS

Three dots (...) in the middle of a quote represent an omission of words from the quote; four dots (....) represent an omission of one or more sentences. All italicised terms in text are new terms that I introduced. Words placed inside block parenthesis [ ] within quotations are my words.

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# CHAPTER ONE

## 1.1 Introduction

This research project explored how Dialogical Argumentation Instruction (DAI) within a Computer-Assisted Learning (CAL) environment enhanced learners' understanding of concepts of chemical equations. It focuses on aspects of dialogical argumentation and investigates whether it is applicable to the science classroom. This study also investigated whether to modify, adopt or redesign existing argumentation theories to improve the learning of concepts of chemical equations. Computer Assisted Learning (CAL) provides the premises to build an appropriate argumentation framework for this study.

Teachers' conceptions and awareness of their tentative discursive Nature of Science (NOS) practices can be enhanced by using dialogical argumentation (Ogunniyi, 2007a). Dialogical argumentation can also contribute to the effective collaborative learning process in the classroom. The National Education Department's e-Education policy encourages the use of computers and computer software in implementing outcome-based curriculum in the classroom. "South African learners in the General Education and Training (GET) and Further Education and Training (FET) bands are expected to be information communication technology (ICT) literate by 2013" (Department of Education, 2003). That implies that learners should be able to use ICT confidently and creatively in order to develop skills and knowledge to participate in the global community. Furthermore, the Education Department promotes the development of new models of learning that will radically change the concept of education and the delivery of it. In this process the education authorities are currently busy to streamlining the curriculum by lessening the administrative burden of both teachers and learners in terms of the revised curriculum, Curriculum Assessment Policy Statements (CAPS).

Since the introduction of computers into education, more than twenty years ago, education authorities globally have believed that it would drastically improve learner performance and achievements (Gardner, 1990). However, many studies have shown that the use of computers in education has not improved learner performance and achievement significantly (Mumtaz,

2000). Therefore, the emphasis of the educational process should be on the pedagogy. However, computers do have a role to play in the educational process, but needs to be used purposefully. Computer Assisted Learning (CAL) with the appropriate pedagogical approach could improve learner performances.

CAL offers a range of different tools for use in school science namely, data capturing, processing and interpretation, multimedia software for simulation of processes and carrying out virtual experiments, information systems like the internet, intranet and CD-ROM's, publishing and presentation, digital recording equipment and computer projection technology (Bungum, 2003). According to Bungum (2003) these ICT tools, together with well-designed CAL programs can enhance both the practical and theoretical aspects of science teaching and learning in the classroom. Furthermore, they assert that:

The advantages of CAL in science lessons is that it links school science with contemporary science, providing immediate feedback, help with conceptualising of abstract concepts and minimises laborious manual processes and give more time for thinking, discussion and interpretation. (p. 32)

Another study by (Gardner, 1990) found that ICT-tools used within a conducive pedagogical environment improved learner performance. The role of the teacher and the computer helps to mediate the learning process acts as co-constructors of knowledge (Vygotsky, 1978). For example, a number of schools in the Western Cape have ICT resources and in particular, one of the schools has data projectors in every classroom. The grade 12 pass rate of most of these schools' performance was above average (Department of Education, 2001). However, my observation was that the ICT resources are not used optimally in most of these schools. This study will also determine to what extend the selected schools have ICT resources and the utility thereof.

## **1.2 Curriculum reform in South Africa**

In 1960 a worldwide wave of reform in school curricula, with a move towards inquiry learning and more emphasis on practical work hit schools (Ball, 2000). Although local situations in different countries can result in reforms, curriculum reforms often result from

global educational changes. The 1990's saw another wave of science curriculum reform internationally, with a focus on activity-based and learner-centred approach. The current wave of international reforms, which requires knowledge to be actively constructed by the learners, and cannot simply be passed unchanged from teacher to learner (Cobley, McKenne, Baker, & Wattie, 2009).

The recent curriculum reforms in South Africa were politically motivated. After the first democratic elections in 1994, new education policies were adopted in South Africa in order to change the unjust and discriminating policies of the Apartheid regime. These reforms also presented the curriculum developers the opportunity to incorporate new educational methods, based on recent research on how learning happens and how it can be made more effective (Christie, 2008). In 1998, a new curriculum, Curriculum 2005 (C2005), was introduced in South African schools. This curriculum was developed within the Outcome-Based Education (OBE) framework. The OBE framework specifies intended outcomes of the curriculum and these outcomes provide targets for teachers that learners must achieve. It places an emphasis on producing learners who are critical thinkers, capable of solving problems and who are responsible for their own learning. Curriculum 2005 aimed to produce learners who not only have the knowledge, but also the skills, attitudes and values in order to become competent, responsible and critical citizens. While these aims are important for individual learners, they are also important for South Africa as a developing country. In support of the implementation of Curriculum 2005, a national strategy was developed for mathematics, science and technology education in South Africa, which included the preparation of qualified and competent teachers in these learning areas as well as providing adequate resources for classrooms (Department of Education, 2001).

During the period 1998 to 2008 there was a large theory-practice gap in the implementation of the new approaches by science teachers. Teachers play a pivotal role in the successful implementation of any new curriculum; however, if they do not understand what it is they are required to do, they will struggle to make the changes intended by the new curriculum developers. Most science teachers are not familiar with the new terms used in the policy documents and are not sure about what the terms mean, or whether they are doing what the policy requires them to do (Sanders & Kasalu, 1992). In 2009, the National Curriculum



Statements (NCS) replaced C2005. The NCS are documents detailing the new curriculum in different learning areas and subjects. The content areas in the General Education and Training (GET) level is called subjects and in the Further Education and Training (FET) level is called learning areas. Figure 1.1 illustrates the similarities and differences between the GET and FET bands. The National Curriculum Statement Grades R – 12 (NCS) stipulates policy on curriculum and assessment in the schooling sector.

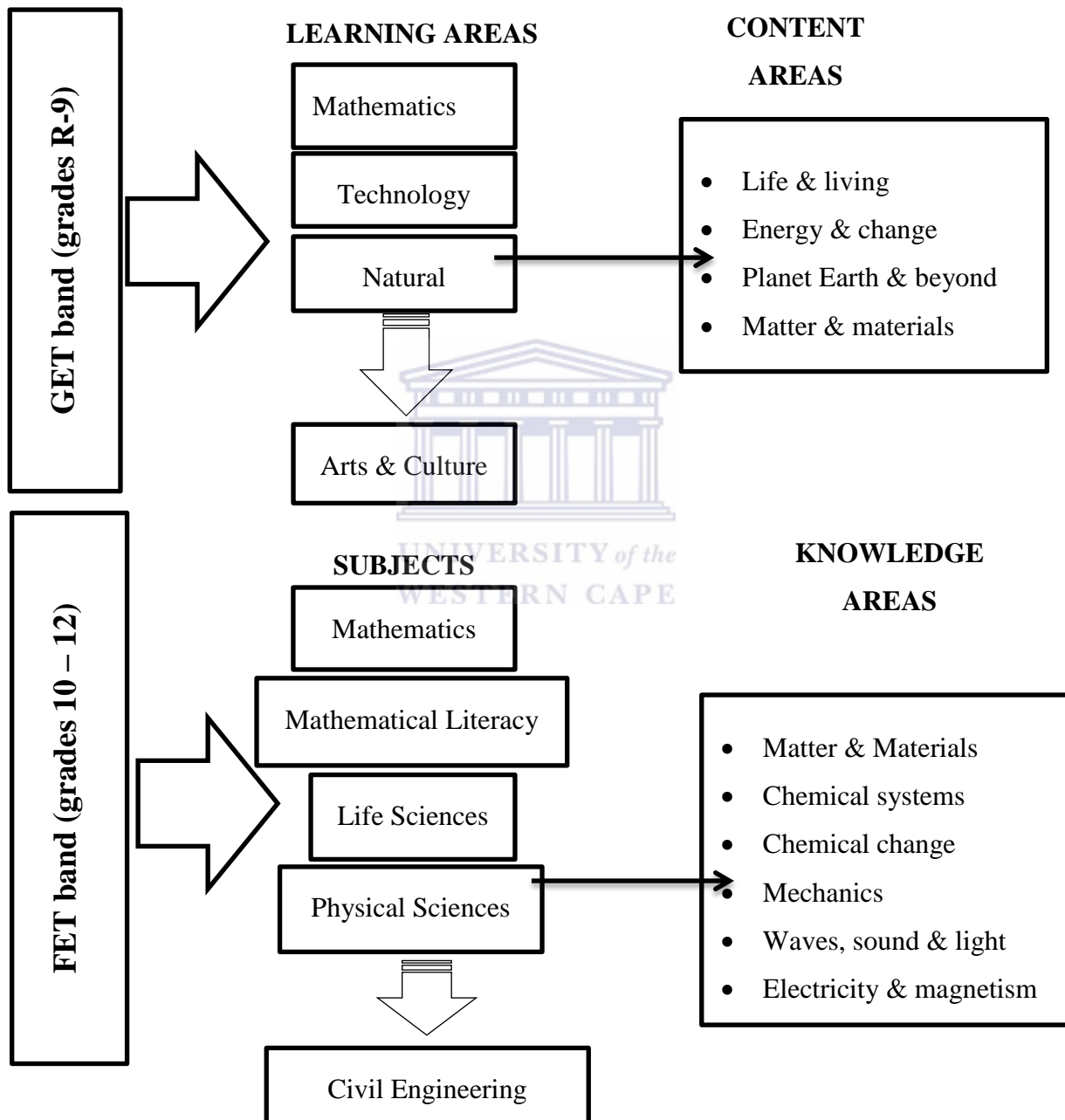


Figure 1.1: Structure of the GET and the FET bands

In order to improve the implementation of the National Curriculum Statement amendments were made in January 2012. A single comprehensive national Curriculum and Assessment Policy Statement (CAPS) was developed for each subject to replace the old Subject Statements, Learning Programme Guidelines and Subject Assessment Guidelines in grades R to 12. The amended national Curriculum and Assessment Policy Statements replaced the National Curriculum Statements (Department of Basic Education, 2012).

Science teachers had to make significant changes to what and how they teach the revised curriculum. CAPS requires science teachers to change their practices in such a way that they are facilitators of the learning process and the learning activities should be learner-centred, enquiry-based, relevant and be integrated across other learning areas.

### **1.3 Significance of study**

The significance of this study is to assess whether Dialogical Argumentation Instruction has the potential to revitalise science education and to contribute to the pedagogy of science teaching. I believe dialogical argumentation instruction (DAI) has the potential of revitalising science education and becoming the core approach for science teaching. Hopefully the findings of this study will help to identify problems associated with the implementation of computer-assisted learning (CAL) in the selected schools as well as to suggest ways in which the problems can be ameliorated. The findings may provide useful information about the effectiveness of using a DAI in teaching science concepts or concepts in any other learning area in general. The improvement in understanding of science concepts will revitalise physical sciences as a preferred subject choice. It is also expected that an effective instructional methodology such as DAI will lessen the time and energy a teacher spend on lesson preparations and presentations. It will increase the utility and usability of the curriculum. It is also expected to have far reaching implications for policy objectives and the education system in general.

DAI and CAL could be useful in realising the National Education Department's objective to have learners ICT literate and the development of new models of learning. Dialogical argumentation instruction has the possibility to provide the necessary atmosphere within

which learners can learn, to acquire communication skills, correct erroneous concepts and broaden their understanding of scientific concepts as well as their worldview. Generally, learners find it very difficult to master chemical equation concepts that are one of the fundamental bases of chemistry in physical sciences (Bricker & Bell, 2008).

The outcome-based education (OBE) policy emphasises that the classroom process should follow a learner-centred approach and that physical sciences in particular should be an enquiry based learning area (Department of Education, 2003). Furthermore, the policy emphasises in one of its Specific Outcomes that learners should develop critical thinking skills. This is in contrast to the apartheid education that existed prior to 1994 which forced learners to be passive receivers of knowledge and teachers, transmitters of knowledge (Van Rooyen & De Beer, 2007).

The results of the Annual National Assessment (ANA), a systemic test which was conducted nation-wide to test learners in grade eight in mathematics and sciences was poor (Department of Education, 2001). This trend is also observed in the National Senior Certificate (NSC) examinations of the past five years, which indicate that learners struggle with science and mathematics. In particular, the examiner's report of the chemistry paper always refers to the poor attempts of candidates in answering the question on extent and rate of chemical reactions. Ogunniyi (1999) made similar findings when he investigated the knowledge, attitudes or views about science and technology held, by grade seven to nine learners in the Western Cape, on conceptions of chemical change in substances. He found that learners had a poor understanding of the concepts and those who had a valid understanding of the concepts did so at a relatively low cognitive level. These observations make it crucial for education authorities to come with interventions to address the poor performance of learners in mathematics and science, which is the focus of this study.

The legacy of Apartheid also left lasting impressions in terms of gender and socio-economic inequalities in the educational setup of South Africa (Van Rooyen & De Beer, 2007). For instance, the apartheid education system discouraged girls from taking technical subjects like civil technology and engineering technology (Gardner, 1990). On the other hand, boys were discouraged from taking subjects like food technology. This is still evident within the

classrooms setup today. In some classroom environments, it is found that girl-learners are less participative than boy-learners are (Viswanaman, 2001). This could be because in some cultures women are expected to be seen; and not heard. In some schools, older learners are sometimes domineering and they bully younger learners, which cause the younger learners to participate less in class.

During my 17 years' experience of teaching physical sciences in all grades at high school level, I found that learners struggle almost painfully to understand the macroscopic and microscopic views of chemical reactions. Their inability seems to stem from the inability to write correct formulae, visualisation of certain chemical compounds and the process of chemical bonding, which predisposes them to misconceptions.

In addition, I observed in my teaching career that learners are inclined to excessively cut-and-paste from textbooks and research material and not even be aware that they are plagiarising. Teachers also do not do justice to group work activities, leaving learners to their own devices and not facilitating interaction (argumentation) effectively. These actions by learners and teachers appear to be a result of the wrong implementation of the OBE curriculum in general and CAPS in particular. Therefore, I strongly argue that dialogical argumentation should be an integral part of the learning process in the classroom.

#### **1.4 Rationale**

The current information explosion forces education systems to become more creative and relevant in terms of methodologies. The South African outcome-based education (OBE) encourages teachers to use various instructional strategies (Department of Education, 2003). This is deemed useful in helping teachers to tap into learners' interests and hobbies. We are living in an information age in which learners are daily confronted with the electronic media and the use computers technology to design and to create images of all sorts; these should be part of their learning environment. Modern electronic items like, cell phones, television, computer games, computers, etc. can be useful in creating a learning environment that is engaging and interesting; one that augments the expository talk-and-chalk traditional form of instruction, but does not effectively address the challenges of the new curriculum outcomes.

The particulate nature of matter and concepts of chemical equations is crucial in understanding the different chemistry phenomena in physical sciences. Physical sciences is one of the focus learning areas, identified by the education department, and consequently invested money and training in promoting it. The perception out there is that science is a “difficult” subject and learners tend to avoid taking it when selecting subject choices (Van Rooyen & De Beer, 2007). South Africa is in need of experts in the field of science and technology, especially now that it hosts at least two major scientific projects; namely the Southern Africa Largest Telescope (SALT) and the Square Kilometre Array (SKA) radio telescope. It would be in the interest of the country to produce its own scientists, rather than importing expertise from abroad.

### **1.5 Problem statement**

Many learners find it difficult to learn physical science concepts (Bricker & Bell, 2008). The difference between the conceptual understanding of a learner and the commonly accepted scientific meaning of a term presents learning barriers and may result in misconceptions. In their attempt to cover the content laden curriculum, teachers hastily cover important theoretical concepts of a unit, which result in learners not understanding the work. I found that the majority of schools in the Western Cape have information communication technology (ICT) resources, but they do not know how to use it or to use them optimally. The problem is also exacerbated by the fact that many schools do not have well equipped and functional laboratories to do hands-on experiments and libraries to access research material (Department of Education, 2001). Chemical equations concepts are difficult for many learners to master, which could be a consequence of an ineffective instruction methodology. The stereotyping of gender in which females are treated and accept to be inferior to males, which is also a consequence of the apartheid ideology, could play a role in the performance of learners in the classroom.

The socio-economic background of learners could also have an impact on the performance of learners in class. If the learners do not have adequate resources at home they would not be able to do homework, which is an important aspect of the new Curriculum Assessment Policy Statements (CAPS), needless to speak of the lack of required resources at most schools. The

principles in the CAPS document, presented below, must be addressed by an appropriate instructional methodology:

- Identify and solve problems and make decisions using critical and creative thinking.
- Work effectively as individuals and with others as members of a team.
- Organise and manage themselves and their activities responsibly and effectively.
- Collect, analyse, organise and critically evaluate information.
- Communicate effectively using visual, symbolic and/or language skills in various modes.
- Use science and technology effectively and critically showing responsibility towards the environment and the health of others.
- Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.
- Social transformation - ensuring that the educational imbalances of the past are redressed, and that equal educational opportunities are provided for all sections of our population.
- Active and critical learning - encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths.

## **1.6 Research questions**

This study attempted to determine whether Dialogical Argumentation Instruction (DAI) can enhance grade ten learners' understanding of chemical equations concepts within a Computer-Assisted Learning (CAL) classroom environment.

This study sought to answer the following questions:

- 1) What is the status of information communication technology (ICT) resources and their usage in certain selected schools in the Western Cape?

- 2) Do grade 10 learners exposed to dialogical argumentation instruction (DAI) in computer-assisted learning environment demonstrate a better understanding of chemical equation than those who are not so exposed?
- 3) To what extent are the conceptions of chemical equations that the grade 10 learners hold relate to their age, sex and socio-economic background?

## 1.7 Theoretical framework

A theoretical framework position your research in the discipline or subject in which you are working. It explains the theories that underpin your research and helps to make explicit your assumptions about the interconnectedness of the concepts you use and indicate how they are related to the world (Creswell, 2009). Henning et al. (2004) assert that the theoretical framework also provides an orientation to the study and reflects the stance of the researcher in the research field and describe it as:

A theoretical framework is like the lenses through which you view the world. An educationalist would view the world in different way to, say, a sociologist or a psychologist, depending on their research topics and the purpose of their inquiries. (p.55)

The following interrelated theories, Toulmin's Argumentation Pattern (1958), Contiguity Argumentation Theory (1992), socio-cultural constructionist theory of Vygotsky (1978) and the personal constructionist theory of Piaget (1936) frame this research study. "Constructivism involves the transfer of knowledge from the knower to the learner, but actively constructed by the learner, drawing from prior experience" (Ausubel, 1968; Driver, Asoko, Leach, Mortimar & Scott, 1994). The above-mentioned theories are pertinent to this study and help to shaping and guiding this research. These theoretical constructs, Toulmin's Argumentation Pattern (TAP), Contiguity Argumentation Theory (CAT) and constructivism complement each other. Toulmin's (1958) argumentation pattern is used by many researchers in science education to promote scientific discourses in the science classroom because it is more amenable to inductive-deductive logical forms of reasoning predominant in most science discourses.

Toulmin's Argumentation Pattern (1958) model analyses the argumentation discourse to determine the quality of an argument. Erduran et al. (2004) explain TAP as an interconnected set consisting of a claim, data supporting the claim and warrants that provide a link between the data and the claim. This model also includes backings that strengthen the warrants and rebuttals, which point to the circumstances under which the claim would not hold true.

The Contiguity Argumentation Theory (CAT) of Ogunniyi (2005) construes learning as a dynamic process, which changes an individual's mental state from one context to another. CAT fills the metaphysical gap that TAP is not able to cover, because it explains the personal, non-logical experiences. This theory contends that a worldview that is dominant in a given context may become suppress in another context or may be assimilated into a more dominant worldview (Ogunniyi, 2005):

CAT holds that claims and counters on any subject matter within fields [for example religion and science] can only be justified if neither thought system is dominant. There must also be valid grounds for juxtaposing the two distinctive worldviews within a given dialogical space. The role of such a dialogical space is to facilitate the process of re-articulation, appropriation, and/or negotiation of meanings of the different worldviews. Students must therefore be able to negotiate the meanings across the two distinct thought systems in order to integrate them. (p.33)

Construction of new ideas take place internally, within the learner's head and the constructivists' theories provides teaching tools that might help learners' attempt of conceptual reconstruction (Millar, 1989). The constructivists' theories will be used in the context of dialogical argumentation instruction, which assumes teacher intervention, learners' participation and interaction between them. These theories, which form the foundation of this study will be unpacked further in the next chapter.

### **1.8 Limitations experienced during the study**

Teachers have huge workloads and few administration periods at school to do preparations and planning. This makes it difficult to set up activities before and after a period; and in the majority of schools, laboratory assistance is a luxury that they cannot afford.



In the classrooms, the behaviour of learners varies greatly, from being inquisitive and eager to learn to delinquent, apathetic and disruptive. This made it difficult to conduct lesson activities according to plan, because a great amount of time is used to discipline learners in order to have a conducive teaching atmosphere. Some of the participants who fall in the latter category had to be discarded from the study, which forced me to reduce the research sample.

At the research site, the daily programme was often disrupted and the data gathering sessions were shortened. Sport activities after school and prolonged staff meetings, caused periods to be shortened and lesson presentations for the purpose of data collection could not be completed as planned. Another major challenge was the principal of the research school who acted like a gatekeeper and insisted that I should not deviate too much from the traditional instructional method to incorporate dialogical argumentation instruction. I attribute his attitude to ignorance of alternative instructional methods. I also had minimum assistance from the teachers at the research school. They did not assist or cooperate with the research project if they did not benefit. I attribute this to professional jealousy.

A major setback to the research project was when I changed schools in the middle of the research study. The instruments had to be changed and the collection of data had to start all over again with new subjects in a different research setting.

## **1.9 Thesis layout**

Chapter One introduced the study by focussing on the research questions and the reasons why this research project was embarked upon, the importance of the study and the limitations. It also alludes to the theoretical and conceptual frames that underpin this study. The curriculum reform processes that preceded the current curriculum are also outlined in this chapter.

Chapter Two interrogates the literature regarding the research questions in order to explicate the use of the selected appropriate conceptual framework and theoretical bases. This chapter focuses on the different constructionist theories, collaborative learning, language, argumentation, learning styles, computer-assisted learning and socio-economic factors in education.

In Chapter Three the research sample, setting and conditions are described in detail. The methodology that was followed includes the research design, sampling, research instruments, collection of data, validity and reliability, delimitations, limitations and ethical considerations of the study.

In Chapter Four the analysis of the results and findings are broadly discussed in answering the research questions. The qualitative and quantitative findings are discussed at length in terms of the intervention strategy and the conceptual framework.

In Chapter Five an overview of the research project is given and the implications of the study for the classroom, teaching and learning, as well as for the education policy makers. Recommendations and suggestions for further study are also presented here.

### **1.10 Terms and operational definitions**

**Learner:** This term refers to children attending school from grade 1 to grade 12.

**Teacher:** This term refers to the person in charge of the teaching process in the classroom at a school.

**Learner performance:** This phrase refers to the complete record of assessment of a learner during the learning process.

**Learner achievement:** This phrase refers to the result of the assessment of the learner at the end of a section of work.

**Dialogical argumentation:** This refers to an instructional strategy used in the science classroom during which statements or viewpoints are made and challenged or defended through an organised protocol.

**Chalk-and-talk teaching method:** It is the traditional teaching method that includes formal, expository and teacher-centred methods, during which learners had to read text or listen to a lecture.

**Socio-cultural construction:** The construction of knowledge with reference to contextual practices and the building or constructing that occurs in learners' minds when they learn. During this process, learners construct their knowledge actively, rather than mechanically 'ingest' information from their teacher or textbooks.

**Computer assisted learning:** Learning process supported by computer software. This learning includes various media that depend upon a computer for their use.

**Information Communication Technology in education:** The convergence of the audio-visual with computer hardware and software. Teaching and learning the subject matter that enables the understanding by making use of multi-media computer software.

**Learning styles:** The way learners processes information and distinguishes between how an individual senses, thinks, solves problems and remembers information.



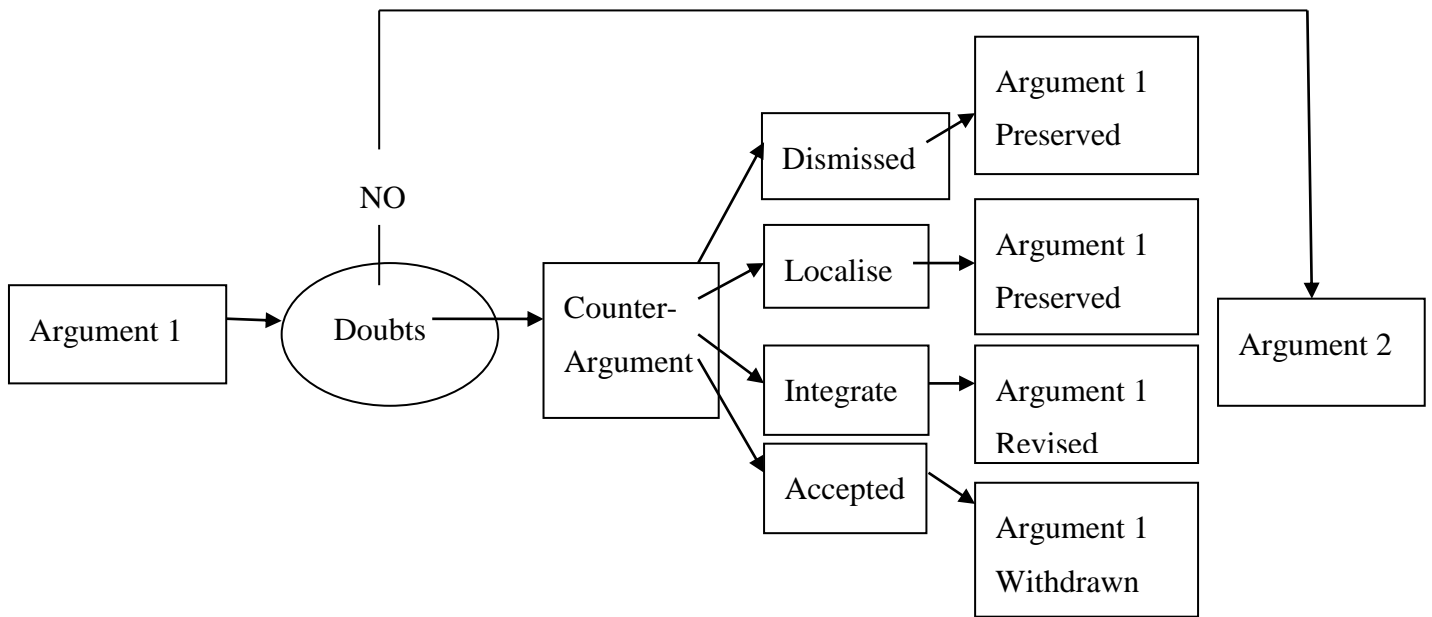
## CHAPTER TWO - LITERATURE REVIEW

### 2.1 Introduction

In chapter one, I discussed the focus and purpose of the study as well as how the thesis is outlined. This chapter focuses on the different theoretical concepts linked to knowledge construction, group discussion and learner-centred learning. I will also explore how argumentation is used as a tool in applying the selected cognitive theories. Toulmin's Argumentation Pattern (TAP) and the Contiguity Argumentation Theory (CAT) are used as instruments to give structure and evaluate the learning process within a classroom environment. Finally, I engaged the literature about the debate on the use of computer software in the classroom to highlight the significance of computer-assisted learning (CAL).

Literature on argumentation spans a wide range of disciplines (philosophy, education, law, computer programming, etc.) and is widely researched (Diwu, 2010; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Erduran, 2004; Langenhoven, 2009; Ogunniyi & Hewson, 2008; Reed, 2006; Van Der Linde, 2011; Toulmin, 1958). I will show the connection between the different knowledge constructs and argumentation. In order to transform pedagogy, teachers need to be innovative and be prepared to take risks, a venture that is best supported by establishing the practice of collaborative reflection within a community of professional learning (De Vries, 2006). De Vries (2006) asserts that argumentation contribute greatly to the efficacy of collaborative learning.

Figure 2.1 illustrates the process of an argument and its possible outcomes according to Leitaó (2000), whether it will be persevered or withdrawn in the presence of a counter-argument. Leitaó asserts that when a formulated argument meets opposition, four alternative forms of responses can follow. The counter-argument can be dismissed, localised, integrated or fully accepted. Dismissing or localising the oppressed idea may imply the preservation of the original argument. On the other hand, by integrating and fully accepting the counter-argument, it will prompt the arguer to withdraw the original argument.



**Figure 2.1: The process of argument reappraisal**

## 2.2 Socio-cultural constructivism

Socio-cultural theories proposed by Piaget (1936), Ausubel (1968) and Vygotsky (1978) accentuate the importance of prior knowledge and learning experience as the basis for further learning. This study is greatly influenced by Vygotsky's social constructivism that maintains that learning takes place when the learner incorporates new experiences into existing mental structures and reorganises those structures to deal with more complex problem experiences. Vygotsky (1978) asserts that:

Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level - first between people (inter-psychological), and then inside the child (intra-psychological). (p.75)

In other words, knowledge is constructed as one makes sense of the world around you. When interacting with one's environment experiences are gained which are then used to relate to that environment in a sensible and responsible manner. It is in this regard that a learner takes responsibility for his learning process.

However, this sort of learning environment is not likely to occur if the teacher dominates the instruction process through the talk-and-chalk teaching method. Learning is a cultural activity, which enables one to relate in a meaningful way to the human and material environment. Within the socio-cultural constructivist, regime arguments and dialogues are an effective way of communication and expression of freedom (Tao, 2004). According to Piaget (1936), knowledge cannot be given to learners; learners construct knowledge from their mental and physical experiences with the environment. Learning is both a physical and psychological activity and to be meaningful, it has to be internalised into one's cognitive structures. Ausubel (1968) also concurs with this notion, that learning is a process of assimilation and accommodation of new knowledge into existing cognitive structures depending on the learner's prior knowledge (Ogunniyi, 2005). It is incumbent upon the teacher to create an environment, which encourages effective learning in the classroom. The teacher should use teaching methods that will make the lessons interesting and encourages learners' creative and critical thinking and to make sense of their surrounding environment.

Argumentation forms part of Piaget's work during 1971, in which he studied children's disagreements about intellectual or moral issues as a developmentally relevant experience that foster cognitive development. In his findings, children's discussions were depicted as a privileged scenario that allows for conflict prompting, after which children seek new forms of knowledge that fit reality better than their original perspectives. In terms of conflict resolution, Piaget focuses on operation of regulatory internal mechanisms, while argumentation is a social practice involving negotiation of divergences. Obviously, cognitive and social constructivist learning theories provide theoretical support for the pedagogical and social design of effective learning environment; therefore, both perspectives are important in the learning process.

Ausubel (1968) asserts that an adult [teacher] has to mediate the learners' learning experience by selecting from their environment significant sources of experience, which will develop their cognitive structures. Ausubel states that during instruction, the teacher has to draw examples from the learners' everyday lives, but in doing so, the teacher has to ensure that these examples are relevant and will be able to stimulate the learner's cognitive structure.

Therefore, everyday knowledge and experiences of learners forms an important part of their knowledge construction.

### **2.3 Collaborative learning**

The thrust of constructivism is that teachers should facilitate learners' learning process in creating a conducive environment for learners to be able to construct their own knowledge (Vygotsky, 1978). The outcome-based education (OBE) curriculum for physical sciences is based on constructivism, therefore it is expected of the teacher to guide the learners in such a way that they are able to construct their own knowledge based on their direct experiences within and outside the classroom environment.

Studies of (Farenga & Joyce, 1999; Ogunniyi, 2003; Mason & Macrae, 2004; Tao, 2004) emphasize the important role played by peer interactions in the development and negotiation of shared meaning and understanding. In particular, Tao (2004) identified three cognitive benefits resulting from an argumentation process:

- **Articulation** - This is important when learners collaborate to air their ideas and thus helping them to clarify their viewpoints. Conflict is based on the Piagetian-perspective of learning, which involves disequilibria between new information and existing knowledge resulting in cognitive development.
- **To resolve conflict** - when disagreement arises, learners have to justify and defend their positions and this forces them to reflect on and review their understandings.
- **Co-construction of knowledge** - when working jointly on a task, learners can compete and build on each other's ideas and incrementally co-construct shared understanding. This is based on the Vygotskian-perspective, where mediation assists the learning process.

These cognitive benefits are crucial in knowledge construction and in the argumentation process. Ausubel (1968) also found that collaborative learning could play an important role in the learning process of learners and the importance of argumentation within the collaborative learning process. He stresses that when it comes to conceptualising the nature of science

(NOS) the different kinds of talk [conversation] between learners is essential for the construction of knowledge. He identifies three types of talk from collaborative interactions:

- **Disputational talk** which is characterised by disagreement and individual decision-making.
- **Cumulative talk** which is positive but uncritical decision-making.
- **Explorative talk** which is a constructive and critical engagement involving argumentation and hypothesis testing.

Drawing from their earlier studies Driver, Asoko, Leach, Mortimer and Scott (1994) claim that exploratory talk is the most productive talk as it deals with ideas that are explicitly debated, ideas and justifications for challenges are made, and alternative suggestions are offered. They emphasised that the quality of learners' interactions is critical to the learning outcome.

The combination of the cognitive benefits (articulation, conflict resolution and co-construction of knowledge) and the different talks (disputational, cumulative and explorative talk) can be used in group work environments to improve the learning process. Some group learning literature argues that poor group experiences often result from poorly designed group tasks. Another problem that stems from group is the high degree of sub-division of tasks; this is usually unreported by learners and is only noticeable when the teacher observes the group work process. Group interaction and intensity must outweigh efficiency, over-emphasis of the acquisition of team skills as an outcome of group work; because this may lead to group work not promoting quality learning. Slavin (1983:431) asserts that it is important that groups should be diverse or heterogonous to ensure that learners can learn from each other and provide stimulation and support to each other in different aspects and of different levels of the curriculum.

## **2.4 Role of language in argumentation**

The use of scientific language plays a crucial role in the mastering of scientific concepts. It is important to know the rules that govern a language and how to use it to be an effective



participant of the language. It is vital that teachers should emphasise the technical language of science, because it involve more than just having a bunch of formal symbols. It involves having an interpretation, or a meaning attached to those symbols. Habermas (1968) views it as a quasi-deductive process:

That starts from the apprehension of indefinite-definite parts and proceeds to the attempt to grasp the meaning of the whole, alternating with the attempt to take this meaning as a basis for defining the parts more clearly. Failure makes itself known when individual parts cannot be understood in this way. This then creates the need to redefine the meaning so that it will take account of these parts. This attempt goes on until the entire meaning has been grasped. (p.170)

Therefore, the lack of and incorrect use the technical language of science contributes a great deal to misinterpretation of learners. According to Kerlin, McDonald and Kelly (2009), language used in textbooks may reinforce learners' misconceptions about chemical change, because some teachers follow textbook content religiously even if they suspect errors.

Chemical equation problems are among the most important and at the same time most complex and difficult in the chemistry discipline. That is why researchers have dealt with them from a number of perspectives. Mortimer and Scott (2003) studied the problem-solving behaviours of experts and novices engaged in chemical-change problems. They found that unsuccessful participants had many knowledge gaps and misconceptions about chemical change. In another study Habte (2003) found that those participants who use algorithmic methods without understanding the concepts upon which the problems were based help to understand conceptual problems in general. Therefore, it is clear that if you know scientific knowledge it can help you to understand scientific concepts by following the algorithmic rules.

## **2.5 Argumentation**

Argumentation contributes greatly to the effectiveness of dialogical teaching and collaborative learning. The elements of argumentation such as questioning in a way that promotes higher order thinking and appropriate use of different communicative approaches

could include also the motivational factor, which would further lead to meaningful learning activity (Lehesvuori, Viiri, & Rasku-Putten, 2010). There are different definitions attached to the argumentation process by various researchers, for example:

“... a verbal, social, and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint” (Bricker & Bell, 2008).

“The representation of a common language that views locutions as state-changing operations, drawing on an analogy with classical artificial planning” (Reed, 2006).

“In dialogical argumentation discourse the arguer carries out two distinctive operations; justifying a position which requires reasons to be produced [supporting process] and negotiation process which involves getting the addressee to accept reasons and positions that relate to controversial matters” (Kerlin, McDonald, & Kelly, 2009).

“Argument is a product or dispute between people – a process view that stresses the interactive context in which argument emerges. Social activity, individuals who hold contrasting positions attempt to convince each other of the acceptability of each adopted opinion. It refers to the substance of claims, data, warrants and backings that contribute to the content of an argument. Argumentation refers to the process of assembling these components” (Toulmin, 1958).

“Argumentation is a statement or constellation of statements advanced by an individual or group of justify or refute a claim in order to attain the approbation of an audience or to reach consensus on a controversial subject” (Ogunniyi, 2007a).

Recent debates in science education about nature of science (NOS) and nature of indigenous knowledge science (NOIKS) necessitate the processes of critical reasoning and argument (Driver, Leach & Scott, 1996). NOS assume that space has definite dimensions, time is a continuous irreversible series of duration, nature is non-capricious and all events have causes

and humans are capable of understanding and interpreting the natural universe. Empirical testability is the canon of NOS. On the other hand, NOIKS is based on similar presuppositions of reality as NOS except that it also deals with logical and non-logical experiential and metaphysical realms beyond empirical testability.

In order to change the emphasis in teaching science to incorporate argumentation, teachers need to adopt more dialogic approaches (Mortimer & Scott, 2003) that involve learners in discussion and to consider how they themselves interact with fellow-learners to foster argumentation skills. A suitable analytic framework is provided by Toulmin's model (1958), which had been used as a basis for characterising argumentation in science lessons and in other coding schemes. Features of Toulmin's model include the extent to which learners and teachers make use of data, claims, warrants, backings, qualifiers and rebuttals, and the extent to which they engage in claiming, justifying and opposing the arguments of each other. Toulmin's framework can help teachers to conceptualise and evaluate argumentation processes.

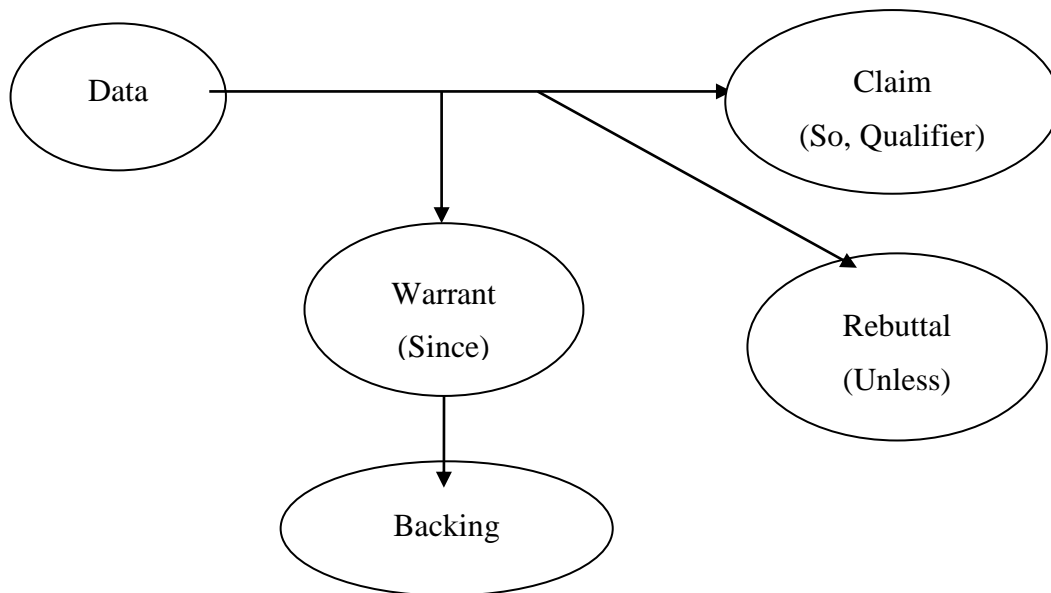
Through providing learners with tasks that require discussion and debate, teachers can support learners in the construction of arguments through the process of argumentation. In order to facilitate the argumentation process in the science classroom the teacher must make sure the following elements are included in the argumentation process; talking and listening, knowing the meaning of argument, positioning, justifying with evidence, constructing arguments, evaluating arguments, counter-arguing, reflecting on the argumentation process. For effective argumentation discourse, learners need to learn to listen and talk, justify claims, etcetera before they could debate and teachers need to value and learn how to implement group discussions and prompt justification before they could orchestrate effective counter-arguments within their teaching.

Learners should be able to engage in decision-making about controversial issues in science, and to do so they will need to understand how evidence is used to construct explanations. They will also need to understand the criteria used in science to evaluate evidence. There is a growing need therefore to educate our learners and citizens about why we believe in the scientific world-view that is, to see science as a distinctive and valuable way of thinking.

## 2.6 Toulmin's Argumentation Pattern (TAP)

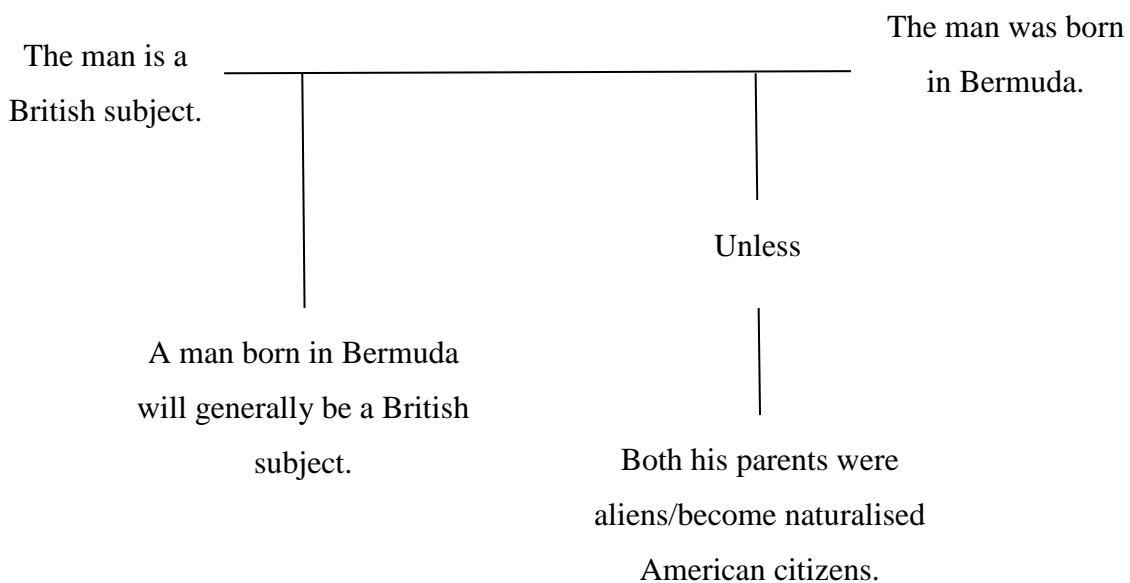
Toulmin (1958) believes that an argumentation process should have certain prerequisite elements. These elements are essential to construct a meaningful argumentation process. He refers to these elements as:

- Claims – these are assertions (declarations without support) about what exist or values that people hold, for example, “Organ trafficking should be banned”
- Data – these are statements that are used as evidence to support the assertion, for example, “People are coming to South Africa to sell organs illegally.”
- Warrants – these statements explain the relationship between the data to the claim, for example, “Illegal organ trafficking means serious risks to people’s health through ‘back street’ surgery.”
- Qualifiers – these are the specified conditions under which the claim holds true, for example, “The ban should only apply to trade in essential organs like kidneys.”
- Backings – these are underlying assumptions, which are often not made explicit, for example, “People have died of septicaemia after organ removal.”
- Rebuttals – these are statements, which contradict the data, warrant, backing or qualifier of an argument, for example, “If proper control measures are in place, like licenced removals in hospitals, banning would not be necessary.”
- Counter-claims – these are simply opposing assertions.



**Figure 2.2: Elements of Toulmin’s Argumentation Pattern**

Toulmin used these elements to formulate his Toulmin’s Argumentation Pattern (TAP), based on deductive-inductive discourses. TAP is adopted and used in science education to enhance learners understanding of the Nature of Science (Erduran, 2004). Figure 2.2 illustrates how these elements are related in terms of the argumentation process. Furthermore, he gives a practical example illustrating the use the different TAP elements, by providing a high-level claim about a man that is a British subject, in Figure 2.3:



**Figure 2.3: Example of Toulmin’s Argumentation Pattern**

Erduran, Simon and Osborn categorised the TAP into seven levels of argumentation in order to determine the degree of an argumentation process. The levels progress from level zero to level six as indicated in Table 2.1:

**Table 2.1: Levels of argumentation**

<b>Quality</b>	<b>Characteristics of an argumentation discourse</b>
Level 0	Non-oppositional
Level 1	Argument involves a single claim with no grounds/evidence or rebuttals.
Level 2	Argument involves claims with grounds /evidence but no rebuttals.
Level 3	Argument involves claims or counterclaims with grounds /evidence but only a single rebuttal.
Level 4	Argument involves multiple rebuttals challenging the claim but no rebuttals challenging the grounds (data, warrants and backings) supporting the claim.
Level 5	Arguments involve multiple rebuttals and at least one rebuttal challenging the grounds.
Level 6	Argument involves multiple rebuttals challenging the claims and grounds

**Note. The levels was modified after Erduran (2004)**

### **2.6.1 Criticism of Toulmin’s model:**

Although the TAP is a very useful tool, in science education, that has enabled both teachers and learners to immensely understand the nature of science and practitioners in the legal field, some researchers believe it has flaws. Kneupper (1978) asserts that, “When actually studying naturally occurring argumentation, the model [TAP] becomes problematic as it greatly limits the analyst’s ability to consider the different perspectives in the discussion, the perspective of the speaker and that of the critical interlocutor. It does not suit the purpose of displaying how the speaker’s arguments are mutually influenced and subtly transformed in the course of a discussion.” Willard maintains that TAP is too much focused on the protocol that is being followed.

Another researcher, Kneupper (1978) asserts that, Toulmin is critical of the disjuncture of formal logic and the practical concerns of “real life”. His assertion is that Toulmin view non-logical phenomena as not important, because it is not based on testable facts. Furthermore, he believes that TAP cannot explain metaphysical experiences and concepts, because it is based on the “science of logic”. Kneupper’s views is supported by Jegede (1995) and Ogunniyi

(1998) who formulated the Contiguity Argumentation Theory (CAT), which addresses the flaws of TAP.

## **2.7 Contiguity Argumentation Theory (CAT)**

Jegede (1995) asserts that a learner might partially or totally accept what is taught in the science classroom (formal knowledge) and compare it with what he knows (informal knowledge). He can decide whether to keep the formal and informal knowledge separate or side-by-side. Jegede (1995) calls it “collateral learning” and Ogunniyi (1999) terms it “harmonious dualism”, which explains how concepts like nature, nurture, predictable and unpredictable, physical and metaphysical, western science and indigenous knowledge science (IKS) can co-exist in a mental state. Ogunniyi further developed his theory of harmonious dualism into the Contiguity Argumentation Theory (CAT).

Ogunniyi’s (1999) Contiguity Argumentation Theory (CAT) does not only explain the deductive-inductive reasoning, but also metaphysical reasoning. His theory dates back to the Platonic and Aristotelian era. Ogunniyi cites that the Aristotelian Contiguity Theory asserts that one or two states of mind [for example western science and IKS] tend to readily couple with, or recall each other to create an optimum cognitive state. The Contiguity Theory is a learning theory, which states that more than one distinct thought systems can co-exist to create an optimum cognitive state. The CAT recognizes five categories into which conceptions can move within an individual’s mind or amongst individuals involved in dialogues justifying scientific and or metaphysical conceptions. These five categories exist in a dynamic state of flux in a person’s mind, namely:

- Dominant mental state – when it is the most adaptable to a given context for example living in a community where people strongly belief in witchcraft.
- Suppressed mental state – when the dominant cognitive stage is overpowered by another more adaptable mental stage for example a religious persons that become enlighten by scientific facts.

- Assimilated mental state – when the dominant mental stage is absorbed into another more adaptable mental stage for example a black person taking on customs of a white culture.
- Emergent cognitive stage – when an individual has no previous knowledge of a given phenomenon as would be the case with scientific concepts and theories for example atoms, gene, entropy, theory of relativity, etc.
- Equipollent mental state – when two competing ideas or worldviews tend to co-exist in the mind of the individual, without necessarily resulting in a conflict for example a religious teacher teaching the evolution of man without any bias to his religion.

## **2.8 Construction of knowledge and misconception**

Bricker and Bell (2008) assert that learners struggle to learn physical science concepts. They furthermore argues that learners generate their own meaning of concepts based on their backgrounds, attitudes and experiences and to what information learners pay attention to is determined by their preconceptions. This means that learners learn by formulating their own understanding as they make sense of information around them from their own point of view; the basis of knowledge construction. These concepts come from two sources namely, scientific knowledge (formal knowledge) and everyday informal knowledge (Jegede, 1995). Bricker and Bell (2008) regard learning as a cyclical process in which new information is compared to prior knowledge, and then it is fed back into that same knowledge base. They assert that learners selectively attend to new information presented and their preconceptions determine which information they make part of their knowledge base. Bricker and Bell also contend that the brain actively interprets this selected information and draws inferences based on its stored information. The newly generated meanings are then actively linked to the learner's prior knowledge base.

Furthermore, they explain that these coherent understanding of events and phenomena are cognitive structures which are made up of interrelated concepts. Each concept forms part of a linked set of simple, declarative statements called propositions that represent the body of knowledge the learner possesses about a concept. For example, “An atom contains a positive nucleus at the centre”, is a proposition that contains a declarative statement. This statement



contains a set of interrelated concepts like, atomic structure, electrostatics forces, etcetera, which give meaning to the declarative statements. Concepts, therefore, are considered to be the set of propositions that a person uses to infer meaning for a particular topic. If some or all of the interrelated concepts are not part of the prior knowledge base it may lead to misconceptions. Bricker and Bell (2008) define misconceptions as:

“When there is a difference between the connectional understanding of a learner and the commonly accepted scientific meaning of a term, there is interference in the learning process. These interferences are called many names like, misconceptions, preconceptions, alternative frameworks, children’s science, and learners’ descriptive and explanatory systems. Creating a cognitive structure of complex body of knowledge in science and chemistry in particular, is not easy, that is why learners find it difficult to do science”. (p.95)

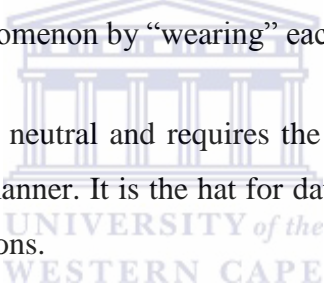
The abstract nature of science leads to “tacit assumptions” on the part of the learner, about which the teacher is quite unaware, and which account for the common misconceptions of which some is, the particulate nature of matter, balancing of chemical equations, synthesis and decomposition chemical reactions. It is important that these misconceptions be determined as early as possible and addressed, or be prevented during a learning process. A possible prevention strategy could be the use of computer-assisted learning, which will make these abstract concepts more comprehensible.

## **2.9 Learning styles**

Understanding learners’ learning styles helps teachers make learning more relevant and effective. Dunn and Griggs (1989) asserts that, “Learners’ individual learning style is a genetically and developmentally imposed set of characteristics that explain why the same lessons, readings, interactions, classroom setting and teachers affect individuals differently”. It is therefore important that teachers should create a multi-sensory classroom environment to accommodate as many learning styles as possible. There are many different ways to classify learning styles. Van Rooyen et al. (2007) summarise the learning styles in three general categories:

- Perceptual modalities define biologically based reactions to our physical environment and represent the way we most efficiently adopt data.
- Information processing distinguishes between the way an individual senses, thinks, solves problems and remembers information.
- Personality patterns focus on attention, emotion and values. These reflect the way an individual will react, feel about and value different situations.

Edward De Bono (1997) asserts that individuals have preferred ways of thinking about the same thing. He believes that some people are emotional and others clinical or factual when they interpret objects or concepts. He claims that many disagreements are probably set off by these different ways of thinking. He proposes a Six Thinking Hats technique that teaches learners to view an issue from six different perspectives. This is a particularly useful tool for dialogical argumentation instruction, because it makes the learners sensitive to other points of view. Each of these hats describes a different thinking approach and learners are asked to view a particular problem or phenomenon by “wearing” each of the hats in turn:

- 
- White hat – be clinical or neutral and requires the thinker to discover the facts of a situation in an objective manner. It is the hat for data, detail, figures, information and the asking of useful questions.
  - Yellow hat – be bright and positive and requires the learner to look at the good points in a situation or proposal.
  - Red hat – be hot and encourages the learner to allow his/her emotions, intentions, and general feelings to hold court without any need for justice or substantiation. The thinker uses his/her emotions to lead the thinking.
  - Black hat – be serious and encourages the thinker to be cautious about an idea or a subject under discussion. This is the most important hat in critical thinking as it prevents the learner’s emotions from dominating. The thinker plays devil’s advocate, asking questions that are likely to expose weaknesses in an argument.
  - Green hat – be creative and heralding new beginnings. This hat invites lateral solutions, creativity and innovative suggestions.

- Blue hat – be the sky and suggests an overview in thinking. It is the meta-cognitive hat. This hat challenges the thinker to be self-analytical and evaluative, and to think holistically.

## **2.10 The computer-assisted learning (CAL) debate**

A popular belief exists that the use of information communication technology (ICT) resources can improve learner performance drastically (Bungum, 2003). However, the use of ICT resources in the classroom can only be effective when used within a CAL environment. Some researchers conducted studies and suggest that CAL improves the achievement of learners in certain learning settings (De Vries, 2006; Wang, 2008 and Layton, 1993). Other scholars (Bungum, 2003; De Vries, 2006 and Reyes, 2012) negate these findings and are critical about the use and success of CAL in the learning process. The interpretations that teachers have of CAL influence the measure with which they integrate CAL into their lessons.

The different meanings attached to technology also depict the views teachers have about the use of ICT resources in the classroom (Layton, 1993). Layton indicated that teachers have three viewpoints of technology. These are: the ‘human view’ which sees technology as responding to and serving human needs; the ‘titanic view’ which takes technology as heroic and attempting to control nature; and the ‘satanic view’ in which technology is used to produce destructive machinery, and social and environmental problems.

### **2.10.1 Why CAL could work in the classroom**

Effective integration of ICT into teaching and learning is becoming an essential competency for teachers, because of the rapid narrowing of the global digital divide. In a survey commissioned by the United Nations investigating ICT and education revealed that in 2006, approximately 23% of schools in Africa surveyed conducted some form of CAL and the schools increased to 38% (Vision Learning, 2012). Integration of ICT into learning environments is happening at fast rate, urging teachers to make use of CAL. The pedagogical rationale according to Bungum (2003) asserts that computers can improve the teaching and learning process and enhance the instruction of traditional subjects in the curriculum.

Skoumios and Hatzinikita (2009) agree that computers should be integrated into the content domains and that learners should learn to apply computers in a meaningful way in the different subject areas, to facilitate coherence and conceptual understanding of the necessary computer skills and the accompanying computer application software. They also emphasise the importance that the teaching of computer skills cannot take place in isolation, for example in separate computer classes, without integrating it into the content domain, because it is not beneficial or advantageous to the learners (Omar, 2003).

Layton (1993) asserts that computer-assisted learning helps to re-package knowledge, reconstruct knowledge and contextualise knowledge in the science classroom. A number of studies (Naicker, 2010; Mumtaz, 2000; Gardner, 1990) concur with his findings that CAL programs offer mostly individual learning, but these programs can also be used in a collaborative context. Naicker (2010) contends that learners interacting around a computer is a productive way of learning, arguing that the ensuing peer interaction facilitate individual learning as well as the joint construction of knowledge. Mumtaz (2000) who asserts that the benefits of classroom computer use arise from the fact that computers lend themselves very well to the collaborative mode of use supports these views. Geer and Sweeney (2012) further support this viewpoint by suggesting that while traditional teaching can often be very teacher-centred, the computer does not have the same social role and authority as a teacher and so learners are much less inhibitive in their discussions by its presence.

Geer and Sweeney (2012) assert that if CAL programs are well designed and with multimedia features, it can offer unique learning experiences to learners that other media cannot provide. Simulations, as one form of CAL programs allows learner to freely experience, explore and manipulate the micro-world and macro-world by changing parameters and variables and visualising immediately the consequences of their actions. Using these programs learners can formulate and test their hypotheses and reconcile any discrepancy between their ideas and the observations” (Tao, 2004). In their study, Tao (2004) illustrates how physics phenomena and process with multimedia (moving pictures, narration and text) can help learners develop understanding in ways that are superior to forms that use one media, for example, text alone. Importantly, they provide focal points for discussion and reflections if learners are directed to the relevant key questions or issues of a topic. Geer and Sweeney (2012) also assert that

simulations are well-suited for discovering learning, hypothesis generation and testing that leads to knowledge construction.

The cognitive-motivational-approach proposed by Gardner (1990) presents technological applications very early in the instructional sequence in order to capture learners' interest in the topic and then teach the scientific concepts. For example, learners are taught shapes and sizes of molecules by firstly showing them simulations and animations and then explaining the textbook content. The aim is to attract the learners' interest and to use CAL as a mediator of knowledge construction.

Hendricks (2001, p.135) asserts that, "... my hunch based on my experience in the study - while Computer Based Instruction does not enhance learning directly it proved an addition to manipulate information and hence, overcome cognitive deficits".

### **2.10.2 Why CAL might not work in the classroom**

Many researchers question the effectiveness of computer-assisted learning (CAL) and the use of information communication technology (ICT) in the classroom. The argument they put forward is that since the introduction of ICT into the classrooms there are no tangible proof that it is responsible for improvement of learner achievement (Bungum, 2003; De Vries, 2006 and Reyes, 2012). Furthermore, most teachers do not usually follow linear instructional design models, which are required when planning to integrate ICT into lessons (Wang, 2008). Teachers need to plan thoughtfully before they start ICT integration into a curriculum; for example, they have to choose the correct ICT resources for particular learning objectives or contents, modify existing ICT resources or develop new learning environments to engage specific groups of learners, or decide scaffolding strategies for learner-centred learning. Teachers might feel overburdened in implementing all these aspects of CAL. In his studies, Mumtaz (2000) investigated why teachers avoid or are inhibited from using ICT resources in their teaching. He categorised the main inhibitors as follows:

- Lack of teaching experience with ICT;
- Lack of on-site support for teachers using technology;
- Lack of help supervising learners when using computers;

- Lack of ICT specialist teachers to teach learners computer skills;
- Lack of computer availability;
- Lack of time required to successfully integrate technology into the curriculum;
- Lack of financial support.

These inhibitors play an important role in teacher and learner access to computer-assisted learning. In addition, Mumtaz identified three styles of computer use among teachers: avoidance, integration and technical specialisation. He found the dominant style to be avoidance, where teachers typically distance themselves from computers and otherwise reduced the amount of time they spent attending to computer-related activities. Furthermore, studies have shown that teachers who are trained in using linear instructional design models (utilising ICT in presentation, analysing, evaluating and revising teaching material) are often reluctant to apply them in real instructional planning processes due to the impracticality of the models in a complex school environment.

### 2.10.3 How to make CAL work in the classroom

Mumtaz (2000) asserts that, “Learners using stand-alone computers allow them to interact with embedded learning resources. With computer-mediated communication (CMC), like internet and intranet, it can make social activities more convenient and flexible. Learners may still use computers individually.” In addition, he emphasises that human-computer interface design is crucial, as it determine the usability of a technology-based learning, ease of use and aesthetics. Mumtaz developed a generic model for effective integration of ICT into teaching and learning. His model consists of three key components:

- **Pedagogy**, which is necessary to have the correct approach in terms of the learning system, educational purposes, scaffolding learner during learning processes.
- **Social interaction**, which is crucial in daily life activities and the learning process, should be incorporated into the CAL process.
- **Technological component**, which includes activity and easy access are initial requirements for effective computer-assisted learning.

Furthermore, Mumtaz asserts that learners should have the opportunity to work collaboratively, for example in problem solving exercises. He also posits that computer-assisted learning has positive effects on learners' performance in solving problem-based tasks.

In summary, pedagogy, social interaction and technology are critical components of a technology-enhanced learning environment. However, the primary factor that influences the effectiveness of learning is not the availability of technology, but the pedagogical design and social design. Teacher pedagogies are the highest predictors on the use of computers in the classroom. Therefore, the various ICT resources should be adopted according to the educational models employed in classrooms (Naicker, 2010).

## **2.11 Gender and socio-economic influences on learning**

Greenfield (1997) uses the word “gender” to imply the social or environmental causation of differences that are observed between sexes. She refers to the word “sex” when referring to biologically determined behaviours. It is not always possible to separate social and biological influences and perhaps it is not always necessary to do so. In this study, the position of non-separation between the social and biological is adopted. Hendricks (2001) cites in his study that although 54% of Science and Engineering workforce in South Africa are females, they mainly filled the ranks of the social scientists. Males predominantly occupy fields such as engineering, natural science and technology, which were promoted by the South African apartheid regime.

Banks (1995) describing the aims of multicultural education as seeking to create:

Equal educational opportunity for learners from diverse social class, racial, ethnic and cultural groups to help all learners to acquire knowledge, attitudes and skills needed to function effectively in a pluralistic democratic society to interact, negotiate and communicate with people from diverse groups ... to create a civic and moral community that works for the common good. (p. 11)

The cultural diversity of our country is reflected in many classrooms and language is usually used to cross cultural borders. If the home language of a learner does not coincide with the language of instruction then the learner is likely to struggle with the course content. This is because of issues such as thinking in one's own language while listening to another, finding difficulty in expressing conceptions, even alternative conceptions in a second language and the difficulty associated with formulating logical reasoning in a translated language. In other words, one knows what to say but does not know how to say it (Wray & Kumpulainen, 2009). For this reason, Wray et al. (2009) advise that the mother tongue be used for class discussions and speculations. However, she warns against an over use of the home language because the learner needs more, not less exposure to the second language, in this case English, to do business and to participate in a host of activities.

Wray et al. (2009) studies concluded that in multi-cultural settings the background of the learners influences their conceptions and if teachers are not aware they can reinforce misconceptions that learners might hold.

## **2.12 Summary**

In this chapter, I introduced argumentation by referring to its relevance in other disciplines in general and in the education field in particular. The importance of argumentation in the construction of knowledge was also highlighted by interrogating literature on the role of language in the learning process, the learning styles of learners and how misconceptions can be circumvented. It also alluded to how these concepts form the building blocks of the theoretical framework namely, CAT and TAP.

The different elements of DAI were highlighted by indicating its pivotal role in collaborative learning practices. The debate on the effectiveness CAL and the use of ICT in the classroom, or lack thereof, was also presented by referring to literature of the proponents and the antagonists. This chapter concluded with the influences of gender and socio-economic factors on learning and argumentation. The next chapter describes the methodology, instrumentation and data collection of this study.



## CHAPTER 3 – METHODOLOGY

### 3.1 Introduction

In the previous chapter, a review of the extant literature was done to explore the various perspectives concerning argumentation and computer-assist learning (CAL). In this chapter, I will describe the procedures that were followed in order to generate and collect the necessary data to answer the research questions. Research Question One deals with the status quo of information communication technology (ICT) resources at the selected schools in the region of the research school. The main objective for doing the survey was because ICT is becoming increasingly an integral part of the education setup at schools and a huge amount of money and training is invested in this aspect, especially at the research school. Part of this research project particularly focuses on the use of ICT resources in the teaching and learning process.

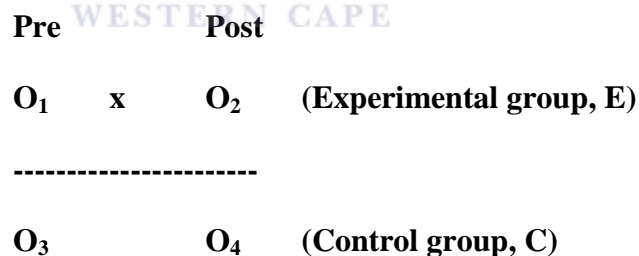
Research Question Two focuses on the dialogical argumentation instruction methodology as an alternative way of instruction. This study took place in the middle of the third term after the mid-year examinations. At that stage the grade ten learners were supposedly accustomed to the Further Education and Training (FET) phase of the schooling system, which is more examination-orientated as compared to grade nine in the General Education and Training (GET) phase which is less examination focused. In grade nine general sciences as a learning area, covered three subjects namely, physical sciences, life sciences and geography. The researcher had many opportunities to induct the experimental group in the practice of dialogical argumentation protocol during the first two terms by introducing dialogical argumentation instruction (DAI).

Research Question Three attempted to add flesh and colour to the research study by looking at the socio-economic conditions of the participants. It is very important because of the fact that they come from various backgrounds as stated in the research setting. In the following sections, I shall sketch the procedure used in collecting and analysing the data for the study

### 3.2 Research design

This study falls within the descriptive research paradigm, and it includes a quasi-experimental, interpretative and mixed method. The research data is derived directly from primary sources; learners and teachers at Newton High (fictitious name). A sequential mixed method was used in which the study elaborates and expands on the quantitative data findings qualitatively (Creswell, 2009). This research is mainly quantitative with some qualitative aspects. The qualitative approach includes a semi-structured survey, in which information was gathered from the selected schools. The survey also explored the status quo of CAL and at the selected schools. Apart from being quasi-experimental, this study is also located within the interpretive paradigm in which one tries to understand the behaviour of the participants within their context. This study also made use of focus group interviews; classroom observation schedules and a questionnaire in order describe and understand the learners' backgrounds and their classroom environment (Gomm, Hammersley, & Foster, 2000).

The quantitative aspect of the quasi-experimental design measured the differences between the conceptual understanding of the experimental and control groups (Punch, 2009). The following format was used for the quantitative design:



O<sub>1</sub> is the pre-test and O<sub>2</sub> the post-test of the experimental group (E). X depicts the use of Dialogical Argumentation Instruction as an intervention among the experimental group (E). O<sub>3</sub> (the pre-test) and O<sub>4</sub> (the post-test) of the control group (C) was not subjected to Dialogical Argumentation Instruction. However, Computer Assisted Learning was used in both groups. The independent variable of this research was the different instructional strategies that were used and evaluated, namely DAI and Traditional Instruction. This variable was used in order to observe its relation to the participants' "response" (Shavelson, 1981). The dependent variable was the performance of the learners within the different

pedagogical settings and their achievement at the end of these sessions; this is the “response” to the independent variable. In order to ensure that the results of this research are reliable and fair, the degree of difficulty of the content of the activities was kept the same in both groups.

### 3.3 Research sample

The ten schools were randomly selected from twenty high schools of two circuits in the Education Management Development Centre (EMDC) North for the ICT resources survey. The experimental and control group was grade ten classes at Newton High (fictitious name). The experimental group initially consist of 30 learners and the control group 28 learners. Eventually both groups were reduced to 25 participants each, due to attrition.

#### 3.3.1 Sample selection

The two groups were selected out of the four grade ten physical sciences classes, after they completed the pre-test of the Chemistry Achievement Test. The selection of the two groups was based on different home languages (medium of instruction was in their home languages – Afrikaans and English) and different subject choices to minimise contamination (Mouton, 2001). The primary motivation for the group selection was the statistical significant similarity of the groups, based on the pre-test results. The objective and process of the research project was explained to all the participants and they returned consent forms, which their parents completed.

**Table 3.1: Sample distribution in terms of gender, age and race.**

Groups	Gender		Age (years)		Race		Total
	Boys	Girls	14-15	16-17	Coloured	Black	
Control	10	15	9	16	20	5	25
Experimental	17	8	11	14	17	8	25
Total	27	23	20	30	37	13	50

#### 3.3.2 Geographical and historical background of the research site

Newton High is situated in a historically disadvantaged Coloured neighbourhood in the Western Cape Province. Poverty is rife and in most households, parents are single and unemployed. Drug abuse and teenage pregnancy is prevalent amongst the youth. Despite

these dire circumstances, the area has produced prominent role models in the provincial and national sport and political arenas.

The learners of Newton High come from all the social classes (low-income, middle-class and high-income) and racial groups (Coloureds, Blacks and Muslims). The learner population of the school cover a radius of about 50 kilometres and learners travel to school by means of public and private transport. Learners attend the school from various areas, because it is a comprehensive school, offering academic subjects like mathematics, sciences and commerce and technical subjects, such as, civil engineering, mechanical engineering, electrical engineering and graphic design. Newton High is also part of the Dinaledi Project (mathematics and science focus schools), the National Education Department invests many resources in the school to produce excellent results in mathematics and science. Newton High's extra-curricular activities are rugby, netball, soccer and chess of which rugby is the most popular.

Newton High is well known for producing learners with good grade twelve results. In the past five years, the grade twelve overall pass rate were, 60%, 50%, 62%, 86% and 84% respectively. The physical sciences maintained an average mark of 40% over the past five years. The reason for the lower performance in comparison with the overall grade 12 pass rate is because the majority of the science learners do mathematical literacy. An alternative to mathematics, mathematical literacy was introduced into the curriculum as a subject for those who may not be mathematically gifted; hence, it does not include most of the mathematical sections used in physical sciences (Department of Basic Education, 2012).

### **3.3.3 Why the two groups at the same school?**

The majority of the learners come from different suburbs of Cape Town namely, Bellville South, Belhar, Kuils River, Delft, West Bank, Eerste River, Mitchell's Plain, Khayelitsha, Nyanga and Kraaifontein. At the end of the school day learners rush for their transport home. They travel with private transport, busses and trains. There will almost be no time for participants to interact and exchange information. Secondly, the participants of the experimental group have English as home language; the control group have Afrikaans as home language, and usually learners with different home languages do not associate. Thirdly,

the groups had different subject choices. The experimental group had subjects that are more academic, whereas the control group has technical subjects, thus they most probably have different interests and hobbies, which will make it most unlikely that they will associate and interact.

The researcher conducted the sessions with the experimental group since it was difficult to get a teacher who is well trained in Dialogical Argumentation and Mr Jones (fictitious name) conducted the sessions with the control group. The researcher is well trained in the Dialogical Argumentation Instruction being involved for five years in a DAI project at the University of the Western Cape. Mr Jones has 16 years of physical science experience and a four-year professional teaching qualification in science education.

### **3.3.4 Inducting the experimental group in dialogical argumentation**

The researcher taught the experimental group physical sciences, which was convenient, because he could induct the group adequately in the practice of dialogical argumentation during the first and second term of the year. The participants were excited to be part of the research project, especially when it came to group work and argumentation. The presentation of the activities were based on the Dialogical Argumentation for Evolving Cognitive Understanding (DAECU) model of Langehoven (2009), which was inspired largely by the works of Erduran, Simon & Osborne (2004) and Ogunniyi (2007a & b). The DAECU model consists of five stages of cyclic whorls arranged in ever-increasing sizes all starting at a nodal point. The nodal point is where the topic of the activity is presented. The symbolic representation of the cyclic whorls in the model provides space for a return to any stage of the discussions and arguments if required. The following stages of the DAECU model are represented in Figure 3.1.

**Stage 1:** Nodal point – Introducing and eliciting the topic of discussion or activity.

**Stage 2:** Individual task – Allows for individual ‘Thinking Space’. Each learner is provided with stimulus material, than the learner is prompted to engage with the material through a set of questions. These questions promote internal argumentation (intra-

argumentation) with a view to the recording of responses. An accessible writing frame is provided to the learner to record claims, backings, warrants and rebuttals.

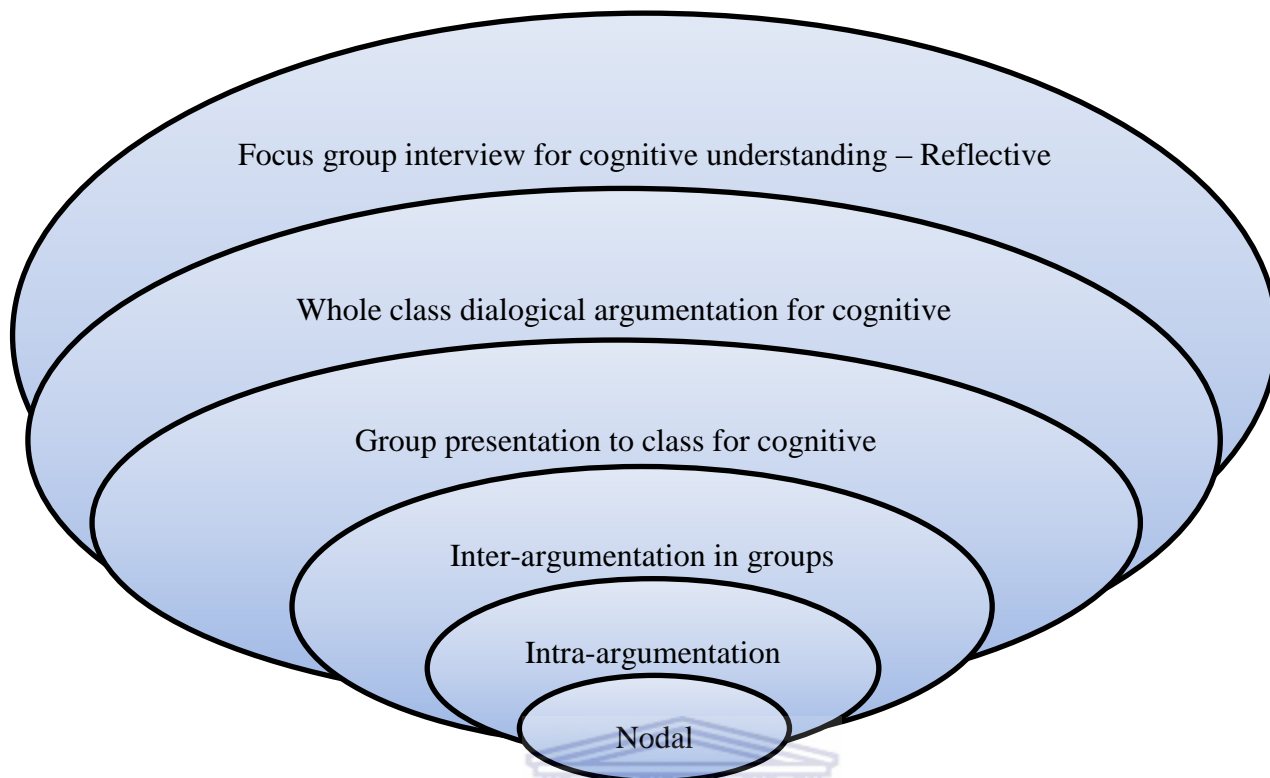
**Stage 3:** Small group discussion and consensus – Allows for individual ‘Sharing Space’ with other members of the group (inter-argumentation). Each learner is invited to present his or her ideas, thus encouraging each group member’s voice to be heard. After the group debate, an internal consensus (cognitive harmonization) is achieved for presentation to the class.

**Stage 4:** Small group presentation – Allows for general ‘Discussion Space’. The group leader presents the arguments, counter-claims, rebuttals, evidence and warrants. These displays are boldly written on paper strips and/or posters and posted on the board or classroom wall.

**Stage 5:** Whole class mediation – Allows also for general ‘Discussion Space’. This process is managed by the facilitator (teacher), who assists in identifying trends and patterns by advancing a cognitive harmonization (understanding of the issues).

**Stage 6:** Focus group evaluation – Allows for a ‘Reflective Space’. An interview process, managed by the facilitator, is held with a random selection of learners, in order to reflect on the process of argumentation and the understanding of the issue (Vaughn, Schumm, & Snagub, 1996).

At the end of the activity, the teacher summarised the different groups’ findings, highlighted the misconceptions and erroneous concepts, and reinforced the intended learning objectives. Formative feedback is important to make sure that the objective of the learning activity is met at the end (Slavin, 1983).



**Figure 3.1: Dialogical Argumentation for Evolving Cognitive Understanding model**

Learners found this new approach using the DAECU model interesting and seemed to enjoy it, measured by the manner how they interacted and took part in the activities. Learners also expressed positive views, which could be construed as evidence to show that the activities have enabled them to appreciate the usefulness of dialogical argumentation. However, the over-eagerness and excitement led to the fact that learners often stray of the point of discussions and lose focus. The researcher had to put down strict house rules and stressed the protocol for group work and dialogical argumentation.

### **3.4 Instrumentation**

The research tools used in the main study emerged from two pilot studies. The designing of the instruments was largely guided by the objectives of the three research questions of this study.

All instruments were based on the grade 10 Matter and Materials sections of the Curriculum Assessment Policies (CAPS) document, which include the following content (Department of Basic Education, 2012:9):

- Revise matter and classification (materials; heterogeneous and homogeneous mixtures; pure substances; names and formulas; metals and non-metals; electrical and thermal conductors and insulators; magnetic and nonmagnetic materials).
- States of matter and the kinetic molecular theory.
- Atomic structure (models of the atom; atomic mass and diameter; protons, neutrons and electrons; isotopes; energy quantization and electron configuration).
- Periodic table (position of the elements; similarities in chemical properties in groups, electron configuration in groups).
- Chemical bonding (covalent bonding; ionic bonding; metallic bonding). Particles substances are made of (atoms and compounds; molecular substances and ionic substances).

#### **3.4.1 Preliminary (pilot) study**

Ogunniyi (1984) asserts that unless the items of instruments are well written, they tend to evince ambiguous responses. The construction of rating scales is not just a matter of writing a list of statements to be responded to. It requires several revisions and pilot testing in order to determine which items are or are not suitable. The instruments which consists of a classroom observation schedule (Appendix B), a questionnaire about learners attitude towards science (Appendix C) and a chemistry achievement test (Appendix E) were developed by the researchers and fellow master students. The pilot study was conducted to improve the validity and reliability of the instruments of the main study. Two classes of grade ten learners of a neighbouring high school and their science teacher were participating of the pilot study.

The content of the pilot study was on concepts of acids and bases. Learners had to identify different household acids and bases items and their properties. They had to do a neutralisation reaction of vinegar and bicarbonate soda and explain their observations. The learners also had



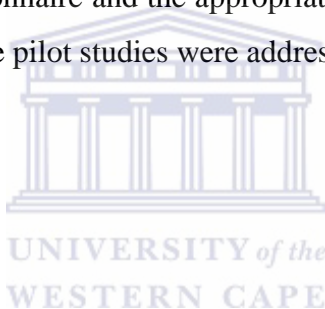
to design an indigenous indicator to test for acids and bases. First, they completed a worksheet individually and thereafter discussed the individual findings and reach consensus within the group. Thereafter, the different groups reported to the whole class and the teacher summarised, gave the “correct” scientific explanations, and addressed the misconceptions expressed by the learners. The responses and observations of the participants were analysed. The findings and recommendations of the study was used to inform the main study.

An additional pilot study was conducted with fellow post-graduate students during Science and Indigenous Knowledge Science Project (SIKSP) workshops and at an Indigenous Knowledge Science (IKS) Conference at the University of the Western Cape. Valuable feedback was received with regard to the structure, content, focus of the instruments, worksheets and how to include the different aspects of group work dynamics into the activities. The findings of the pilot studies revealed certain shortcomings such as, time constraint, structure of the questionnaire and the appropriateness of dialogical argumentation. The shortcomings identified in the pilot studies were address and rectified in the main study.

### **3.4.2 Data collection tools**

#### ***a) Survey questionnaire***

A survey questionnaire (Appendix A) was used to collect the data of the information communication technology (ICT) resources and the use thereof at the selected schools. Field (2009) classifies surveys as one of the approaches to collect data in quantitative research and recommends the use of fixed-choice response formats. Kerlinger (1973) defines survey research as a study, which deal with incidence, distribution, and inter-relationships of sociological and psychological variables. Both Silverman and Kerlinger emphasise the importance of questionnaires as a data-gathering technique in survey research. The advantage of the questionnaire is that generally it helps to get quick responses. Furthermore, questionnaires can be used to obtain vast information within a short period. However, questionnaires also has disadvantages like, the risk that a certain percentage of the questionnaires will never return, if the questionnaire is sent to respondents to complete on their own. In addition, the respondents could misinterpret certain items on the questionnaire.



The survey questionnaire consisted of four sections, which covered information about the science learners at the school, the ICT resources available at the school, how often the ICT resources are used and the teachers' perception of CAL. The format of the questions was open-ended and fixed choice questions. A frequency count was made of the quantity of the different ICT resources that was available at the selected school. The frequencies was converted to percentages for ease of interpretation.

**b) Chemistry Achievement Test (ChAT)**

Ogunniyi (1992) asserts that social sciences instruments were initially developed by psychologists to study underlying conditions that affect a person's behaviour. The commonly used test fall under the categories of achievement tests, criterion-reference tests, intelligence tests, aptitude tests and personality tests. This study made use of an achievement test, "which measures what a person knows or has achieved after learning experience" (Ogunniyi, 1992:70). The Chemistry Achievement Test in this study was used to determine the conceptions of chemical equation concepts of the learners before and after the research study. The levels of Bloom's taxonomy refer to the complexity of the intellectual activity required from the learner (Bloom, 1956). The development of the taxonomy for the cognitive domain shows a progression from the simple to the most complex levels of knowledge and intellectual skills, as illustrated in Table 3.2.

**Table 3.2: Outcomes in terms of Bloom's taxonomy**

<b>Level</b>	<b>Description</b>	<b>Action verbs</b>
Knowledge	Recognition or recalling of ideas and facts	Name, select, state, define, list, tell, give, etc.
Comprehension	Requires an understanding of the facts	Compare, discuss, match, illustrate, tabulate, justify, etc.
Application	Where the learner can use theory in a new situation	Solve, predict, draw, differentiate, determine, etc.
Analysis	The breakdown of content into parts, and discovering the relationships between parts	Analyse, identify, contrast, differentiate, verify, etc.
Synthesis	Recombination of parts into a whole	Organise, design, synthesise, etc.
Evaluation	Judgements about the theory	Evaluate, assess, criticise, defend, etc.

**Source: Taxonomy of Educational Objectives: Handbook 1 (Bloom, 1956)**

Only three themes of Bloom's taxonomy were used in the Chemistry Achievement Test, namely recall of knowledge, applying of knowledge and analysis of knowledge. These three selected themes include the lower, intermediate and higher cognitive abilities of an average learner (Van Rooyen & De Beer, 2007). With the recall theme, learners were expected to define, discuss and explain prescribed scientific knowledge. With the applying of knowledge theme learners were expected to express and explain prescribed scientific principles, theories, models and laws by indicating the relationship between different facts and concepts in own words. The analysis of knowledge theme required learners to compare and evaluate the Nature of Science (NOS) to their everyday life contexts. Table 3.3 summarise the mark allocation of the selected items in the Chemistry Achievement Test. Bloom's taxonomy was used to determine the themes used in the Chemistry Achievement Test to classify the teaching-learning outcomes with respect to cognitive categories.

**Table 3.3: Specification of the Chemistry Achievement Test**

<b>Content</b>	<b>Recall knowledge Marks (%)</b>	<b>Applying knowledge Marks (%)</b>	<b>Analysis of knowledge Marks (%)</b>	<b>Total Marks (%)</b>
<b>Question 1:</b> Shapes and sizes of molecules	3 (25%)	6 (50%)	3 (25%)	12 (20%)
<b>Question 2:</b> Chemical bonding	3 (25%)	5 (55%)	2 (20%)	9 (15%)
<b>Question 3, 4 and 5:</b> 3-Dimensional models of chemical reactions	5 (30%)	8 (47%)	4 (23%)	17 (28%)
<b>Question 6:</b> Balancing of chemical equations and everyday applications	7 (32%)	10 (45%)	5 (23%)	22 (37%)

**c) Worksheets**

The worksheets (Appendix F) were designed based on the findings and recommendations of the preliminary studies and in a way that stimulates discussion and interaction to create interesting and lively debate (Slavin, 1983). The worksheets include the two most important

aspects according to Van Rooyen and De Beer (2007:75) which is detailed steps for the procedures and being an independent learning tool. It makes it easy to assess and evaluate individual learning gained from group tasks. These worksheets include activities that introduce and clarify the chemical equation concepts in the ChAT. The different elements of argumentation were also built in the worksheets.

#### ***d) Observation schedules***

The classroom observation schedules were developed by the researcher, after being peer-reviewed and rated by post-graduate students. The observation schedules (Appendix B) were also modified to include the recommendation of the preliminary studies. The schedules included whole lesson observation, observer's comments and tape-recording of the lesson. The tape-recorded lessons were later transcribed and made it easier for the researcher to zoom in on important aspects of the lesson. The schedules also included the calculation of teacher-talk and learner-talk, which give an indication of the learner-centeredness of the class activities. Wray and Kumpulainen (2009) assert that variables such as student achievement and performance are statistically linked to the frequency of categories as identified in the data. The best known of such category system is probably the Flanders Interaction Analysis (Flanders, 1970). This system has been used extensively in classroom observation. It has two main uses, namely providing evidence of the differences in teaching patterns that distinguish one teaching style from another and it is used to explain differences in learning outcomes associated with different styles of teaching (Wragg, 1999). The Flanders Interaction Analysis Categories (FIAC) consist of ten categories of communication, seven used when the teacher is talking (teacher-talk), two when a learner is talking (learner-talk) and one when there is silence or confusion. An observer using the system makes timed observations every five minutes and categorises the behaviour, which is recorded at each point into one of the ten categories (Table 3.4).

**Table 3.4: Flanders' Interaction Analysis Categories (FIAC)**

Teacher-talk	Accepting feelings: accepting and clarifying learners' feelings
	Praises and encourages learners' actions or behaviour.
	Accept or uses ideas and suggestions of learners.
	Gives facts or opinions about content or procedures.
	Asking questions about content, expecting learners to respond.
	Give directions, commands or orders with which learners are expected to comply.
	Critiques or justifies authority
Learner-talk	Responses: talk by learners in response to teacher.
	Initiation: talk by learners, which they initiate.
Silence	Silence or confusion: pauses, short periods of silences or communication not understood by the observer.

The instrument developed by Van Rooyen et al. (2007) was used to determine the teacher-learner talk ratio. Classroom talk was characterised and analysed by making use of the Communicative Approaches model of Mortimer & Scott (2003). This framework is used to analyse classroom discourse and consists of four categories generated from the combination of two dimensions: interactive – non-interactive and authoritative – dialogic (Table 3.5).

**Figure 3.5: Communicative approaches with teacher interventions and common patterns of talk**

	<b>Interactive</b>	<b>Non-interactive</b>
<b>Authoritative</b> Focus on science's view	Presentation Questions and Answers I-R-F Teacher-learner-talk $\approx$ 1:1 (Teacher talk: 45-65%)	Presentation Lecture Teacher-learner-talk $\approx$ 1.5:1 (Teacher talk: > 65%)
<b>Dialogic</b> Different points of view are considered	Probing Elaborating Supporting I-R-F-R-F Teacher-learner-talk $\approx$ 1:1.5 (Teacher talk: < 45%)	Review Teacher-learner-talk $\approx$ 1:1 (Teacher talk: 45-65%)

**Note:** I = initiation, R = response, F = feedback

The communicative framework can also be used to determine the learner-centeredness of an activity, by measuring the amount of teacher-talk during the activity.

Audio recordings were made during the focus group discussions. The focus group interviews take place when the facilitator (researchers) interviews a member or members of each group in a joint forum (Yin, 2003). The teacher recorded aspects of understanding of content, understanding of context, views on the process of the model design to enhance argumentation, incidences of poor experiences and incidences of good experiences in in the classroom. The researchers analysed the recordings to identify misconceptions and the confidence with which learners presented their arguments. Table 3.6 summarises the different instruments and the analytic categories used in this study.

**Table 3.6: Instruments and analytic categories of the Chemistry Achievement Test.**

<b>Instrument</b>	<b>Measurement scale</b>	<b>Analytic method</b>
Survey questionnaire	Frequency table	Quantitative & qualitative
Chemistry Achievement Test	Memorandum	Quantitative
Worksheets	Memorandum	Quantitative
Preferred teaching styles	5 point Likert Scale	Qualitative
Observation schedule	Schedule	Qualitative

### **3.5 Validity and reliability of instruments**

In order to make valid inferences from data and having consistent data are as important in qualitative research as they are in quantitative research study. Merriam (1998) asserts that the following measures ensure validity and reliability, “Triangulation, member checks, and long-term observations, peer examination, participatory or collaborative modes of research and researchers, bias.” Merriam defines triangulation as:

A process of using more than one source to confirm information data from different sources, confirming observations from different observers and confirming information with different data collection methods. With the discovery of disconfirming information, seeking reasons for contradiction frequently points to the direction for extending or modifying explanations, instead of discarding them. (p.276)

Triangulation is a process for increasing the validity of a given study (Denzin, 1978). Validity of instruments in this study was obtained by the triangulation of the data gathered with the different tools (observation schedules, questionnaires, examination results, test scores and interview responses). There should be a good balance between the internal and external validity of an instrument. The internal validity deals with accuracy and the control of most extraneous variables of the instruments and external validity refers to the usefulness of the instrument. Reliability means that an instrument should consistently reflect the construct that it is measuring.

In order to determine the association between the performances of two tests, researchers make use of a correlation coefficient (Ogunniyi, 1992). The correlation coefficient,  $r$ , ranges between -1.00 and +1.00. A correlation coefficient close to +1.00 is said to be a positive correlation, while one close to -1.00 is said to be a negative correlation. If the correlation coefficient is close to or at zero, then it shows no correlation, therefore there will be no reliability. A reliable instrument gives comparable scores when administered to the same group of participants at different intervals of time. A person should get the same score on a questionnaire if she completes it at different times. The Cronbach's alpha reliability test was used for determining the reliability of the Chemistry Achievement Test instrument and  $r = .76$  was obtained, which is indicating a strong positive reliability.

In order to establish content and construct validity all the instruments were evaluated and ranked by a group of post-graduate science students at the School of Science and Mathematics Education at the University of the Western Cape. The assumption is that experts are not biased but possess relative equal abilities and judgement. The Chemistry Achievement Test was piloted at two schools in different Education Management and Development Centre (EMDC) districts and adjusted to address the research questions effectively.

### **3.6 Data analysis**

The data was analysed quantitatively to find the trends, patterns and to draw clear conclusions in order to ascertain, whether DAI enhanced the understanding of the grade ten learners. Non-parametric methods were used in analysing the quantitative data. The

advantages of this method is that no or very little assumptions need to be made about the format of data and it can be useful when dealing with unexpected observations that might be problematic. The disadvantage of this method is that it is only effective if the sample size is small and geared towards hypothesis testing rather than estimation. Appropriate computer software for non-parametric methods is also limited and how the software package deals with tied values or how it obtains p-values may not always be obvious (Burton & Bartlett, 2009).

In order to answer Research Question One, a frequency-count survey was used to get a general idea of the extent to how the selected schools in the vicinity are equipped with ICT resources. Kerlinger (1973) has defined survey research as studies that deal with the present condition of learning facilities, characteristics of teachers or learners, opinions on an issue, people's perception about one thing or the other, and so on. One of the basic aims of survey research is to determine how the nature or status of things or situations is related to certain observable phenomena. In answering Research Question Two, the results of the chemistry achievement test were used to determine the improvement and difference in the conceptual understanding in the experimental and the control groups. The chemistry achievement test was marked with a marking memorandum, determining whether the answer was correct or incorrect. The levels of TAP was used to analyse the conceptual changes, misconceptions and trends of argumentation of the respondents. The ChAT was piloted and validated by fellow master students.

In answering Research Question Three, data from the interview and classroom observation schedules were classified (coded) and used to give a subjective description of the social background of the learners and the conditions of the school and the classroom (Babbie & Mouton, 2001). Unstructured interviews were used because it was flexible and the respondents could ask questions for clarification, discuss a subject at great length, or go to other related matters not specifically planned for (Ogunniyi, 1984).

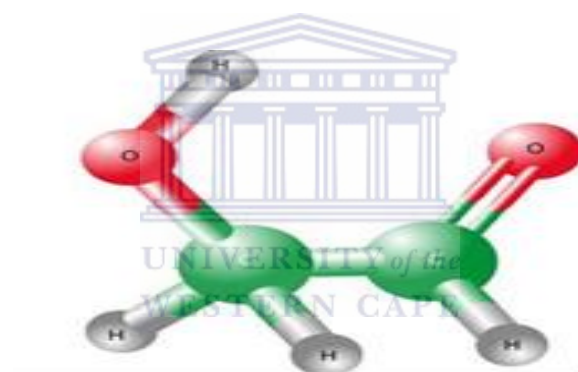
The questionnaires on Attitudes towards Science and the Teaching Styles, which was adopted from the Relevance of Science Education (ROSE) project, was qualitatively analysed to put the scores of the learners into a broader perspective. SPSS computer software was used to compare mean scores, t-ratio and compare with t-critical values in the quantitative analysis of



the data. A semi-structured questionnaire (Burton & Bartlett, 2009) and a classroom observation schedule were used to answer Research Question Three, to learn from the learners' experiences and their personal voices. In addition, questionnaires with structured questions were used to conduct a survey to determine the status of CAL at the selected school.

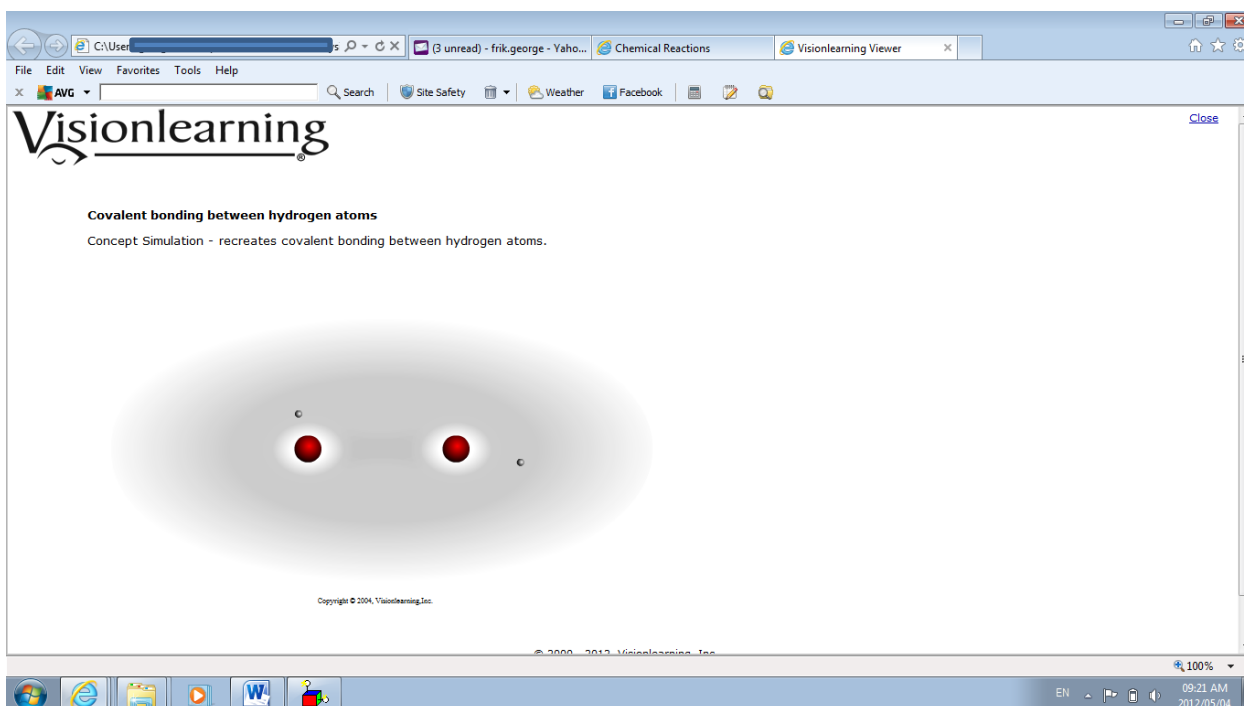
### 3.6.1 The Chemistry Achievement Test (ChAT)

A Chemistry Achievement Test (Appendix G) was used to determine the conceptual understanding of the learners about chemical equations concepts before and after the study. Part 1 of the ChAT tested the learners' knowledge and conception of the atomic and molecule models and their spacial orientation in terms of shape and size. Figure 3.2 illustrate one of the three dimensional ball-and-stick models of molecules. They had to compare the sizes and bonds of the different atoms and molecules.



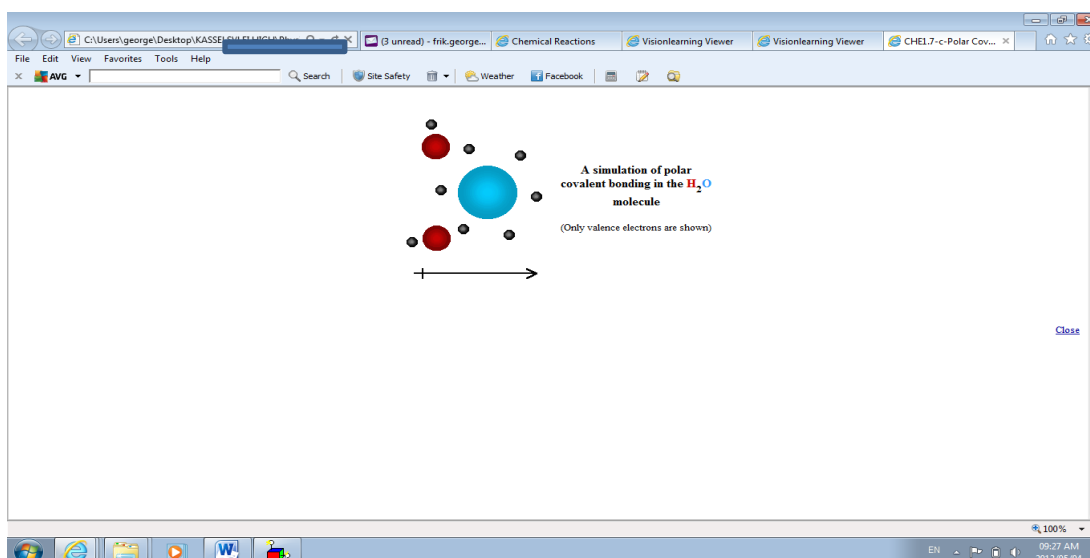
**Figure 3.2: Three dimensional model of a molecule**

Part 2 of the ChAT tested the learners' conception on covalent, ionic and metallic bonding and the chemical changes the substances undergo. Figure 3.3 illustrates the sharing of electrons between two hydrogen atoms in the covalent bond of the hydrogen molecule. The colourful animation shows how the electron of each atom revolves around both nuclei. Learners could easily conceptualise the inside of an atom during covalent bonding in the animation, which would be difficult to explain otherwise.



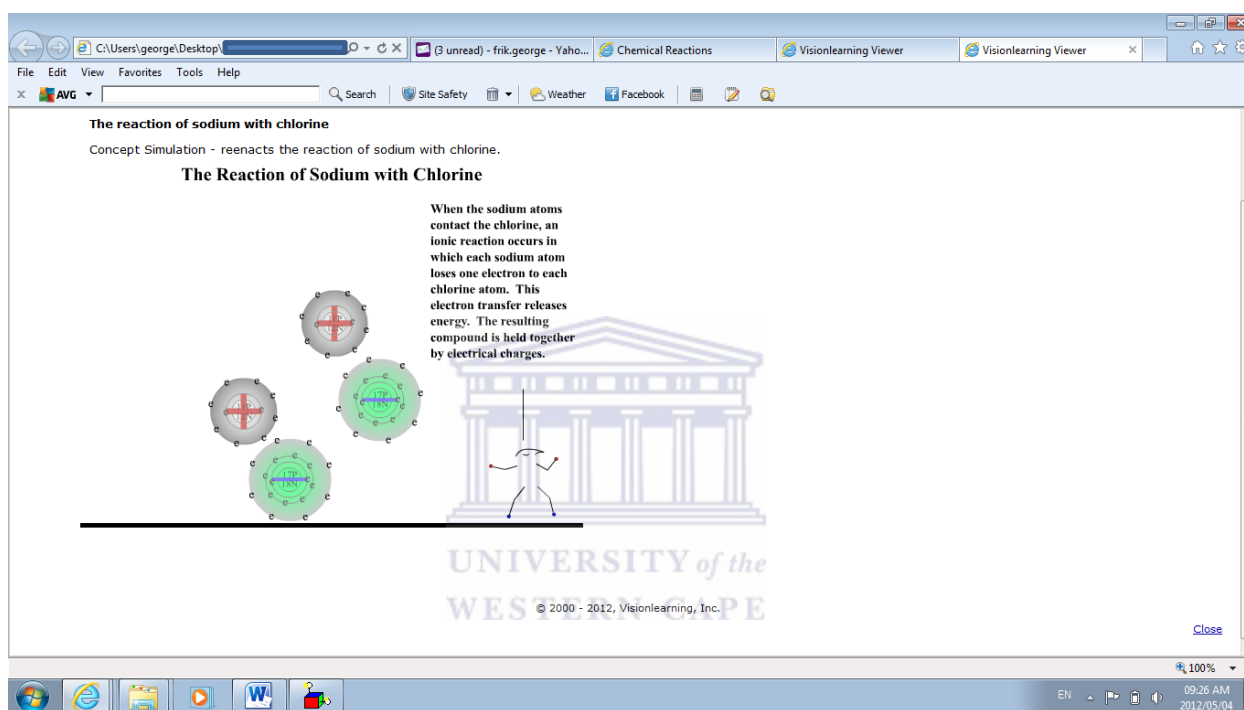
**Figure 3.3: Screenshot of the animation of covalent bonding of the  $H_2$  molecule**

In another animation shown to the learners the polarity of some ionic and covalent molecules were indicated. The learners could clearly see the electronegativity difference between the atoms and the resulting ionic and covalent bonds in the molecules. Figure 3.4 illustrates the polarity of the water molecule.



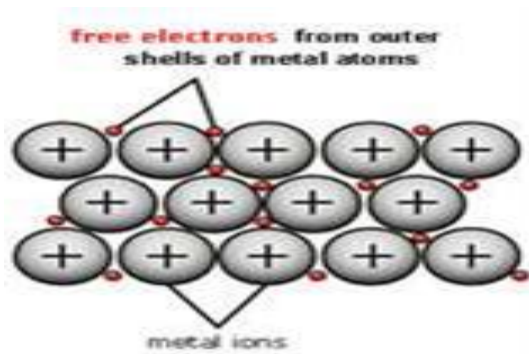
**Figure 3.4: Screenshot of the animation of the polarity in the  $H_2O$  molecule**

The sub-atomic models of the bonding process in molecules were also illustrated to the learners. Figure 3.5 shows the animation of the ionic bonding of sodium chloride. In this animation, the relative sizes of the Na-atoms and Cl-atoms were shown and how the sizes change when the atoms are transformed into ions to form the resulting NaCl-lattice. This animation is useful and safe, because sodium is a very reactive metal and chlorine is a very poisonous gas. The animation also highlights the difference in sizes of the particles (atoms, ions, electrons, protons and neutrons)



**Figure 3.5: Screenshot of the animation of ionic bonding of NaCl (Vision Learning, 2012).**

Part 2 of the ChAT also deals with metallic bonding and in another animation, learners were shown the processes involved. Figure 3.6 is a screenshot of the animation, illustrating the “sea of free electrons” moving between the positive metal kernels when there is a potential difference across a copper wire.



**Figure 3.6: Screenshot of the animation of the metallic bonding of copper.**

In Part 3 of the ChAT the learners were tested on their conception on how to write chemical formulae, balancing of chemical equations and principle of conservation of mass. Figure 3.7 is a screenshot of the electronic worksheets that learners had to complete. In this software programme learners had to write chemical formulae correctly and balance the chemical equations.

Look at the reaction atom by atom. On the left side we find 1 carbon atom, and 1 on the right. There are 4 hydrogen atoms on the left, but only 2 on the right. Therefore, you know 2 water molecules must be formed. Adding this coefficient we get

$$\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$$

Now we have to balance the oxygen atoms. On the left you find 2 atoms, on the right 4 (2 in the  $\text{CO}_2$  molecule and 1 in each of 2  $\text{H}_2\text{O}$  molecules). Therefore we need to start with 4 oxygen atoms, or 2 molecules. The balanced equation would then be:

$$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$$

Try balancing the following equations on your own (note: while you don't need to write the coefficient 1 in a chemical reaction, these examples will not work unless you input a 1 where needed):

- 1)  Na +   $\text{Cl}_2 \rightarrow$   NaCl  
Check
- 2)   $\text{N}_2 +$    $\text{H}_2 \rightarrow$    $\text{NH}_3$   
Check
- 3)  Fe +   $\text{O}_2 \rightarrow$    $\text{Fe}_2\text{O}_3$   
Check
- 4)  Cu +   $\text{AgNO}_3 \rightarrow$   Ag +   $\text{Cu}(\text{NO}_3)_2$  (a Cu atom bonded to 2  $\text{NO}_3$  groups)  
Check
- 5)   $\text{H}_2\text{SO}_4 +$   NaCN  $\rightarrow$   HCN +   $\text{Na}_2\text{SO}_4$

**Figure 3.7: Screenshot of the electronic worksheet on balancing of equations.**

Part 3 of the ChAT contains exercises in which the learners had to write down and balance chemical equations that relate to everyday experiences. The following questions are examples of some of the exercises in Part 3 in Question 5.

5.2(a) *Thandi throws some swimming pool acid granules in the swimming pool. Some of the acid falls on the wet zinc metal strip at the side on top of the pool. She observes a liquid and gas bubbles are formed on the metal. Explain Thandi's observation in terms of the chemical reaction that took place and write a balanced equation to motivate your answer.*

5.2(g) *Thabo always suffers from indigestion after he has had a very spicy meal and lots of Coke Cola. The indigestion is caused by acid build-up in the stomach.*

*Milk of Magnesia [Mg(OH)<sub>2</sub>] ; Rennie tablets (HCl) ; Water (H<sub>2</sub>O) ; Table salt (NaCl)*

*Which of the following substances can he take to relieve the terrible feeling in his stomach? Motivate your answer by writing down a balanced equation for the reaction that takes place in his stomach.*

5.2(h) *John wants to re-ignites a fire that went out by blowing with his breath on the red-hot coals. Explain why the fire catches flames again. Motivate your answer with a balanced chemical equation.*



### **3.7 Delimitations**

The following factors contributed to the success in carrying out the research project:

- Experimental group could be well inducted in the dialogical argumentation process.
- Study was conducted after mid-year examination and learners could focus with a broader mind beyond the curriculum.
- Timing of study ensured maximum inclusion of participants.
- Groups were taught at the same time and the groups have different home languages, therefore they do not usually associate, thus decreasing changes of contamination of data.

### **3.8 Limitations (constraints)**

Prior planning is fundamentally important in any research study, but because of unforeseen changes in the daily program of the research school the researcher has to improvise. There were various factors impeding on the success of the research project, but alternative approaches were taken to protect the validity and reliability of the study. At the research school, were often disruption of the daily program due to meetings, sport activities and absenteeism of teachers, which made it difficult to complete planned activity within the required period.

The examination-orientated curriculum made it difficult to do enrichment and expanded activities. Some of the teachers were sceptical of the alternative instructional method and therefore were hesitant to participate in the study. The fact that the experimental and control group were at the same school, could cause contamination of data when subjects interact and exchange information. The fact that the experimental group had academic subjects and the control group technical subjects could influenced the performance in the ChAT.

Hawthorne-effect which state that, "... if participants are aware that they are being studied, they do not behave normally (Dowling & Brown, 2010)", would have influence the outcome of this study. The improved scores could be due to extraneous factors like extra help at home from parents or tutors, access to additional resources like, computers, internet, because the fact that participants are aware that they are under study. The principal and school management acted like "Gate-keepers", making it difficult to access schools and the freedom to include any material in the presentations. The principal wanted to scrutinise all the material and the curriculum guidelines had to be followed strictly.

### **3.9 Ethical considerations**

According to Mcmillan and Schumacher (2001), "Ethics in research study involve considerations of informed consent, deception, confidentiality, anonymity, privacy and harm to participants". All steps possible were taken to adhere to the ethical aspects of research; hence, this study received ethical clearance from both the University of the Western Cape and

the Western Cape Education Department. The principal and the management of the research school were informed timeously about the study and the effect it will have on the normal running of the classrooms involved in the study. Fair treatment of the groups in terms of computer-assisted learning (CAL) and content was given, because all participants did receive the same learning material and had equally access to the information communication technology (ICT) resources. The anonymity and confidentiality of the school and the participants were maintained throughout the study.

### **3.10 Conclusion**

This chapter described the research design, sample selection, instrumentation and methodology applied in conducting the study. The methodology was also informed by the preliminary studies and peer reviews. The ChAT was explained in detail, which will determine the effect of the interventions. In conclusion, the limitation and ethical considerations were clarified. The findings are discussed in chapter four while the conclusions reached and their implications are presented in chapter five.



## CHAPTER FOUR - RESULTS AND DISCUSSION

### 4.1 Introduction

The purpose of the study has been to determine the effects of dialogical argumentation instruction on grade 10 learners' understanding of chemical equation in an information communication technology (ICT) environment. Specifically, this chapter will present, analyse and discuss the results obtained from the study. For ease of reference, the results are analysed in terms of the following questions:

1. What is the status of information communication technology (ICT) resources and their usage in certain selected schools in the Western Cape?
2. Do grade 10 learners exposed to dialogical argumentation instruction (DAI) in a computer-assisted learning environment demonstrate a better understanding of chemical equation than those who are not so exposed?
3. To what extent are the conceptions of chemical equations that the grade 10 learners hold relate to their age, sex and socio-economic background?

The data analysis and discussion that follow will indicate whether or not dialogical argumentation instruction (DAI) in a computer-assisted learning environment enhanced grade 10 learners' conceptions of chemical equations better than those exposed to the traditional expository method of instruction in a computer-assisted learning environment. A corollary to this is to determine the effectiveness of DAI in addressing the learners' misconceptions or alternative conceptions of chemical equations. Specifically, Toulmin's Argumentation Pattern (TAP) and Contiguity Argumentation Theory (CAT) described in detail in Chapter Two will be used as the units of analysis.

In addressing each of the research questions above, the results will be analysed both quantitatively and qualitatively to provide a holistic picture of the changes that might have occurred because of the intervention. In addition, to avoid the repetition of issues and to keep



within the space limit, only the major issues emanating from the study will be considered later on in the discussion section.

## 4.2 The intervention – Dialogical Argumentation Instruction

Table 4.1 depicts the different levels of argumentation that is used to analyse the ChAT. This study took place over a short period, therefore only four of the six elements of TAP described in chapter 1 have been used to analyse the data in this study. Extant literature (Erduran, 2004; Ogunniyi, 2007a; George, 2012) also acknowledges that considerable time is required to induct learners fully in the different elements of TAP.

**Table 4.1: Levels of TAP used for the ChAT**

<b>Quality</b>	<b>Characteristics of an argumentation discourse</b>
Level 0	Non-oppositional. (an answer without any backing)
Level 1	Argument involves claims with single grounds/evidence but no rebuttals. (statement with a supporting motivation)
Level 2	Argument involves claims or counterclaims with grounds /evidence and single rebuttal. (statement, motivation and backing)
Level 3	Arguments involve multiple rebuttals and at least one rebuttal challenging the grounds.
Level 4	Argument involves multiple rebuttals challenging the claims and grounds

**Modified after Erduran, Simon and Osborne (2004)**

The characteristics of argumentation described in Table 4.1. was used to classify the responses that was given in the ChAT in both the pre-test and the post. The frequency counts of the experimental and control groups were used to determine the level of argumentation in each group.

### 4.3 What is the status of information communication technology (ICT) resources and their usage in certain selected schools in the Western Cape?

Geer and Sweeney (2012) assert that, “Technology should be used to enhance learning; therefore, it is important for teachers to be comfortable using it to ensure that the learners get the full advantages of educational technology” (p. 66). Research findings over the past 20 years provide some evidence about the positive effects of the use of information communications technology (ICT) on learners’ learning (e.g. Geer & Sweeney, 2012; Gardner, 1990; Kiboss & Ogunniyi, 2005). However, in spite of such findings and numerous training programmes and investment by schools in ICT resources, there has been a disappointingly slow uptake of ICT in schools (Mumtaz, 2000). The main purpose of this research question is to give a background of Newton High (pseudonym), the study site, in comparison with other schools in the same socio-cultural context in terms of the ICT resources and the way they are used or appreciated in the science classroom. As stated in Chapter 3, ICT and in particular computer-assisted learning (CAL) forms an increasingly important part of lesson activities in the classroom recently. Figure 4.1 illustrates how much ICT-resource is available, in terms of percentages, at the ten selected schools and its use in the science classroom. The percentages were derived from the frequency counts of sections B and C of the survey questionnaire.

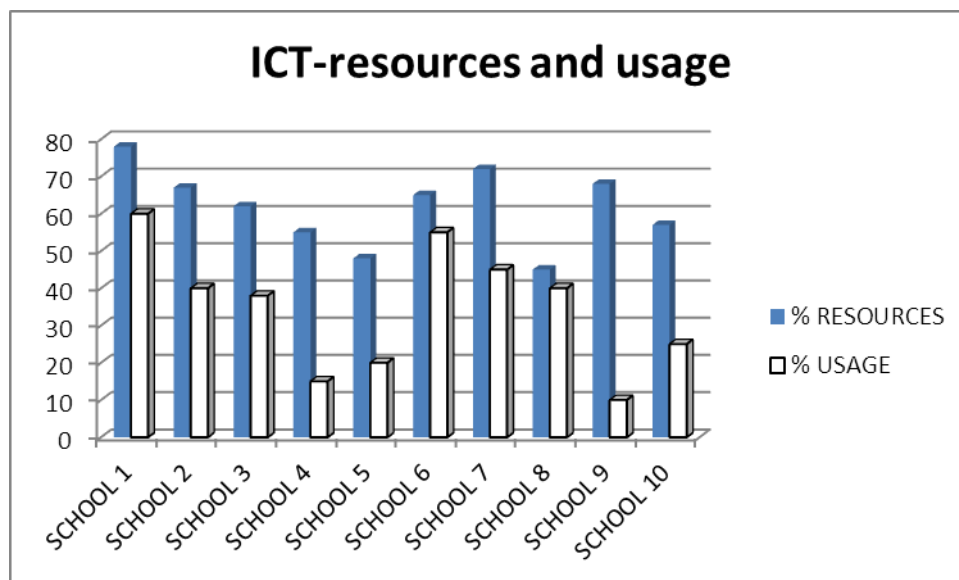


Figure 4.1: ICT resources and usage by the selected schools.

In examining the data in Figure 4.1, it indicates that all the schools have at least basic ICT resources, because all of them are above 40%. The ICT resources range from School 8, which has the least (43%) resources; with a data projector, a computer and internet connection in only one classroom, and School 1 the most (75%) resources; with interactive electronic white boards, internet connection and ten computers in each science classroom.

An examination of Fig. 4.1 also shows a notable disparity between the availability of ICT resources (43% to 78%) in the schools and their frequency of use (10% to 60%). This suggests that the resources are not being used optimally in the science classrooms. This finding is supported by the study of Mumtaz (2000) who provides the following explanation for the disparity between the availability of ICT resources and their use in the schools. He asserts that:

Firstly, the culture dictates what teaching is and how learning occurs. What knowledge is proper in schools, and the learner-teacher [not learner-machine] relationship dominates popular views of proper schooling. Secondly, the age-graded school, an organisational invention of the late nineteenth century, has profoundly shaped what teachers do and do not do in classrooms, including the persistent adaptation of innovations to fit the contours of these age-graded settings. (p.322)

The factors noted by Mumtaz as well as other factors mentioned in Chapter 2 such as, lack of teaching experience with ICT, lack of on-site support for teachers using technology, lack of help supervising learners when using computers, lack of ICT specialist teachers to teach learners computer skills, lack of computer availability, lack of time required to successfully integrate technology into the curriculum and lack of financial support might have contributed to the low usage of ICT-resources at schools.

Some of these factors indicated above are reflected in the responses given by science teachers that were interviewed at the selected schools. The question posed to them was, “Why are the ICT resources not used optimally at your school?”

School 2: “The content laden curriculum does not allow time for learners to work on the computers in the classroom and I will not be able to finish the work [curriculum] in time.”

- School 4: “Although the science learners must also use the computer laboratory of the school, it is always a fight with the CAT [computer application technology] teacher to get a turn to use it.”
- School 3: “I don’t bother working with the computers, it is just a nuisance! The learners do not focus on the work we are doing when we are working with the computers, they fiddle around and do not pay attention to me. I am comfortable with my talk-and-chalk.”
- School 5: “I never got training to use the software on the computers; I am anyway too old for computers. I only use the interactive white board to give notes to the learners.”
- School 8: “Our PC’s [computers] and software are out-dated and the licenses expired long time ago. The principal does not want to give money to update and renew the licenses of the software, therefore the computers are just white elephants in the classroom.”

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The responses above reflect some of the inhibitors described by Mumtaz (2000) in Chapter 2 namely, lack of teaching experience with ICT (School 5); lack of on-site support for teachers using the technology (School 5); lack of help supervising learners when using computers (School 3); lack of ICT specialist teachers to teach learners computer skills (School 5); lack of computer availability (School 4); lack of time required to successfully integrate technology into the curriculum (School 2) and lack of financial support (School 8) and of course the tendency of learners to see computers as a play toy (School 3).

The different meanings attached to technology also depict the views teachers have about the use of ICT resources in the classroom (Layton, 1993). Layton indicated that teachers have three viewpoints of technology. These are: the ‘human view’ which sees technology as responding to and serving human needs; the ‘titanic view’ which takes technology as heroic and attempting to control nature; and the ‘satanic view’ in which technology is used to produce destructive machinery, and social and environmental problems. The teacher of

School 3 probably reflects the 'satanic view'. She feels computers are a nuisance and is an obstacle to her teaching endeavour. This is also the finding of Mirshra and Kochler (2006) in their study of high school teachers. They found that some teachers are often reluctant to make use of technology because they experience lack of support from the administration. In addition, they have time management problems and perceive prior preparation as an extra burden. The teacher from School 2, who feels that she will not finish the curriculum if she makes use of the ICT resources in the classroom, also shares this view. However, they do not realise the long-term benefit of once-off effective preparation. These responses also reflect the avoidance category of Mumtaz (2000) of teachers who distance themselves from computers and otherwise reduce the amount of time they spend attending to computer-related activities.

Whatever, one may surmise from the teachers' responses, it is difficult to ignore their genuine concerns altogether. This is because to apply ICT resources efficaciously, they must be at ease with such resources. When a teacher is uncomfortable with a teaching tool, he/she is not likely to use it as the teacher from School 2 confesses. It would be surprising if the alibis given by the other teachers were not unrelated to the same factor.

On the question whether the use of ICT resources could improve the conception and performance of science learners, some of the teachers responded as follows:

School 1: "Learners seems to understand concepts like covalent bonding must better and quicker when they saw the simulation model of it, than when I am explaining it to them."

School 10: "Learners understand the workings of the computer better than I do. I am too old for computers, so sometime I just let them work on the computers in groups and let them report back to the class. You will be surprised how quickly they understand the work."

School 6: "I let them work through PowerPoint presentations; about work, we did in class, and let them complete worksheets at home or after school. This saves lots of time."

School 9: “The software programmes cover aspects that I would not normally do in class; this gives the learners a broader understanding of the work.”

These responses suggest that ICT resources and use could help some of the teachers to address the inhibitions mentioned by Mumtaz (2000). It is interesting to note that the teacher from School 10 has a positive view of the use of ICT and the teacher from School 5 (response to the first question) expresses a negative, although both teachers regard themselves as too old for computers. This shows that teachers’ perceptions play an important role in their attitude towards ICT (Mumtaz, 2000). The teacher of School 6 has a ‘human view’ perspective, because he allows learners to work on own pace and collaborate with each other in class. Of course, one does not know at this stage if this social instructional practice (i.e. allowing learners to work and interact together in class or after class) reflects a sort of technophobia demonstrated by the teachers from Schools 5 and 10 or a genuine professional belief of the two teachers.

The studies of Gardner (1990) and Habte (2003) support the responses given by the teachers in their assertion that peer interaction facilitates individual learning. Hendricks (2001) points out that CAL programmes are conducive in aiding knowledge construction. The same conclusion was reached about the positive effects of computer-based instruction from a study on the physics concept of measurement carried out among Kenya secondary school students (Kiboss & Ogunniyi, 2005), on electricity among students in a South African technikon (Hendricks, 2001) and among Eritrean technical students respectively (Habte, 2003).

On the whole the responses of the teachers involved in this study suggest a low level of integration of technology into their teaching methods and curriculum, but does not reflect any technical specialisation in terms of Mumtaz’ (2000) categories. It seems obvious that there is a gap between having ICT resources and using them.

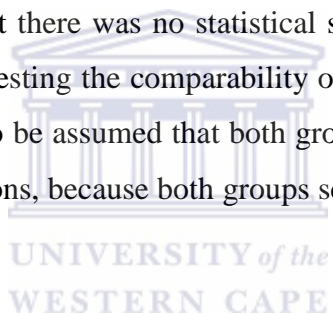
#### **4.4 Do grade 10 learners exposed to dialogical argumentation instruction (DAI) in a computer-assisted learning environment demonstrate a better understanding of chemical equation than those who are not so exposed?**

In answering the second research question, the comparability of the two groups will be established and then their pre-test and post-test responses to the Chemistry Achievement Test

(ChAT) will be interrogated to determine whether or not conceptual changes took place, in the experimental and control groups. The post-test scores of the ChAT will be analysed to determine the effectiveness or otherwise of the intervention strategy. Thereafter, an analysis of the observation schedules, the preferred learning styles of the learners and the socio-economic background will be used to add some ‘flesh’ to the quantitative findings.

#### 4.4.1 A comparability of the groups before the study

The results in Table 4.2.1 were obtained by using the two-group t-test for independent samples to compare the total scores of the groups in the pre-test (Field, 2009). The pre-test results show that the difference between the mean scores (13.88 and 13.16) and the standard deviations (6.63 and 5.69) for the experimental and control groups are very small. The t-ratio value of 0.41 is less than the t-critical value of 2.02 at  $p < 0.05$ , which indicates that the null hypothesis, which expects significant differences between the groups, can be rejected. Therefore, it can be accepted that there was no statistical significant difference between the groups at the pre-test stage, suggesting the comparability of the two groups at the beginning of the study. However, it can also be assumed that both groups did have some understanding of knowledge of chemical equations, because both groups scored a mean average of 13 out of 60 in the pre-test.



**Table 4.2.1: Learners’ pre-test scores on the Chemistry Achievement Test (ChAT)**

Group	N	Mean	SD	t-test
Experimental group	25	13.88	6.63	0.41
Control group	25	13.16	5.69	

**Note:**  $t_{\text{critical}} = 2.02$  ;  $p = 0.05$  ;  $df = 48$

Similarities in the pre-test scores of the experimental and control groups can be assumed to be due to the traditional instructional practices to which they had been exposed before the commencement of the study. A further analysis of the pre-test results in Table 4.2.2 indicates that for all the items tested, there were no statistical significant differences found. This further supports the assumption that the groups were comparable at the pre-test stage.

Table 4.2.2 also indicates that the learners scored the lowest in Question 6 (i.e. everyday life experiences) and highest in Question 1 (i.e. atomic sizes and molecular geometry).

**Table 4.2.2: Learners' pre-test scores per item on the Chemistry Achievement Test (ChAT)**

Item	Group	M	SD	t-value	Sig. (2-tailed)
<b>Question 1:</b>	C	7.00	1.15		
Atomic sizes and molecular geometry	E	7.24	2.48	0.44	0.05
<b>Question 2:</b>	C	2.32	1.60		
Chemical bonding	E	2.95	1.34	1.53	0.01
<b>Questions 3, 4 &amp; 5:</b>	C	3.52	4.65		
3D-models of chemical reactions	E	2.96	2.62	0.52	0.05
<b>Question 6:</b>	C	0.32	0.90		
Everyday life experiences	E	0.72	1.94	0.93	0.04
<b>Total</b>	C	<b>13.16</b>	<b>6.63</b>	<b>0.41</b>	<b>0.05</b>
	E	<b>13.88</b>	<b>5.69</b>		

Note. The  $t_{critical} = 2.02$  ;  $p = 0.05$  ;  $df = 48$ ;  $N_{control\ group} = 25$ ;  $N_{experimental\ group} = 25$

Typical responses to Question 1 in Table 4.22 above, which required learners to compare the sizes of carbon, oxygen, nitrogen, hydrogen and sulphur atoms and also to draw the ball-and-stick models of water, nitrogen, sulphur dioxide, methane and ammonia molecules, was:

Question 1.1 (*Comparing the different atomic sizes*)

- E5: "Oxygen atom is bigger than the hydrogen atom, because it has more electrons"
- C13: "Sulphur atom is bigger than oxygen, because it is in a lower period"
- E18: "Nitrogen and oxygen atoms are the same sizes, because they are in the same period"
- C7: "Sulphur and oxygen have the same size, because they are in the same group"



The response of E5 is valid, but it is not always the case that the number of electrons determines the size of an atom. The atom shrinks from left to right in a period on the periodic table. The response of C13 is valid, but refers to the periodic table instead of the atomic configuration. E18 and C7 both provide invalid responses.

All learners represented the shapes of the water molecule correctly (angular), but 76% of them drew the methane molecule (tetrahedral) and 87% the ammonia molecule (pyramidal) incorrectly with incorrect angles and number of bonds between the different atoms.

A possible explanation for this trend in performance could be that Question 1 is based on recall of knowledge (lower level of cognitive demand) and responses to Question 6 is based on application of knowledge, which is at a higher level of cognitive demand (Bloom, 1956). Typical responses to Question 6 (*Chemical reactions in everyday life*):

E21: “Swimming pool cleaning agents cannot have acid in it because it will burn the people when they swim in the pool.”

C14: “The red-hot coals will not catch fire if you blow on it, because you breath [breathe] CO<sub>2</sub> out which will kill the fire.”

The responses of E21 and C14 are both invalid, but their backings supporting their claims are valid. E21 had probably experienced acid burning his skin and C14 could possibly refers to carbon dioxide used in fire distinguishers. It seems that these learners were not aware of neutralisation reactions and combustion at this stage of the study.

The following section will examine the Chemistry Achievement Test (ChAT) to gain additional insight into the learners’ conceptions of chemical equations at the pre-test stage.

#### **i) Learners’ performance at the pre-test stage:**

Tables 4.3.1 – 4.3.3 depict the learners’ performance in terms of percentages for the selected items, recall of knowledge, application of knowledge and analyses of knowledge. The tables reveal that the learners’ pre-test scores per item for the C group and the E group range from 0.6 % to 26 % and 0.8 % to 26 % respectively. This observation concurs with the statistical comparability established earlier.

In all the selected items, both groups responded poorly to question 6, which deals with balancing of chemical equations and relating it to their daily experiences. This suggests that

the learners do not often relate what they learn in school to their lives outside of the classroom. This observation concurs with Jegede's (1996) assertion that, "Science knowledge for most learners is nothing more than declarative information to be memorized and reproduced when demanded especially during examinations" (p.6). On the other hand, both groups performed relatively well in their responses to question 1, which was based on the prior knowledge of the learners.

**Table 4.3.1: Frequency of learners' pre-test responses to the recall questions of the ChAT**

Item	Recall (prior knowledge)					
	Control			Experimental		
	Valid	Invalid	Vacant	Valid	Invalid	Vacant
<b>Question 1:</b>						
Atomic size and molecular geometry	10	12	3	11	13	2
<b>Question 2:</b>						
Chemical bonding	1	15	9	1	18	6
<b>Question 3, 4 &amp; 5:</b>						
3-Dimensional models of chemical reactions	5	16	4	6	17	3
<b>Question 6:</b>						
Balancing equations and everyday life	8	10	7	10	11	4
<b>Mean</b>	<b>6</b>	<b>13</b>	<b>6</b>	<b>7</b>	<b>14</b>	<b>4</b>

Note: N = 25; Vacant = no response (answer) to the question

**a) Discussing the recall theme:**

The results per item in Table 4.3.1 indicate that the two groups have relatively little prior knowledge of the selected chemistry concepts at the pre-test stage. The frequency of the correct responses varies from 1 (for Question 2) to 10 (for Question 1) in the control group and 1 (for Question 2) to 11 (for Question 1) in the experimental group. This suggests that the groups experience comparable difficulties in answering the ChAT.

### **Question 1:**

*“Study the space filling models of molecule A [water], molecule B [nitrogen], molecule C [methane] and molecule D [ammonia]. State if the sizes of the atoms and the shapes of the molecules are correctly represented. Provide a reason for your answers.”*

About two-thirds of the responses of both the control group (65%) and experimental group (66%) were valid in terms of identifying the different elements in the molecules. However, some learners (23% in the control group and 25% in the experimental group) did not know that different atoms have different sizes. For example:

C7: “The oxygen atom is the same as the magnesium atom, because both have electrons, protons and neutrons.”

E2: “All the atoms are the same size, because all atoms are the same particles.”

The response of E2 suggests that she either forgot or was never taught the properties of the periodic table of the elements in previous grades, because the study of the properties of the first 20 elements of the periodic table are part of the grade 8 and 9 curriculum. Although C7 refers to the subatomic particles of an atom, he is not aware of the configuration of the subatomic particles in the different atoms. C7 and E2 both give backings for their claims, although their claims are invalid. Many learners gave similar inaccurate responses to those of C7 and E2. In terms of Toulmin’s Argumentation Pattern (TAP) level, their responses could be placed at level 1. That is, they simply made claims without supporting them with any valid backings. In terms of the CAT cognitive categories, their responses were probably based on the western scientific worldview probably because the terms were foreign to them. In other words, their responses belong to the CAT emergent cognitive category (Ogunniyi, 2007a & b) Overall, both groups performed relatively well on this recall question with the C and E groups scoring 42% and 45% respectively.

### ***b) Discussing the application of knowledge theme:***

Applying knowledge is an integrated process skill that involves problem solving (Van Rooyen & De Beer, 2007). In this theme, learners were expected to be able to analyse and identify problems and to think divergently and creatively. They have to make use of the

principles of conservation of atoms and constant composition to balance different chemical equations.

**Table 4.3.2: Frequency of learners' pre-test responses to the application questions of the ChAT**

Item	Applying knowledge					
	Control			Experimental		
	Valid	Invalid	Vacant	Valid	Invalid	Vacant
<b>Question 1:</b>						
Atomic size and molecular geometry	7	18	0	6	17	3
<b>Question 2:</b>						
Chemical bonding	6	17	2	5	19	1
<b>Question 3, 4 &amp; 5:</b>						
3-Dimensional models of chemical reactions	7	10	8	6	13	6
<b>Question 6:</b>						
Balancing equations and everyday life	3	19	3	3	20	2
<b>Mean</b>	<b>6</b>	<b>16</b>	<b>3</b>	<b>5</b>	<b>17</b>	<b>3</b>

Note: N = 25; Vacant = no response (answer) to the question

The results in Table 4.3.2 were examined for comparison of the two groups to determine whether or not the learners could apply the relevant theories to solve the chemical equations. This table reveals that the control group performed slightly better than the experimental group in all the selected items except for Question 6 (balancing of everyday equations) where they both gave three valid responses. The mean scores of the control and experimental groups on application were 6 and 5 respectively.

A typical conception in both groups was, "... water is repelled by the ruler, because there is a magnetic field between them ..." which is a misconception. Most of the learners also drew the bonding angles in the methane molecule as  $90^{\circ}$  instead of more or less  $109^{\circ}$ , which is responsible for the tetrahedral shape. It was also evident from the responses that most learners could not explain the metallic properties in terms of the delocalised electrons in metals. The low scores obtained by the learners further suggest that they could not apply their knowledge in solving chemical equation problems adequately. As in Question 1 the learners'

responses in terms of TAP is at level 0 i.e. non-oppositional claims or claims which are only invalid but lack necessary backings. For example, some of the responses to Question 2 (c), which require them to identify and explain metallic bonding were, “Metallic bonding, because the battery gives the ‘free’ electrons to the wire”. These responses also reflect a dominant scientific worldview in terms of CAT, because they try very hard to give scientific explanations instead of everyday experiences. For example, instead of saying the iron nail rusts, they say the iron nail was oxidised.

An examination of Question 2 also reveals the learners’ inability to apply their knowledge of the bonding models. About a third (32%) of the learners did not respond to this question at all. Their poor responses could be attributed to the fact that the learners encountered chemical bonding only for the first time in grade 10. However, they showed knowledge of the physical processes when substances interact. The following responses are representative:

C9: “The teaspoon becomes hot because the steam of the tea makes it hot.”

E11: “NaCl is formed when you evaporate seawater.”

C12: “The ruler pushes the stream of water away, because of the magnetic forces between them.”

E7: “Ionic substances are not as hard as metallic substances because of the presence of non-metal atoms.”

Once again, the responses of most of the learners were at level 1 in terms of TAP. The learners provide backings for the claims, but in most cases, the claim and the backing are invalid, which is evident in the response of C9, who refer to steam instead of the movement of the delocalised electrons in the metal. E11 also provides an invalid backing, “when you evaporate seawater”. This misconception is reflected in many of the responses. In their responses, the learners refer to their personal experiences, moving away from scientific explanations. Both C9 and E11 refer to everyday experiences, “steam” and “evaporation”, instead of scientific concepts of “delocalised electrons” and “electron transfer”. In terms of CAT, the everyday knowledge worldview is dominant in these responses, which is the most adaptable mental state of the learners at this stage of the study.

In Question 6, learners had to balance chemical equations on an electronic worksheet making use of computer software. They have to answer questions relating chemical reactions to everyday life examples. The electronic worksheets give brief instructions to guide the learners to complete the worksheet. The following excerpts represent 63% of the responses for Question 6 (g):

*Thabo always suffers from indigestion after he has had a very spicy meal and same glasses of Coke Cola. The indigestion is caused by acid build-up in the stomach. Which of the following substances would you suggest he take to relief the terrible feeling in his stomach? Motivate your answer by referring to the chemical process involved.*

*Milk of Magnesia [ $Mg(OH)_2$ ] ; Rennie tablets ( $HCl$ ) ; Water ( $H_2O$ ) ; Table salt ( $NaCl$ )*

C5: “Thabo should drink milk of magnesia, because it is milk and will take away the burning feeling”

E17: “Thabo should drink a lot of water, because it will wash away the spicy food and Coke Cola out of his stomach.”

C10: “Thabo should take the Rennie tablets, because it will take the burning feeling away.”

C10, C5 and E17 refer to a physical process and probably does not realise that the digestive process in the stomach involves chemical reactions. E17 also fails to relate this scenario to acid-base reactions, which is dealt with in the grade nine curriculum. From the 50 learners 17 did not bother to answer this question and the rest of Question 6. This suggests that the learners failed to make the connection between western science knowledge and everyday knowledge (Jegede, 1995). The responses of C5 and E17, “... because it is milk ...” and “... because it will wash away the spicy food and Coke Cola ...” in terms of TAP are at Level 2. The fact that the learners refer to physical processes instead of chemical processes suggest that they held a strong everyday science worldview, which is their dominant mental state in terms of CAT. In other words, the learners tend to express their common-sense perceptions (Ogunniyi & Mikalsen, 2004).

*c) Discussing the analysis of knowledge theme:*

In this theme, learners were assessed on how they applied scientific laws, theories and principles to balance chemical equations and solve problems. A brief explanation is given of the concepts at the start, before the learners attempt to respond to the questions.

**Table 4.3.3: Frequency of learners' pre-test responses to the analysis of knowledge questions of the ChAT**

Item	Analysis of knowledge					
	Control			Experimental		
	Valid	Invalid	Vacant	Valid	Invalid	Vacant
<b>Question 1:</b>						
Atomic size and molecular geometry	-	-	-	-	-	-
<b>Question 2:</b>						
Chemical bonding	3	20	2	4	19	2
<b>Question 3, 4 &amp; 5:</b>						
3-Dimensional models of chemical reactions	2	22	1	3	22	1
<b>Question 6:</b>						
Balancing equations and everyday life	3	19	3	3	21	1
<b>Mean</b>	<b>3</b>	<b>20</b>	<b>2</b>	<b>3</b>	<b>21</b>	<b>1</b>

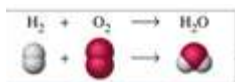
**Note:** N = 25; Vacant = no response (answer) to the question

Question 1 only requires the learners to recall prior knowledge; therefore, this question has no score in Table 4.3.3. The total performance of both groups were poor, only 3 valid responses in each group, at the pre-test stage. This suggests that most of the concepts in this test are foreign to the learners at the pre-test stage and that they did not have the required scientific theory to analyse the concepts yet. The learners were presented with 3-dimensional diagrams illustrating different chemical reactions. Learners had to choose the correct representation of the chemical reactions and in each case. They were required to provide reasons for the invalid reactions and motivate their choice. Learners' responses revealed that they could not relate the spatial orientation of the molecules with the symbolic representation of the chemical equations. Some of the learners have the misconception that all atoms have

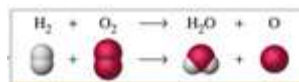
the same size. The following responses were given by the learners to the diagram illustrating the chemical reaction of the formation of water molecules:

Question 4: *Only one set of the following chemical reactions represents the formation of the water molecule correctly. Choose the correct one and motivate your choice:*

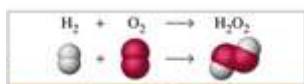
Reaction A



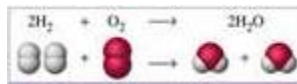
Reaction B



Reaction C



Reaction D

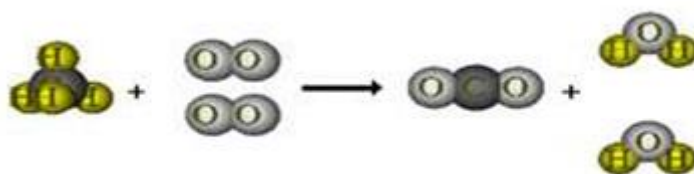


C5: “Reaction C ( $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}_2$ ), because the number of atoms are equal on both sides of the equation.”

E11: “Reaction A ( $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$ ), because water molecule is formed as the product.”

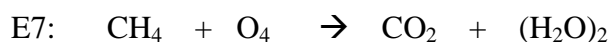
C5 did not know the difference between the chemical formula of the peroxide ( $\text{H}_2\text{O}_2$ ) molecule and the water ( $\text{H}_2\text{O}$ ) molecule. He focussed more on the principle of conservation of matter (atoms), as reflected in his motivation, than on the correct presentation of the water molecule. E11 gives the correct representation of the product, but contrary to C5, she ignored the principle of conservation of matter.

The following excerpts represent the 25% of the responses to Questions 3 and 4, where they had to write balance the chemical equations for the 3D models of chemical reactions:



C4:  $\text{CH}_4 + 4\text{O} \rightarrow \text{CO}_2 + \text{H}_4\text{O}_2$





Both C4 and E7 are not aware that oxygen is a diatomic molecule ( $\text{O}_2$ ). C4 represent the two oxygen molecules as four oxygen atoms and E7 represent them as one molecule with four atoms. They also have correct presentations of the two water molecules. C4 represent the two water molecules as one molecule and E7 write the balancing number at the wrong place in the formula for the water molecule.

In this question (Question 3,4 & 5), the experiment group (3 valid responses) performed slightly better than the control group (2 valid responses) and reach a level 1 in terms of TAP. In these responses, the dominant everyday knowledge worldview is suppressed by the western scientific worldview, because they only make use of scientific language in their responses.

### Interpretive summary

An examination of Tables 4.3.1 – 4.3.3 shows that the overall learners' performance for the selected items for the experimental group was slightly better than for the control group, except for the application of knowledge process skill. However, the differences were not statistically significant as determined earlier. The responses reveal that most of the learners have a dominant everyday knowledge worldview at the pre-test stage according to CAT and most of their responses are at level 1 in terms of TAP, because they provided invalid responses and/or no backings. Most of the responses of the learners were brief and they did not elaborate.

#### 4.4.2 Comparing the learners' pre-test and post-test achievement

Table 4.4.1 reflects the pre-test and post-test scores obtained by the experimental group in the Chemistry Achievement Test (ChAT).

**Table 4.4.1: Experimental group learners' pre-test and post-test scores on ChAT**

ChAT	N	Mean	SD	t-test
Pre-test	25	20.08	6.58	6.52*

Post-test	25	37.52	11.65
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**Note.** The  $t_{\text{critical}} = 2.02$  at  $p = 0.05$  ;  $df = 24$ ; (\*) statistical significant difference

The null hypothesis which expects no statistical significant differences between the pre-test and post-test scores of the experimental group can be rejected, because the t-ratio value of 6,56 is greater than the t-critical value of 2.02 at  $p < 0.05$ . This indicates a statistical difference between the pre- and post-test results of the experimental group. The t-test results indicates a significant change in the means of the pre-test and the post-test, thus it is safe to assume that the experimental group did improve their conceptions considerably on chemical equations in the Chemistry Achievement Test. The assumption could be that the improvement of the experimental group in their understanding of chemical equations can be attributed to the dialogical argumentation instruction (DAI) that the experimental group received.

**Table 4.4.2: Control group learners' pre-test and post-test scores on the ChAT**

ChAT	N	Mean	SD	t-test
Pre-test	25	19.32	5.66	4.04*
Post-test	25	28.28	9.52	

**Note.** The  $t_{\text{critical}} = 2.02$  at  $p = 0.05$  ;  $df = 24$ ; (\*) statistical significant difference

As in the case of the experimental group, there was also a statistical significant difference between the pre-test and post-test scores of the control group as reflected in Table 4.4.2. There is also a significant increase in the means from the pre-test to the post-test. Thus, the traditional instructional method used in the control group did also produce an improvement in the performance of the group relative to the concept of chemical equations, but to a lesser extent compared to the experimental group.

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).

**Table 4.4.3: Learners' pre-test and post-test scores on the ChAT**

Statistics	Experimental Group			Control Group		
	Pre-test	Post-test	Difference	Pre-test	Post-test	Difference
Mean	20.08	37.52	17.44	19.32	28.28	8.96
Mean %	33.47	62.53	29.06	32.20	47.13	14.93
SD	6.58	11.65	5.07	5.66	9.52	3.86
t-test		6.52*			4.04*	

**Note.** The  $t_{critical} = 2.02$  at  $p = 0.05$  ;  $df = 24$ ; (\*) statistical significant difference

The mean scores in the pre-test of the experimental group (20.08) and the control group (19.32) suggest that there was basically no difference at the start of the study. However, the post-test mean scores suggest a significant difference in the scores of 9.24. The difference in the improvement during the study of the two groups is 8.48 (14%). The smaller standard deviation of the pre-test and the bigger standard deviation of the post-test of both groups indicate there is a greater variability at the post-test stage (Table 4.4.3).

#### 4.4.3 Comparing the groups after the study

Table 4.5 reflects the post-test results of the experimental and the control group, which reveals a t-ratio value of 4.04 obtained against a t-critical value of 2.02 at  $p < 0.05$ . Thus, the null hypothesis expecting no statistical significant difference between the two groups is rejected. This indicates that the dialogical argumentation instructional (DAI) method used in the experimental group classroom is more effective than the traditional expository method of instruction used in the control group classroom. The difference between the pre-test and post-test percentage mean scores for the experimental group is 17.44 and for the control group is 8.96, which is indicative that the experimental group has experience a greater conceptual improvement. Although the experimental group outperformed the control group with a difference in the post-test scores of 9.24, it is worthy to notice that the control group also improved with 8.96 from the pre-test (19.32) to the post-test (28.28).

**Table 4.5: Comparison of the post-test scores of the groups in the ChAT**

ChAT	N	Mean	SD	t-test
Experimental group	25	38.64	5.39	
Control group	25	28.28	9.71	4.66*
Difference		10.36	4.32	

Note. The  $t_{\text{critical}} = 2.02$ ;  $N = 25$ ;  $p = 0.05$ ; (\*) statistical significant difference

Further comparison of the pre-test and post-test results in terms of the selected items reveals additional information about the change in performances of the groups from the pre-test to the post-test stage as indicated in Table 4.6.1.

**Table 4.6.1: Learners' performance per item in pre-test and post-test in the ChAT**

Item	Group	Pre-test (%)	Post-test (%)
<b>Question1:</b> Atomic size and molecular geometry	Control	7.00 (58%)	7.80 (65%)
	Experimental	7.24 (60%)	8.00 (67%)
<b>Question2:</b> Chemical bonding	Control	2.23 (26%)	5.76 (64%)
	Experimental	2.95 (33%)	6.20 (69%)
<b>Questions 3, 4 &amp; 5:</b> 3D-models of chemical reactions	Control	3.52 (21%)	10.64 (63%)
	Experimental	2.96 (17%)	13.16 (77%)
<b>Question 6:</b> Everyday life examples	Control	0.32 (2%)	4.08 (19%)
	Experimental	0.72 (3%)	11.28 (51%)
<b>Total</b>	Control	13.16 (22%)	28.28 (47%)
	Experimental	13.88 (23%)	38.64 (64%)

Note. C (N=25) and E (N=25)

Table 4.6.1 compares the learners' performance in the pre-test and the post-test per item. The performance of the learners ranges from 51% to 77% for the experimental group and 19% to 65% for the control group at the post-test stage. The scores for Question 6, which requires

learners to relate chemical equations to everyday experiences, attracted the least valid responses in both the pre- and post-test for both groups. This suggests that the learners found it very difficult to answer this question compared to the other questions. In the pre-test the experimental and control groups scored 3% and 2% respectively for Question 6, suggesting that the learners relate chemical equation poorly to everyday experiences at the start of the study. The performance for this question improved to 51% and 19% respectively, suggesting substantial improvement.

Questions 3, 4 and 5, requiring learners to interpret 3D models of chemical reactions, attracted the most valid responses (77%) in the experimental group and these questions also shows the best improvement from the pre-test (17%) to the post-test (77%) by 60%. In the control group Question 1, which deals with molecular geometry, attracted the most valid responses (65%) and the best improvement from the pre-test (21%) to the post-test (63%) is shown by Questions 3, 4 and 5 (42%). Both groups show the best improvement in the same questions, this is probably because more time was spent in that section, compared to the other questions. However, it is interesting to note that the questions attracting the most valid responses differ for the groups, in the control group its question 1 and experimental group it is questions 3, 4 and 5. This could be a result of the different instructional methods received by the groups. Question 1 requires mostly the recall of prior knowledge, which is promoted by the traditional lecture type instruction. Questions 4, 5 and 6 expect learners to interpret and apply scientific principles that involve argumentation protocols.

### **Discussing the learners' performance at the post-test stage:**

Table 4.6.2 compares the pre-test and post-test scores per item of the learners. TAP and CAT will be used to compare and analysed the responses.

#### ***a) Recall of knowledge***

Both groups achieved the highest average scores, 65% and 82%, for the recall theme respectively, compared to the other themes. In terms of Bloom's taxonomy (Bloom, 1956) recall and recognition of knowledge is rated at a low cognitive level that is probably why both groups achieved high scores.

**Table 4.6.2: Pre-test and post-test scores per theme in the ChAT**

Item	Group	Recall	Application	Analysis
		Pre (Post)	Pre (Post)	Pre (Post)
<b>Question1:</b> Atomic size and molecular geometry	C	42 (78)	26 (67)	-
	E	45 (93)	25 (82)	-
<b>Question2:</b> Chemical bonding	C	1 (61)	24 (58)	14 (47)
	E	1 (85)	23 (69)	16 (58)
<b>Questions 3, 4 &amp; 5:</b> 3D-models of chemical reactions	C	9 (58)	24 (55)	7 (44)
	E	10 (79)	23 (73)	8 (68)
<b>Question 6:</b> Everyday life examples	C	31 (62)	2 (65)	10 (56)
	E	33 (69)	2 (75)	12 (65)
<b>Total</b>	C	21 (65)	19 (61)	10 (49)
	E	22 (82)	18 (75)	12 (64)

**Note.** C (N=25) and E (N=25); Figures before the brackets are pre-test scores and figures inside brackets are post-test scores; C = control group; E = experimental group

The learners performed best in Question 1 and had the lowest performance was in Questions 3, 4 and 5. The following responses represent the trend of the responses to Question 1, in which learners were expected to apply the theory of the atomic model and the configuration of electrons in an atom.

**Question 1:** *Are the sizes of the atoms correctly presented in the diagram [in the diagram a 3D water molecule is illustrated with all atoms the same size]?*

**Table 4.7.1: Pre-test and post-test responses to Question 1 in the ChAT**

<b>Learner</b>	<b>Pre-test responses</b>	<b>Post-test responses</b>
C13	“Yes. They are the same size, because all atoms are microscopic small,”	“No. They are not the same size, because the O-atom is bigger than the H-atom, because the O-atom has more e- than the H-atom and is in a higher period.”
E5	“Yes, all atoms have the same size, because all atoms are identical particles.”	“No, they are not the same size, because, oxygen is bigger than hydrogen, because the oxygen has more orbitals and energy levels, thus it will have more electrons.”

Both learners show a positive shift in their conceptual understanding of molecular geometry from pre-test to the post-test stage. E5 provides an invalid response in the pre-test and demonstrates the misconception that “all atoms are identical in size”. However, in the post-test E5 provides a valid response, “... oxygen is bigger than hydrogen, because the oxygen has more orbitals and energy levels, thus it will have more electrons.” which includes a backing and a warrant, “... thus it will have more electrons”. C13 expressed the same misconception as E5 in the pre-test, but showed an improvement in the post-test response, “because the O-atom is bigger than the H-atom, because the O-atom has more electrons than the H-atom”. C13 and E5 gave invalid responses in the pre-test. However, in the post-test they provided valid claims, “... they are not the same size ...” with evidence, “... because the O-atom has more energy levels ...” These improved conceptions, could be attributed to the respective instructional methods to which they had been exposed. The argumentation process of learner C13 is at Level 3 and learner E5 is at Level 2.

The response of E5 does contain some elements of TAP i.e. linking the claim implied in the question with some warrant namely, linking the size of the atom to the number of orbitals and electrons. The post-test response of E5 demonstrates an improved conception of geometry of

molecules, in which she becomes aware that atoms of different elements have different configurations, because of the composition of subatomic particles. E5 shift from Level 1 (i.e. includes a valid claim and a backing) to Level 2 (i.e. it includes a valid claim, a backing and a warrant) in terms of TAP and holds a strong scientific viewpoint in her responses, because of her rational backings. C13 also demonstrates some improved conception of molecular geometry, because he is linking the claim with a warrant (relating the size of an atom to its number of electrons) and providing a qualifier by stating that the O-atom is in a higher period. When the number of electrons increases in a period on the periodic table, the atomic size shrinks. Therefore, C13 progressed from Level 1 (claim and backing) to Level 3 (claim, backing, warrant and qualifier) in terms of TAP and holds the same western scientific viewpoint as E5.

### ***b) Application of knowledge***

In this, theme learners had to apply the abovementioned scientific principles to solve and predict the solutions to different chemical reactions. This theme seemed to be more challenging for the learners because they scored slightly lower compared to the previous theme, i.e. dropping from 65% to 61% and 82% to 75% for the control group and experimental group respectively. In Questions 2a and 2b, the learners had to apply the theory of the atomic model, kinetic theory model and models of chemical bonding to answer the questions. Here are some of the responses:



**Question 2a:** “What type of chemical bonding takes place in the formation of pure table salt ( $\text{NaCl}$ )? Explain the chemical bonding process involve.”

**Table 4.7.2: Pre-test and post-test response to Question 2a in the ChAT**

Learner	Pre-test responses	Post-test responses
C3	“It is an ionic bonding. A metal atom and a non-metal atom are involved in the bonding.”	“It is an ionic bonding, because the Na-atom gives away an electron, which is accepted by the Cl-atom to form the NaCl-crystal.”
E6	“It is an ionic bonding, because NaCl is formed by evaporating water from sea water.”	“It is an ionic bonding, because the Na-atom donates an electron and become a $\text{Na}^+$ -ion. The Cl-atom accepts the released electron and become a $\text{Cl}^-$ -ion. Therefore, the positive ion and the negative ion attract each other because of electrostatic forces between them and form an ordered arrangement of negative and positive ions.”

**Question 2b:** “What type of chemical bonding is found in the silver teaspoon? Explain why the handle of a teaspoon feels hot after a few seconds when it is put in hot tea.”

**Table 4.7.3: Pre-test and post-test responses to Question 2b in ChAT**

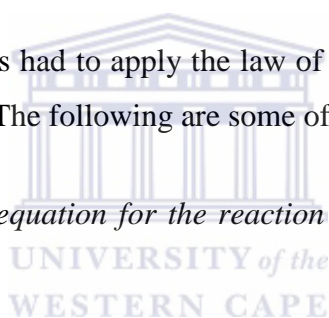
Learner	Pre-test responses	Post-test responses
C15	“It is a metallic bonding. Heat diffuses from hot to cold areas.”	“It is metallic bonding. The teaspoon is a metal and metals are good conductors of heat.”
E20	“It is metallic bonding. The steam of the tea made the teaspoon handle hot.”	“The teaspoon’s handle become hot because of the loose [delocalised] electrons between the positive metal ions that are given heat energy by the hot tea making it vibrating faster and bump into colder loose electrons and conducting the heat, therefore the handle becomes hot.”

C15 and E20 both refer to the physical transfer of heat, diffusion and convection, rather than conduction in their pre-test responses. In their post-test responses, both refer to the

conduction process. In his post-test response E20 provides a backing, "... because of the loose [delocalised] electrons between the positive metal ions" with valid data and warrants, "... are given heat energy by the hot tea, making it vibrating faster and bump into colder loose electrons and conducting the heat, therefore the handle becomes hot", supporting her claim. The post-test response of C15 indicates little improvement in the conceptual understanding of metallic bonding, because he does not refer to the chemical process involve. E20 progress from Level 1 to Level 3 no progress is evident in C15's responses leaving him on Level 1 in terms of TAP. C15 demonstrate a dominant scientific viewpoint in his pre-test response and suppress the scientific viewpoint in the post-test response by moving to an everyday notion (he might have experienced that a metal get hot when put in a hot liquid) in terms of CAT. E20 moves from an everyday notion (steam makes a metal hot) to a dominant scientific viewpoint (movement of delocalised electrons), thus expressing an emergent mental state in terms of CAT.

In response to Question 5 learners had to apply the law of conservation of mass (atoms) and the law of constant composition. The following are some of the responses given by learners:

**Question 5:** *"Write a balanced equation for the reaction of hydrogen with oxygen to form water"*



**Table 4.7.4: Pre-test and post-test responses to Question 5 in the ChAT**

Learner	Pre-test responses	Post-test responses
C18	$\text{Mg} + \text{O}_2 = \text{MgO}_2$	$2\text{Mg} + 2\text{O}_2 \rightarrow 2\text{MgO}$
E11	$2\text{H} + 2\text{O} \rightarrow \text{H}_4\text{O}_2$	$\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

Question 5 deals with the principle of conservation of matter, where learners had to balance chemical equations. Learners were provided with 3-dimensional diagrams of the chemical reactions and they had to select the correct chemical reaction. 25% of all the responses demonstrate misconceptions in this question, which relates to the learners' mathematical and interpretive skills. It appears that these misconceptions were addressed during the respective intervention sessions, because most of these misconceptions were not evident in the post-test

responses. C18 used an equal-to-sign, " $\text{Mg} + \text{O}_2 = \text{MgO}_2$ " instead of an arrow to symbolise that the reactants change in to products, he also wrote the chemical formula for magnesium oxide incorrectly, " $\text{MgO}_2$ " in the pre-test.

The post-test response of C18 wrote the formula for magnesium oxide correctly ( $\text{MgO}$ ), but the law of conservation of atoms is not adhered to (in the reactants there is four O-atoms, but in the products there is only two O-atoms present). C18 shows conceptual improvement in terms of representing chemical equations and writing chemical formula, needs improvement in balancing of equations. Therefore, C18 progress from Level 1 to Level 2 in terms of TAP. E11 shows a huge conceptual improvement of applying chemical equations principle, because in the pre-test response ( $2\text{H} + 2\text{O} \rightarrow \text{H}_4\text{O}_2$ ) most of the chemical equation principles, representation of diatomic molecules, format of chemical equations, write correct formulae and conservation of atoms were violated. However, in the post-test all these scientific principles were adhered to, suggesting a progress from Level 0 to Level 3 in terms of TAP. A dominant scientific viewpoint is expressed in the responses of C18 and E11.

### ***c) Analysis of knowledge***

In this theme, learners were expected to compare, evaluate and explain how science concepts relate to their everyday experiences. In Question 6g learners referred to their personal experiences when backing their claims.

Question 6 g: *Thabo always suffers from indigestion after he has had a very spicy meal and same glasses of Coke Cola. The indigestion is caused by acid build-up in the stomach. Which of the following substances would you suggest he take to relief the terrible feeling in his stomach? Motivate your answer by referring to the chemical process involve.*

*Milk of Magnesia [ $\text{Mg}(\text{OH})_2$ ] ; Rennie tablets ( $\text{HCl}$ ) ; Water ( $\text{H}_2\text{O}$ ) ; Table salt ( $\text{NaCl}$ )*

**Table 4.7.5: Pre-test and post-test responses to Question 6 in the ChAT**

<b>Learner</b>	<b>Pre-test responses</b>	<b>Post-test responses</b>
C5	“Thabo should drink a lot of water, because it will wash away the spicy food and Coke Cola out of his stomach.”	“Thabo should milk of magnesia, because it will neutralise the acid built-up. The milk of magnesia is a base and the spicy food and Coke Cola cause the acid in the stomach.”
E17	“Thabo should drink milk of magnesia, because it is milk and will take away the burning feeling”	“Thabo must drink milk of magnesia, because it has OH <sup>-</sup> ions and the acid build-up in the stomach has H <sub>3</sub> O <sup>+</sup> ions. The OH <sup>-</sup> and H <sub>3</sub> O <sup>+</sup> ions will combine to form H <sub>2</sub> O, which will neutralise the acid feeling.”

The pre-test response of C5 refers to a physical process, “...wash away the spicy food ...” and E17 provide a valid claim, “... it is milk and will take away the burning feeling ...” but does not explain the chemical process involved. Both learners demonstrated a positive shift in their conceptual understanding of acid and base reactions in their post-test responses. C5 is aware that the interaction of an acid and base results in a neutralisation reaction. E17 has the same awareness, but indicates a better improvement in her conception by referring to the ionic reaction of the hydroxyl and oxonium ions. C5 progressed from Level 1 to Level 2 and E17 from Level 1 to Level 3 in terms of TAP.

Both pre-test responses express everyday notions of chemical reactions. C5 probably refers to the use of water to put out fires in his response the water will “wash away” the spicy food. When I asked E17 about her pre-test response, she said her parents use to tell her to drink milk when she has heartburn. The post-test responses (reference to the neutralisation process) suggest, in terms of CAT, that both C5 and E17 have been become assimilated into the scientific worldview.

## **Interpretive summary**

Most learners only focussed on the elements on both sides of the equation by counting the atoms, but do not realise that atoms only combine in fixed ratios to form molecule and some elements are diatomic molecules. They also use the equal sign instead of the arrow sign to symbolise the chemical reaction. These misconceptions are probably the result of learners not being acquainted with the scientific language and confuse it with the mathematical language (Bricker & Bell, 2008).

### **4.4.4 Analysis of responses to the ChAT in terms of CAT cognitive categories**

The Contiguity Argumentation Theory (CAT) describes probable ways in which ideas move in the mind of an individual from one context to another. In other words, it attempts to reflect cognitive shifts, because of contextual changes and thus showing the dynamic nature of worldviews (Ogunniyi, 2007a). This contrasts sharply with other learning theories e.g. collateral learning and border crossing which tend to reflect fixed cognitive categories (e.g. Aikenhead & Jegede, 1999; Jegede, 1996). In terms of CAT, the cognitive shifts reflected in the learners' explanations could actually be traced say, from logical to non-logical, commonsensical, intuitive, value-laden, metaphysical and indigenous knowledge-based explanations or the reverse depending on the contexts in vogue. Another way to state this is to see shifts in their worldviews in terms of everyday knowledge worldview (EKW), to logical and scientific explanations or western science worldview (WSW), and vice versa.

There are many overlapping areas, like in the responses of the learners that milk of magnesia will relieve acid burn in the stomach (EKW) and the neutralisation reaction between milk and magnesia and the acids in the stomach (WSW), and clear connections between the EKW and WSW, the latter being a refined form of the former. In other words, scientific explanations confirm the everyday experience notions in a more sophisticated empirical form. Even scientists from time to time do use elements of intuition, hunches, trial-and-error particularly when a new phenomenon is encountered (Ogunniyi, 2007a). Similarly, it seems that the learners have learnt from the invalid responses made in the pre-test and therefore were able to make more valid predictions when faced with problems. One of the characteristics of scientists is serendipity i.e. the ability to make fortunate and unexpected discovery probably

because of the readiness or alertness of their minds as they engage with a problem (Ogunniyi, 1986, 1992). According to Ogunniyi (1986), “Incentive, intuition, creativity, alertness of the mind, trial and error, etc. all plays an important role in a scientific investigation” (p. 15). He argues further that:

A logico-mathematical system involves deduction, induction, creativity and sometimes serendipity i.e. happy accidents or chance as in the way penicillin or the Archimedes principle was discovered. It should be pointed out however, that such a happy coincidence favours only well-prepared minds - not minds bereft of the essential elements of the library of knowledge. Creativity, intuition or serendipity involves the chemistry or psychology of reflection, alertness and passion for knowledge. It is beyond the level of logic alone and only a few displays this ability at a sophisticated level. (p.20)

**Table 4.8: Frequency of CAT categories of learners’ responses in the ChAT**

Worldview	CAT category	Experimental group frequencies		Control Group frequencies	
		Pre	Post	Pre	Post
<b>Everyday Knowledge Worldview (EKW)</b>	Dominant	15	4	17	8
	Suppressed	8	3	4	2
	Assimilated	0	11	0	9
	Emergent	0	17	0	14
<b>Western Science Worldview (WSW)</b>	Dominant	3	11	7	10
	Suppressed	2	9	1	5
	Assimilated	0	2	0	4
	Emergent	0	21	0	16
<b>EKW and WSW</b>	Equipollent	5	10	5	7

Note:  $N_{\text{experimental}} = 25$ ;  $N_{\text{control}} = 25$

**a) *The dominant view category:***

In this category, responses that expressed the most adaptable worldview to a given context were analysed. Both the experimental and control group displayed dominant EKW (15 and 17 respectively) in the pre-test, such as, “water will wash away the spicy food and Coke Cola in the stomach...” and “... the iron will rust ...” while a few (4 and 8 respectively) displayed such dominant EKW views in the post-test. However, most (11 and 10 respectively) of the post-test responses expressed dominant WSW views like, “The  $\text{OH}^-$  and  $\text{H}_3\text{O}^+$  ions will combine to form  $\text{H}_2\text{O}$ , which will neutralise the acid feeling in the stomach” and “... the iron is oxidised ...” This suggests that the intervention methods received by the groups shifted their every dominant view from EKW to WSW.

**b) *The suppressed view category:***

In this category, a more adaptable mental stage overpowers the dominant cognitive stage. Eight (8) learners in the experimental group displayed suppressed EKW in the pre-test that dropped to 3 in the post-test. For example some learners stated in their pre-test “The steam of the tea made the teaspoon handle hot” and then in their post-test, “the loose [delocalised] electrons between the positive metal ions that are given heat energy by the hot tea making it vibrating faster and bump into colder loose electrons and conducting the heat”. The experimental group also shows an increase in suppressed views from 2 to 9 in terms of WSW. The control group shows a similar trend, a decrease in the suppressed EKW (4 to 2) and an increased in the suppressed WSW (1 to 5).

The learners in both groups that displayed a shift in the suppressed worldview category were very small; hence not much can be said or concluded regarding the suppressed view category. One can probably say that the majority of learners from both groups did not seem to display views that can be classified as being suppressed regarding chemical equations concepts. This could mean that, whatever changes might have occurred in their views are due to their own interest or arousal context, which they encountered.

***c) The assimilated view category:***

When the dominant worldview is absorbed into another more adaptable one, the latter assimilates the former (Ogunniyi, 2007a). Eleven (11) experimental group learners as opposed to 9 learners in the control group displayed assimilated EKW and 2 learners opposed to 4 learners respectively displayed assimilated WSW at the post-test. At the pre-test many learners misunderstand chemical reactions for physical changes such as, "... evaporation of water ..." and "... conduction of heat..." Comparing the pre-test responses to the learners' post-test responses like, "... transfer of electrons ..." and "... movement of sea of delocalised electrons ..." it suggests that their EKW has been assimilated into a WSW.

***d) The emergent view category:***

This category determines which learners had no previous knowledge of a given chemical equation concept, but were able to demonstrate such knowledge at the post-test. No learner displayed emergent views in the pre-test, because at this stage, they have not been exposed to the content of the learning activities. Seventeen (17) experimental group learners displayed emergent knowledge as opposed to 14 in the control group for the EKW. For example, some learners did not respond to the question referring to saponification, treatment of bee sting, red cabbage and tooth decay. In the post-test the following responses were give, "...boiling fats and an alkali ...", "... through baking powder on a bee sting ...", "... an extract of red cabbage turns a Handy Andy solution pink ..." and "...bacteria in the mouth change the sugary solution into acid ...".

For the WSW 21 learners in the experimental group displayed emergent concepts compared to the 16 learners in the control group. In their post-test responses some learners mention that "... acid cannot be used in swimming pools, it will burn people ...", "iron nail rusts" and "... all acids are harmful ..." in the post-test they mention, "... acids in swimming pools are used to keep the pH at 7 ...", "iron nail was oxidised" and "... some acids is useful for digestion ..."



***e) The equipollent view category:***

This category analysed responses that indicate the co-existence of the two worldviews, western science (WSW) and everyday knowledge (EKW), in the mind of the learner, without necessarily resulting in a conflict. In both groups 5 learners displayed equipollent worldviews at the pre-test, this might be because learners had a dominant everyday knowledge worldview and are not exposed to the scientific basis yet. At the post-test, the equipollent views increased to 10 and 7 respectively for the experimental and control group. Examples of equipollent views expressed by learners were, "... nails rust, because when metals are exposed to oxygen and water oxidation takes place ..." and "... when there were no fridges people coated meat and fish heavily with salt to preserve it, because micro-organisms responsible for food decay cannot live in high concentration of sodium chloride."

**Interpretive summary**

Table 4.8 reveals that the cognitive shifts experienced by learners relating to the worldviews they hold. In the pre-test frequencies in both groups, learners expressed a dominant everyday knowledge worldview and in the post-test the western science worldview is dominant. Whereas, the experimental group's responses reflected higher levels of argumentation, most of the responses of the control group lacked elements of argumentation. The manner in which the learners received their intervention could have influenced the cognitive shifts they experienced. The great number of emergent views expressed in the post-test demonstrates that the learners experienced an improvement in their conception of chemical equation concepts. Furthermore, the number of emergent views of the experimental group is more than the emergent views expressed by the control group, suggesting a greater improvement of conception of chemical equation concepts in the experimental group.

The experimental group expressed more equipollent views compared to the control group, which was evident in how they related their everyday experiences with the appropriate western scientific notions. These observations could be attributed to the dialogical argumentation instruction received by the experimental group, which explain the elaborate responses given.

#### **4.4.5 Classroom observation in the two groups:**

##### ***a) The experimental group***

The experimental group was divided into six groups, of four learners each, in an effort to have a co-operative learning environment in the classroom. Co-operative learning, in the form of group work, is defined in extant literature as a teaching strategy that encourages learners to work in small, heterogeneous learning groups in order to promote individual learning (Dunn & Griggs, 1989; Reyes, 2012; Slavin, 1983; Van Rooyen & De Beer, 2007). During all the sessions, the desks of the learners were arranged in clusters, to make it easy for group discussions. This arrangement was adopted to assist in the argumentation instructional method.

##### **Argumentation in the experimental group**

The experimental teacher employed the Dialogical Argumentation for Evolving Cognitive Understanding (DAECU) model developed by Langenhoven (2009). The DAECU model is a modification of the Dialogical Argumentation Instruction Model (Ogunniyi, 2007a & b) and focusses on the following learning spaces; nodal point, individual thinking space (intra-argumentation), sharing dialogical space (inter-argumentation) and whole group presentation (trans-argumentation). This model also allows for class discussion or a sort of reflexive space and the teacher assists the class to identify any emergent trends and patterns in the process of reaching cognitive understanding (harmonisation) regarding the outcomes of the activities.

The following is a group discussion that took place in one of the experimental group sessions. The learners used dialogical argumentation to determine the chemical bonding that took place in the formation of the aluminium chloride compound:

Teacher: “Explain how the chemical bonding in the aluminium chloride compound takes place. What claim can you make, and give backings and warrants to support your claims?”

Learner E6: “My claim is that, ‘Three chloride atoms combine with an aluminium atom to form aluminium chloride, which is ionic’”.

Learner E8: “No! A claim would be, ‘Ionic bonding takes place in aluminium chloride.’ And what you [E6] say is the data, because it explains what happens when the bonds takes place.”

Learner E5: “Yes! I agree with you, E8, we can also say that the aluminium atom donates its three unpaired valence electrons to three chlorine atoms with which it bond, to become a stable compound.”

Learner E7: “I don’t agree with you guys! Aluminium chloride is covalently bonded, because the difference in electronegativity is 3.2 minus 1.6 which give you 1.6. And Sir said if the difference in electronegativity is less than 1.8, it is a covalent bond.”

Learner E6: “It can’t be a covalent bonding, a metal and non-metal atom is involved!”

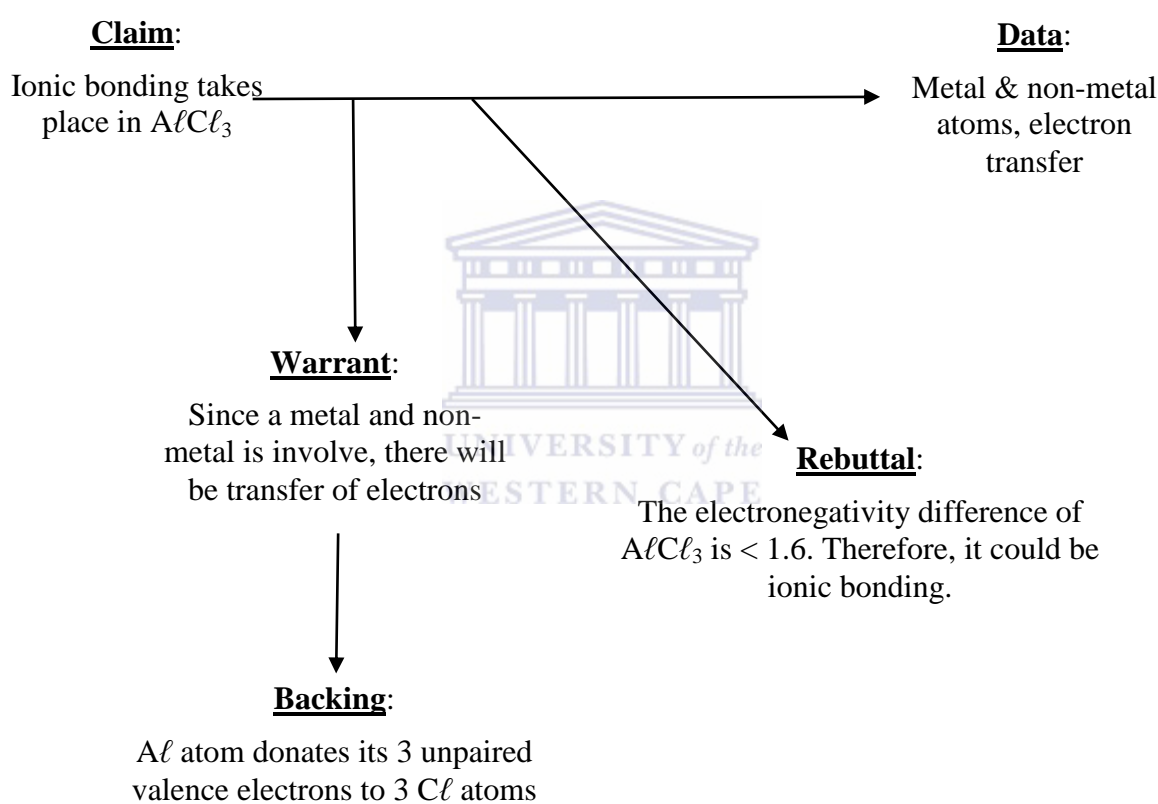
Learner E1: “Well, E7 is correct, but that [electronegativity difference] is the only evidence that it could be a covalent bond, in comparison to the fact that a metal and non-metal is involved, which mean electron transfer WILL take place. Should we agree that E7’s statement is a rebuttal?”

Group: “Yes! We accept it is a rebuttal.”

The above discussion follows the process of argument reappraisal of Leita0 (2000), which states that when doubts arise from a claim, because of a counter-claim or rebuttal the arguers can dismiss, localise, integrate or accept the counter-claim in order to preserve or withdraw the original claim. The group decided to localise the rebuttal, that it is a covalent bond, and preserve their original claim, that it is an ionic bond. This is also an example of Ausubel’s (1968) disputational talk, which is characterised by disagreement and collective consensus. In terms of the CAT the dominant view of E8, that it is a covalent bond, is suppressed and E8 accepts the more appropriate view that it is an ionic bond. Learner E1 expressed an emergent

view when she became aware that compounds might have both ionic and covalent properties. At the end of the group discussion, the learners reached cognitive harmonisation when they agreed on the claim and rebuttal.

The group also showed that they are competent with the argumentation protocol of Toulmin's Argumentation Pattern (TAP), because the different elements of TAP could be identified in the group discussion. Figure 4.2 illustrates those elements namely, a claim, a warrant, a backing, a rebuttal and data for the claim.



**Figure 4.2: Argumentation in terms of TAP used in the group discussion**

This argumentation process would obtain a Level 3 in terms of TAP, because it involves most of the elements of TAP. This group discussion is in accord with Toulmin's (1984) assertion that, "Scientific arguments involve no real conflict of interest, nor are there any permanent winners or losers as a result of their resolution" (p. 345).

During the reflection on the feed-back of the different groups, the teacher provided clarification on the question about the chemical bonding of aluminium chloride as follows:

An ionic bond will acquire a degree of covalent character if the positive metal ion can attract electron density from the negative non-metal ion back into the region between the nuclei. The covalent character arises because the valence electrons will then be partially shared. The extent to which a positive metal ion can do this is called its polarising power. The greater the charge density on the positive ion,  $Al^{+3}$ , the greater its polarising power and the greater the covalent character of the bond that it forms with the negative ( $Cl^-$ ) ion. These types of covalent bonds are exceptions to the electronegativity difference rule of the Pauling scale (Clugston, Flemming, & Vogt, 2002).

In most of the activities, the learners in the experimental group showed lots of interest and seemed to enjoy such activities in the way they interacted with each other and took part in the activities. The following positive views were expressed in one of the focus group discussions:

Learner E24: “I wish my maths teacher could also teach us in this way”

Learner E8: “It is nice to work in groups and to debate about the work, now I understand it better”

Learner E15: “I have learnt that I cannot just give an answer, but have to motivate and give reasons why I say something”

These responses could be construed as evidence to show that the activities have enabled them to appreciate the usefulness of dialogical argumentation. These views accord with the Vygotskian perspective of learning as a social activity. Rochat, (2002) cited Vygotsky’s asserts that:

All higher psychological functions are internalised relationships of the social kind, and constitute the social structure of personality. Their composition, genetic structure, ways of functioning – in one word – all their nature is social. Even

when they have become psychological processes, their nature remains quasi-social. The human being who is alone retains the function of interaction. (p.141)

Throughout the period, the teacher plays devil's advocate by asking thought-provoking questions randomly to all groups individually in order to reflect on the process of argumentation and understanding in each group. During the whole class discussion (reflexive space) the teacher did an appraisal of the success or otherwise of the instructional strategies used in the learning activity. (e.g. Diwu & Ogunniyi, 2012; Erduran, Simon & Osborne, 2004; Ogunniyi, 2004, 2007a & b).

### ***b) Control group***

In the control group, the teaching process was rigid and predictable in comparison to the experimental group's activities. In most of the sessions, a seats-in-a-row desk arrangement was used in the class and the teacher mostly used the lecture style of teaching. Only when there was group discussions, the desks were arranged in clusters and although group work was also used, the teacher did not include the argumentation elements of the DAECU model. The teacher would start by introducing a topic of the activity briefly and handed out the worksheets for the different groups, which the learners had to complete collectively as a group. The teacher would also walk among the learners and gave assistance to those he think are struggling with the activities. At the end of the lesson, he would write the correct answers of the worksheets on the chalkboard and the learners would then correct their own answers. If time permitted, he would entertain a few questions from the learners on issues that learners would understand.

In one of the lessons in the control group, I observed the following interactions between the teacher and the learners during a whole class discussion. The topic of discussion was the atomic sizes of different elements.

Teacher: "Who can tell us, which one of the sodium atom and the chlorine atom has the smallest size in terms of atomic volume?"

Learner C1: "I think it is sodium, Sir!"

Teacher: “How do you know that, Mohamed?”

Learner C1: “Sodium atom has fewer electrons than the chlorine atom, the more electron the bigger the atom.”

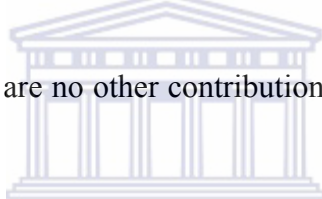
Teacher: “Ok! Let’s hear what the others have to say. Do you all agree with the answer of Mohamed?”

Learner C20: (Raises his hand up) “Yes, I agree with Mohamed. In the picture in the text book the sodium is drawn smaller than chlorine.”

Teacher: “Anyone else wants to add anything?” (Looking for a hand, but there is no movement in the class.)

Learner C18: (Shouts out) “No! Sodium is smaller than chlorine!”

Teacher: “Right, since there are no other contributions, let’s find out what is the correct answer.”



(The teacher showed a simulation of how electron transfer takes place between sodium atoms and chlorine atoms to form sodium and chlorine ions and the NaCl-lattice.)

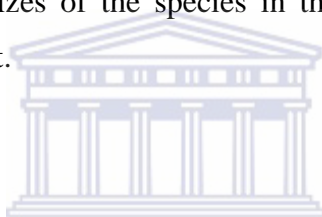
Teacher: (Pointing to the images on the electronic board) “Now, look! As you can see, the sodium atom is bigger than the chlorine atom and here the sodium ion is smaller than the chlorine ion”.

Class: (Some learners exclaimed) “Ok, now we see!”

This discussion does not reveal effective interrogation of the question to elicit argumentation from the learners and/or the teacher. The teacher also does not encourage maximum participation from the class and conveniently resort to the simulation to explain the concept of atomic volume to the learners. Certain areas of science are more difficult for learners to understand (Bricker & Bell, 2008). Here he should have explained that, the atomic radius shrink as one move from left to right in the period of the periodic table, because the

positive nuclear charge increases and pulls the electrons closer to the nucleus. In a group the atomic radius increases from the top to bottom, because of the increased levels filled with electrons are farther from the nucleus (Clugston, Flemming, & Vogt, 2002).

The teacher also failed to address the misconception held by Learner C1 who stated that that if the number of electrons in an atom increases, the size of the atom will increase. The teacher was not creative enough by engaging his learners on how to understand the concept of atomic sizes. Creative teaching involves combining existing and new knowledge to create a totally new knowledge to obtain a useful result (Amabile, 1996). This could result in a situation “where the learner is confronted with new ideas that cannot be fitted into his/her existing conception, leading to an inability to cope adequately with the new information” (Skoumios & Hatzinikita, 2009). Learner C20 was not aware that the species in the NaCl-lattice are ions, not atoms. The sizes of the sodium and chlorine atoms change drastically when they are ions. Although the learners saw the sizes of the species in the simulation, they still could not explain why the sizes are different.



### ***c) Interpretive summary***

Class discussions are very important in the outcome-based education (OBE) classroom. Learners should be able to communicate not only through the written, but also through the spoken word (Department of Basic Education, 2012). Both the experimental and the control group made use of group work, which seemed to be very effective in promoting the sharing of opinions, developing of argumentation skills and learning to respect other’s viewpoints. However, the control group teacher was more dominant and presented his lessons in the form of a lecture. Although he attempted to change the mostly one-way communication style in the classroom by making use of group discussions, asking a few questions and using ICT resources, he still limited the interactions between the learners and the learning content and experience. The lecture teaching method does have its advantages over heuristic strategies. For instance, it allows learners to see the lesson as a structured unit. In addition, it enables the teacher to be able to stress important facts and to show the ‘big picture’ to the learners. However, its major disadvantage is that it makes the learners passive and consequently learners tend to lose interest in the lesson (Amabile, 1996).



The Dialogical Argumentation Evolving Cognitive Understanding (DAECU) model, which deals with the interaction of the different mental spaces to reach cognitive understanding, used by the experimental teacher, allowed the learners to be more actively involved in the lesson, because different thinking spaces were created such that the learners were free to ask questions at any time. The responses of the experimental group were also more elaborate, compared to the control group, because they had to provide backings for their responses.

The authoritative approach used by the control group teacher focused more on the scientific worldview of the activities. In contrast, the experimental teacher used the dialogical approach to explore and exploit the learners' ideas (i.e. their everyday knowledge). It is important that a teacher must have the necessary communicative repertoire in order to impart content knowledge effectively and to have a positive influence on the learners' personal and cultural beliefs (Lehesvuori, Viiri, & Rasku-Putten, 2010). The experimental teacher seems to possess more of these skills in his communicative repertoire than the control teacher does.

These are illustrations of the cognitive connection between argumentation and learning and thinking. Aristotle, cited by Bricker and Bell (2008), frequently mentioned learning as, "Imparting knowledge as the result of effective presentation of ideas and arguments, [and] in turn the result of making the best possible verbal choices". They believe that we can use argument as a window through which to look not only at what people think, but also how and why they think the way they do. "Through dialogue, the teacher-of-the-students and the students-of-the-teacher cease to exist and a new term must emerge, 'teacher-student with students-teacher'" (Freire, 1984). Freire (1990) expresses the same view further as what he termed "liberatory pedagogy" a concept akin to Habermas' emancipatory knowledge i.e. the possessor has developed ownership of such knowledge (Habermas, 1971).

It should be stressed, however, that although the past 30 years has seen substantial growth in approaches to and study of classroom interactions in a range of contexts, we are still in the infancy of our understanding of what goes on inside the "black box" of classrooms, or learning situations (Wray & Kumpulainen, 2009).

#### 4.4.6 Preferred learning styles of learners

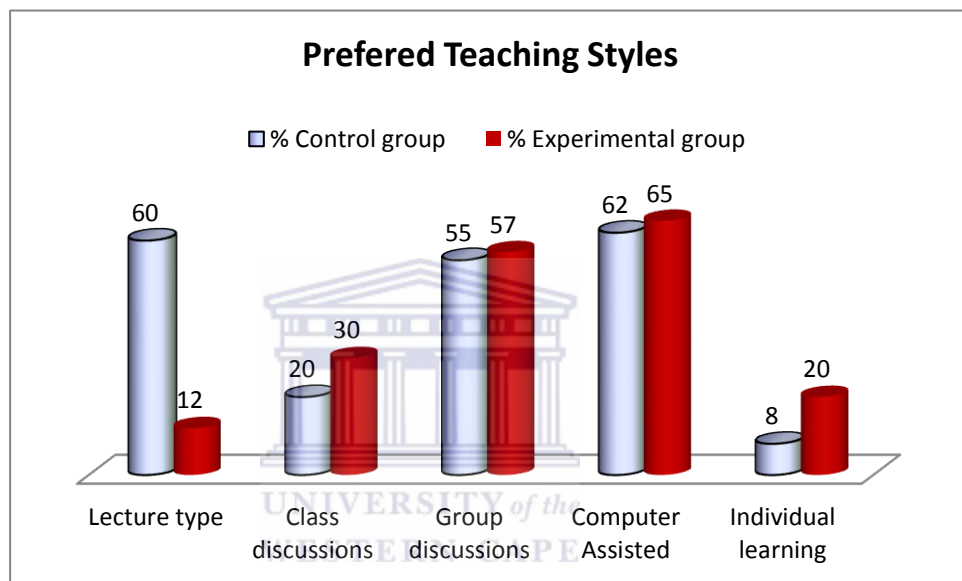
Teachers need to know their learners, so that they respect each learner as an individual, which will enable the teacher to be sensitive to the learner's specific efforts or preferences (Van Rooyen & De Beer, 2007). The teacher must be observant about their learners and pay attention on how they act, who their friends are, their reactions to assignments, whether they are able to learn independently, etc. This can also be established by finding things out through people who interact with them, like their fellow-learners, parents and other teachers. This interest towards learners is termed by Parsons and Brown (2002) as the culturally sensitive instructional approach.

This approach is also supported by the studies of Lehesvuori, Viiri and Rasku-Putten (2010) who emphasises that teaching styles of teachers should correspond with the learning styles of learners in order for the learning process to be effective. In this regard, teachers need to provide opportunities for the learners to acquire knowledge and a large number of skills, including automatisms (Van Rooyen & De Beer, 2007). Automatisms are the basic concepts that an individual needs in any particular subject. They assert that a creative learner is able to acquire a magnitude of automatisms in a specific field of knowledge. Since concepts, facts and principles are acquired in any field of knowledge, teachers should ensure that learners are helped to acquire the relevant automatisms in order to solve specific problems.

The dilemma that teachers in public schools are facing is that the learning styles of the learners in a classroom vary greatly, especially in a school like Newton High where learners came from a various socio-cultural backgrounds. Another problem teachers experience is the large number of learners in a class, which make it difficult to pay the necessary individual attention to learners. However, Dieber (1991) argues that, "The link between strategic teaching and effective learning is creativity, which must be the keystone of any professional development plan". They assert that this link can be achieved when teachers adapt to learners' learning ability. In addition, they found that learners' performance increased when they were taught according to their preferred learning styles.

Figure 4.3 compares the learning styles of the experimental and control group and it reveals that both groups preferred working with ICT resources (65% and 62% respectively). The

second choice of the experimental group is group discussion (57%) as oppose to lecture style of teaching (60%) of the control group. It is interesting to note that the least preferred teaching style for the experimental group is lecture style (12%) and for the control group it is individual learning (8%). This observation supports the different learning approaches of De Bono (1997), which makes it clear that not all the learners share the same appreciation of teaching styles. Group work activities however, could make it possible to include the six perspectives described by Bono; the clinical thinker, the optimist, the emotional thinker, the critical thinker, the creative thinker and the analytical thinker, proposed by De Bono.



**Fig. 4.3: Preferred learning styles of the learners**

A closer examination of Figure 4.3 shows that the experimental group learners preferred to make more use of computers in the learning process compared to the learners in the control group, this resembles De Bono's clinical, creative and analytical thinkers. It is also interesting to note that the experimental group prefers working in groups, rather than the teacher explaining the work and the control group's preference is vice versa. The experimental group had more elaborate group discussion, than the control group, which had limited discussions about the content. In terms of De Bono's (1997) classification the control group is clinical, cautious and holistic in their preferred learning styles. This difference in preference could be accredited to the different instructional methodologies to which the groups had been exposed. The teaching methods could also be linked to the difference in the

learners' preferences to work on their own. This is indicative of the tendency of learners not doing homework and these stresses the need for social interaction in the classroom.

### **Interpretive summary**

Feeding the results of the preferred learning style questionnaire into the results of the post-test scores of the groups suggests a causal relationship. The control group preferred teacher-talk, because they received lecture-style teaching and the experimental group preferred computers and group work, because they were exposed to the dialogical argumentation instruction method. Although these outcomes are not surprising, they do have implications for learning.

In Hong's (2009) study of learners' learning anxiety and attitudes towards science, the researcher found that the attitudes of learners improved significantly when they are actively participating in scientific discussion of their novel ideas, working co-operatively on science projects, and presenting findings in front of classmates during the collaborative science intervention. This is consistent with the findings of this study. West et al. (2007) also found that group work and argumentation increases the interest and self-efficacy (belief about how well he or she can effectively finish a task) of learners. This is evident in a regular physical sciences classroom, where the teacher tends to dominate classroom talks and manipulate the learning activities, whereas in a DAI augmented class the learner dominates both verbal and non-verbal activities (Kiboss & Ogunniyi, 2005).

It is evident that most learners do not know how to argue and/or do not engage in the practice effectively. In order to remedy the situation Bricker & Bell (2008) proposes the notion of collaborative argumentation, which they say, is the type of argumentation in which scientists engage. If learners are taught collaborative argumentation practices, then they will be arguing to learn. As part of participation in argumentation, learners will be engaged in practices, such as elaboration, reflection and reasoning, which are rich learning practices. Collaborative science interventions provide learners opportunities to observe role models, gain realistic views about the world, and help learners expand their positive commitment to and continual interest in science (Hong, 2009).

#### **4.5 To what extent are the conceptions of chemical equations that the grade 10 learners hold relate to their age, sex and socio-economic background?**

The third research question puts the study in perspective and contextualises the background of the participants by looking at their biographic and socio-economic conditions and comparing it to their achievement in the chemistry achievement test. This question is essential because the participants come from diverse backgrounds as explained in chapter three. There are substantial evidence in the literature to show that biographic and socio-economic variables can impact the way in which learners conceptualize diverse natural phenomena (e.g. Cogley, McKenne, Baker, & Wattie, 2009; Greenfield, 1997; Jones, Howe, & Rua, 2000; Lee & Burkam, 1996). In the section that follows, I shall briefly treat each variable in relation the participants' conceptions of chemical equations.

##### **4.5.1 Gender, age and race**

###### ***a) Gender***

The analysis of the data, based on gender, was performed across the experimental and control group using the post-test scores. Table 4.9 indicates that the girls, with a mean score of 36.56, performed slightly better compared to the boys, with a mean score of 34.55. However, the t-statistics ( $t_{\text{observed}} = 0.83$ ;  $t_{\text{critical}} = 2.02$ ;  $p < 0.05$ ) do not show a significant difference between the gender groups, although the girls performed slightly better than the boys did. My observation as a teacher has been that this trend is found in other learning areas in grade 10 as well. Several studies indicate differences in performance of science, and interest in science based on gender, especially in the physical sciences (e.g. Greenfield, 1997; Farenga & Love, 1999; Jones, Howe & Rua, 2000; Lee & Burkam, 1996). These studies suggest that girls perform better than boys and there exist a perception that subjects like mathematics and physical sciences are masculine, whereas subjects such as life sciences, languages and art are believed to be feminine (Farenga & Joyce, 1999).

**Table 4.9: Learners' conceptions of chemical equations according to gender**

	<b>N</b>	<b>Mean (%)</b>	<b>SD</b>	<b>t - value</b>	<b>Sig. (2-Tailed)</b>
Girls	23	36.56 (61%)	5.79		
<b>Gender</b>				0.83	0.41
Boys	27	34.55 (58%)	10.23		

**Note.** t-critical = 2.02 ; df = 48 ; p = 0.05 ; (\*) indicates a significant difference

There are also studies that contradict the findings of this study e.g. Bricker & Bell (2008) and Geer & Sweeney (2012) who assert that male learners performed significantly better than their female counterparts in physical science in middle school grades did. In their studies, they also suggest that argumentation is a male-dominated practice, because it reinforces certain cultural customs men must take the lead and has the last say and women must be obedient. Therefore, boys are expected to perform better compared to girls. This claim is of course equivocal because argumentation is a human characteristic and not necessarily gender-based. Nevertheless, apart from this there are many underlying factors involved, such as gender sensitivity and cultural validity of the context in which the study was undertaking. The instructional method used, background and ability of the participants, interest and attitudes of the participants are also factors to be taken into account (Bricker & Bell, 2008). The issue is more complex than is often realized. For example, in a large-scale study involving over 6000 learners from all the nine provinces grades 7-9 girls consistently outperformed their male counterparts on energy and change including chemical reactions and several other concepts (Ogunniyi, 1999; 2003; Lee & Burkam, 1996; Leedy, Lalonde & Runk, 2003).

### ***b) Age***

Table 4.10 indicates that the younger learners have performed better than their older counterparts, with a mean score difference of 9.61. The t-statistics indicate a significant difference ( $t_{\text{obtained}} = 4.13$ ;  $t_{\text{critical}} = 2.02$ ;  $p < 0.05$ ) between the two age groups. The same trend was observed in the large-scale study alluded to earlier (Ogunniyi, 1999, 2003). This could be attributed to the fact that during the activity sessions the younger learners were more eager and attentive than the older learners, who seemed to be making jokes and even posed

disciplinary challenges to the teacher. On the other hand, it might be related to such factors as slow learners or repeaters (Ogunniyi, 1999, 2003; Cobley, McKenne, Baker, & Wattie, 2009; Greenfield, 1997), because the teachers mostly work at the pace of the curriculum or they are bored because the work is not new to them.

**Table 4.10: Learners' conceptions of chemical equations according to age**

	N	Mean (%)	SD	t - value	Sig. (2-Tailed)
16 years	18	40.33 (67%)	5.00		
<b>Age</b>				4.13*	0.00
17 years	32	30.72 (51%)	9.10		

**Note.** t-critical = 2.021 ; df = 48 ; p = 0.05 ; (\*) indicates a significant difference

There are also studies that produced results contrary to this study, suggesting that older learners are more mature and they find it easier to engage with content material. Hendricks (2001) asserts that, "Age does play a significant role in determining the participants understanding of science concepts". Colbey et al. (2009) concur with Hendricks' claim and found in their study that, "Strong evidence suggest that subtle age differences between pupils in the same school year contribute to varying levels of attainment between learners, irrespective of gender, stage of education, subject or type of assessment examined." They also found that the older learners attain significantly higher when compared to their relatively younger counterparts. The results in Table 4.10 contradict the findings of Hendricks and Colbey et al. (2009) who found that older learners generally perform better compared to their younger counterparts in middle school. They also found that the measure of this discrepancy appears to be greatest during initial stages of secondary school, being the highest at 10%, and then declining in the latter years of education.

### **c) Race**

The Apartheid policies of South Africa prior to 1994 were based on the separation of ethnic cultures in terms of culture, language education and race. In the process of applying Apartheid in practice, each ethnic culture, Whites, Blacks and Coloureds, was systematically isolated, both physically and culturally from each other along language, colour, education and

even social lines (Fatar, 2007). Acculturation, the process whereby an individual becomes adapted to a new culture, is determined by the degree of social and psychological distance between the learner and the target cultural group (Dinie, 2000). These factors have to be acknowledged when discussing race in the South African school context.

Table 4.11 suggests that the Black learners performed better the Coloured learners with mean score of 36.69 and 32.29 respectively, but there is no statistical significant difference ( $t_{\text{obtained}} = 0.18$  and  $t_{\text{critical}} = 2.02$  at  $p < 0.05$ ) between the two racial groups. This slight better performance of the Black learners could be attributed to the fact that they have to prove that they are acculturated. In the Apartheid era, more education resources were allocated to the Coloured population group, than to the Blacks by the government. Now in the post-Apartheid era, the education resources are being shared “equally” amongst all population groups, which results in a movement of Black learners to Coloured schools and Coloured learners to White schools and White learners to private school (Fatar, 2007).

**Table 4.11: Learners’ conceptions of chemical equations according to race**

	N	Mean (%)	SD	t - value	Sig. (2-Tailed)
<b>Race</b>	Coloured	37	32.29 (54%)	10.45	1.37 0.18
	Black	13	36.69 (61%)	8.25	

**Note.**  $t_{\text{critical}} = 2.021$  ;  $df = 48$  ;  $p = 0.05$  ; (\*) indicates a significant difference

The Black learners on the “move” probably work much harder to prove themselves than those from the immediate Coloured community around the school. This might be one of the reasons that this group of Black learners performed better than their Coloured counterparts in the predominately-Coloured school. The Coloured learners seem to take their educational opportunities for granted, because they become complacent. There is no doubt that it may be related to their generally lax attitudes to learning, a factor which is of great concern to school administrators, parents and the community at large. However, relevant as this issue is, it is not the central concern of this study, warrants a more detailed investigation in future studies.



## **Interpretive summary**

The analysis of the performance of the learners based on gender, race and age contextualises the responses of the participants. The results indicate that the girls, in this study, perform slightly better than the boys in understanding chemical equation concepts, but the difference is not statistically significant. This finding concurs with the study of Brecker & Bell (2008), who found that in the initial grades of secondary school girls generally perform better than boys and in the final grades boys out-perform girls. The results in terms of the age difference indicate that the younger participants perform significantly better than their seniors do. Hendricks (2001) asserts that the performance gap between the age groups shrinks in the higher grades and at tertiary level the older students perform better than their younger counterparts do. The analysis in terms of race groups suggests that the Black learners slightly perform better than the Coloured cohort does. However, the difference is not statistically significant. These findings are confirmed by studies of Fatar (2007) and could mainly be attributed to the complacency of the Coloured learners and the eagerness of the Black learners to prove themselves in the Coloured sub-culture.

### **4.5.2 Socio-economic background**

In Table 4.12 the learners with advanced ICT-resources, who own computers and have internet access at home achieved higher scores in their post-test than the learners with basic ICT-resources, no computers and internet access at home. The difference in the mean scores is 4.97, it is a statistically significant difference ( $t_{\text{observed}} = 2.20$ ;  $t_{\text{critical}} = 2.02$ ;  $p < 0.05$ ). The difference in the mean scores suggests that the access to ICT-resources did influence the performance of the learners, if they make optimal use of the ICT-resources at home. Learners also have easy access to ICT-resources at school, most classrooms have ICT-resources, and the local municipality libraries.

**Table 4.12: Learner performance in the ChAT according to socio-economic factors**

<b>Item</b>		<b>N</b>	<b>Mean (%)</b>	<b>SD</b>	<b>t-value</b>
<b>ICT-resources</b>	Basic	32	25.25 (42%)	8.19	2.20*
	Advanced	18	30.22 (51%)	6.60	
<b>Residence</b>	Sub-economic	30	27.03 (45%)	10.58	1.02
	Economic	20	29.75 (49%)	6.64	
<b>Household</b>	Single parent	16	21.56 (36%)	9.32	4.74*
	Both parents	34	31.50 (52%)	5.48	

**Note:** t-crit = 2.021 ; df = 48 ; p = 0.05 ; (\*) indicates significance

Table 4.12 also reveals that the learners from economic (middle- class) households performed better than the learners from the sub-economic (low-income) households, they scored 29.75 and 21.03 respectively. However, there is no statistical difference between the types of households ( $t_{\text{observed}} = 1.02$ ;  $t_{\text{critical}} = 2.02$ ;  $p < 0.05$ ). One would expect poorer performance by the learners from sub-economic households, because the assumption is that they will not have the same recourses as their counterparts in economic households. These results are contrary to the findings of Reyes (2012) who asserts that, “Parents with low income are less educated and have a limited vocabulary, which is reflected in their interaction with their children. These learners have a backlog compared to learners with higher income [educated] parents” (p.44).

Table 4.12 also indicates that the learners from families where both parents are present in the household outperform the single parent households with mean scores of 31.50 and 21.56 respectively. The differences in the scores is statistically significant,  $t_{\text{observed}} = 4.74$  and  $t_{\text{critical}} = 2.02$  at  $p < 0.05$ . The results confirm the assumption that learners with both parents would perform better compared to learners with single parent. This could be attributed to the fact that single parent families may not have the necessary emotional and psychological support structures necessary for excelling learners (Greenfield, 1997).

## 4.6 Overall summary

As indicated at the beginning of this chapter, the data obtained from the study have been analysed and presented in both quantitative and qualitative terms as deemed appropriate. In addition, where feasible the data set was analysed in terms of the Toulmin's (1985) Argumentation Pattern (TAP) and Ogunniyi's (1997) Contiguity Argumentation Theory (CAT), the two main theoretical constructs underpinning the study. However, data related to Questions 1 and 3 based on ex-post factors i.e. those that have not been experimentally manipulated in the study such as status of resources, gender, age and race were not analysed in terms of TAP and CAT. Furthermore, to keep with the space allowed for a Master's thesis and to avoid repetition of issues that have been interrogated in the section under interpretive summaries, only the major issues emanating from the study will be addressed in the section that follows.

This chapter analysed the findings of this study based on the theoretical and conceptual frame outlined in the earlier chapters. The major findings that have emerged from the examination of both the qualitative and quantitative data are the following. The majority of the selected schools do have the basic ICT-resources, but the resources are not used optimally. The teachers engage in avoidance of computer-use provide various reasons, but most teachers responded positively and acknowledge the importance of the ICT-resources. Teachers should be aware that ICT resources and the use thereof have both advantages and disadvantages, but it largely depends on the teacher's perception and willingness to make it workable. Gardner (1999) suggests that learners should be espoused very early in the instructional sequence in order to capture learners' interest in the topic and then teach the scientific concepts. The aim is to attract learners' interest first.

The analyses have shown that the participants in both the experimental and control groups held inadequate conceptions of chemical equations at the beginning of the study according to the pre-test results. The knowledge that they had could be due to the prior knowledge they held about the chemical equation concepts that had been covered in the grade nine natural sciences curriculum. In the grades eight and nine curriculum, the writing and balancing of simple chemical equations is introduced, only in grade ten are they introduced to the

development of the atomic model, shapes and sizes of molecules, molecular geometry and chemical bonding models. It was also evident during the intervention sessions that the animations and simulations used helped the learners to understand the abstract concepts. Another important aspect is that teachers should induct learners thoroughly in the scientific language. Bricker & Bell (2008) claims that arguments are not solely constructed verbally, but also by using a semiotic combination of text, mathematical expressions, diagrams, photographs, and so forth. They assert that symbolic representation of scientific terms must be interpreted in terms of a scientific context to comprehend the argument being made. This is crucial for the interpretation and representation of chemical symbols and the writing of balanced chemical equations. Lazarou (2010) said that learning science involves learning to, “talk the language of science and acting as a member of the community of that practice”.

An analysis of the post-test data shows improvement in the achievement of both the groups, thus indicating a better grasp of chemical equation concepts. This improvement is assumed to be as a result of the method used. As indicated in chapter 3, the participants in the experimental group were exposed to an argumentation-based instruction underpinned by Toulmin’s Argumentation Pattern (TAP). The scores of the subjects were higher than that of the control group. In examination, the experimental group’s responses are more and stronger backed with data (evidence), backing and warrants than was the case in the control group at the post-test. This could be attributed to the critical argumentation spaces provided by the DAECU model. This has further corroborated a plethora of studies indicating that dialogical argumentation instruction does enhance learners’ conceptual development e.g. Angaama, 2012; Bricker & Bell, 2008; Diwu, 2010; George, 2012; Langenhoven, 2009; Magerman, 2011; Newton, Driver, & Osborne, 1999; Ogunniyi, 2007 and Ogunniyi & Hewson, 2008.

This study also found that there is no significant difference between gender and race; therefore, they cannot be related to the conception of the learners in terms of chemical equation concepts. However, it was found that age did relate to the performance of the learners. This study also could not significantly indicate that access to ICT resources at home and the type of residence influence the performance of learners in this study. It did revealed that the family setting in which learners find themselves do play an important role in the performance of learners in this study.

The change in attitudes and the higher level of collaboration and communication in the classroom made it possible to improve learners' higher order thinking skills, such as reasoning and scientific creativity. Thus, the paradigm shift towards a learner-centred learning environment and the use of a socially derived teaching approach is crucial for improving the learners' attitudes towards science learning and thereby to achieve the desired goals of an increased level of learners' scientific literacy within its different components (Rannikmae & Laius, 2010: p.159).



## CHAPTER FIVE - SUMMARY AND RECOMMENDATIONS

### 5.1 Introduction

This chapter summarizes the major findings of the study as well as highlights the implications of such findings for curriculum development, instructional practice and research. For ease of reference, the findings will be related to the questions of the study.

#### 5.2.1 Research question 1:

*What is the status of information communication technology (ICT) resources and their usage in certain selected schools in the Western Cape?*

Certain innovative practices, such as the use of computers, have provided some solutions to the teaching profession. However, the use of computers have placed an extra burden on some teachers, since not all of them are equally computer literate. In this study, many teachers found it useful to integrate information-communication-technology resources in their classroom practices. The extant literature supports the finding of this study by showing that teachers who used computers in their lessons were more efficacious than those who not avail themselves of such learning aids (De Vries, 2006; Layton, 1993; Naicker, 2010).

This study has found that the selected schools are well resourced and do have the basic ICT infrastructure, but the majority of teachers are not adequately trained to use the resources effectively. Technology changes at a fast rate and technological inventions today become obsolete within a short time. This leads to a situation where schools become dumping sites of private companies' out-dated technology, when they upgrade their technology resources, and these schools accept the donations with gratitude, unaware of the problems they inherent. This is evident from the responses of the teacher of School 8, "Our PC's and software are out-dated and the licenses expired long time ago..." Another teacher from School 4 responded, "... we have received printers and photocopy machines from a company, but when they break we cannot find parts to repair it, anywhere ..." From the ten selected school that were interviewed, teachers of four schools mentioned that they were victims of outdated technology resource donations. Some schools still spend money procuring overhead

projectors and chalkboards, instead of equipping themselves with the latest ICT resources, like data projectors, computers, interactive boards, internet connections, etc.

There are many electronic teaching and learning material and resources readily available from the Education Department, but appropriate infrastructures and policies should be put into place at these institutions to maintain and support the ICT resources. Education authorities and policy makers will also have to change the curriculum and teacher training to incorporate computer-assisted learning (CAL) into the learning content. Bungum (2003) indicates in his studies that the relationship between education and technology has an influence on the economic growth of a country. Ogunniyi (1996) asserts that there is evidence that there is a strong link between education and technology with economic progress. The fact that South Africa is hosting the Square Kilometre Array (SKA) radio telescopes and the Southern Africa Largest Telescope (SALT) makes the integration of technology into science education more imperative. Another author, De Vries (2006) confirms this relationship in his assertion that, “Human resource development has become a central feature of most national development strategies and within this, the emphasis has more often than not been on the acquisition of scientific and technological skills and capabilities.” (p.1)

### **5.2.2 Research questions 2:**

***Do grade 10 learners exposed to dialogical argumentation instruction (DAI) in a computer-assisted learning environment demonstrate a better understanding of chemical equation than those who are not so exposed?***

Although some learners in both groups in the pre-test demonstrated some knowledge of chemical equation concepts it was very superficial. This could be because some natural sciences teachers in grade eight and nine do not have the necessary training and skills to teach these concepts, rushed through the content, and focused only on the content they are familiar and comfortable with. The teachers in the General Education and Training (GET) phase are usually not specialists and sometimes have to teach different learning areas to fill up their timetables, because of operational challenges faced by schools. However, the post-test results showed that there were an improvement in both groups and that the experimental group outperformed the control group significantly (t-ratio value of 4.04; t-critical value of 2.02 at p

< 0.05). The significant improvement of the experimental group could be attributed to the dialogical argumentation instruction (DAI) intervention.

The results revealed that the learning environment and interaction of the experimental group was more learner-centred where learners interacted amongst themselves and with the educator. The Dialogical Argumentation Evolving Cognitive Understanding (DAECU) model provided the platform for learners to experience learning in the different thinking spaces for the experimental group. Furthermore, the preferred learning style of the experimental group (group discussions) compared to the preferred learning style of the control group (lecture style) seems to be more effective according to the post-test cores of the ChAT.

### **5.2.3 Research question 3:**

*To what extent are the conceptions of chemical equations that the grade 10 learners hold relate to their age, sex and socio-economic background?*

This study found that there is a definite relationship between the learners' cultural and socio-economic backgrounds and their performance in the Chemistry Achievement Test (ChAT). Learners from lower-income households scored slightly lower marks compared to learners from high-income households, but the difference was not significant. Therefore, one can assume that the economic background of the participants did not influence their performance. It was also found that girl-learners outperformed the boy-learners, which I found to be the trend at in other grades as well. It is interesting to note that this trend is verse versa at the primary school level. Extant literature shows that subjects like engineering and technology are viewed as male-dominated domains and an inclination towards caring and well-being is normally associated with girls (Greenfield, 1997; Lee & Burkam, 1996; Leedy, Lalonde, & Runk, 2003). It was also found that younger learners out-performed older learners and it is my belief that the younger learners would even perform better if they were in a homogenous class group in terms of age (Ogunniyi, 1999).



## 5.3 Implications

Recent studies (Ball, 2000; Eisner, 2004; Reyes, 2012) have shown that there is a gap between the objectives of the curriculum and the way it has actually been implemented in the science classroom. There are two perspectives of a curriculum, namely a plan or an intention of curriculum developers as depicted in the written document and what really happens at schools (Stenhouse, 1988). The former view of curriculum is concerned with the formal or the official curriculum. The latter perspective focuses on what the learners actually experience in learning institutions (Graham-Jolly, 2002). However, the success of education is determined by the measure in which the gap between the two perspectives is closed.

Learners do not enter the science classroom as empty slates, but do have prior knowledge and misconceptions; therefore, teachers should become action researchers who are aware of the misconceptions they hold. It is also imperative that teachers should be aware of the socio-economic backgrounds of the learners and adjust their teaching styles to match the learning styles of the learners. At school level, principals together with the school management should encourage teachers to implement alternative instructional methodologies to accommodate the different learning preferences and multiple intelligences of the learners.

### 5.3.1 Implications for the curriculum

The aim of outcome-based education (OBE), which is streamlined into the Curriculum Assessment Policy Statements (CAPS), is to enable learners to acquire scientific and technological knowledge, skills and attitudes that would enhance scientific and technological literacy for learners to be able to participate effectively in society (Department of Basic Education, 2012). However, these aspirations seem to be difficult to achieve, because it is examination-driven and does not allow for the innovation and initiative of teachers (Stenhouse, 1988). The curriculum makes many promises, which is difficult to fulfil, because the socio-economic and contextual conditions of schools differ. In addition, it is burdensome for teachers to cover the prescribed sections of work in the required sequence and period according to the CAPS document. The content laden curriculum and the prescriptive nature of CAPS also pose challenges to teachers, assuming that all learners, teachers and schools are identical (Ball, 2000).

When embarking on the integration of DAI and CAPS, the in-service training needs to be planned and re-organised in a way compatible to the postulates of the curriculum. It is very important to teach science in such a way that learners will understand the conventional scientific view of the topic under discussion and to relate it to the everyday experiences, in order to create cognitive harmonisation (Ogunniyi, 2007a). In order to achieve this, strategies such as exposure to real life experiences, demonstrations, productive participation, group work, practical work and collaborative learning have proven to be useful (Angaama, 2012; Van Rooyen & De Beer, 2007). Paulo Freire (1987) asserts that education becomes relevant and emancipatory if the curriculum is stimulating and it sustains the consciousness in learners.

Curriculum evaluation is an integral part of any curriculum, because it establishes whether curriculum designs, curriculum development and curriculum implementation are producing what is intended to achieve (Ornstein & Hunkins, 1993). The dialogical argumentation instruction (DAI) methodology allows for evaluations of the learning activities at the end of each session, when the learners give feedback individually or as groups. These assessment activities should also be included into the formal assessment of the curriculum to ensure implementation of DAI.

### **5.3.2 Implications for research**

There is relative little research literature on curriculum content, based on Dialogical Argumentation Instruction (DAI) in a computer-assisted learning (CAL) environment in South Africa (De Vries, 2006). This study has shown how DAI could be implemented effectively in a high school classroom context. The study has to some extent shown how argumentation instruction can be implemented to achieve the essential competencies of a school curriculum in general. More research needs to be done for teacher development to guide learners to reach equipollent cognitive stages on the different worldviews to which learners are exposed to. Jegede (1995) calls it “collateral learning” and Ogunniyi (1998) terms it “harmonious dualism”, which explains how concepts like nature and human, predictable and unpredictable, physical and metaphysical, science and indigenous knowledge science (IKS) can co-exist in a mental state.

### **5.3.3 Implications for the classroom**

Learners need to understand that science is a way of constructing theories, which explain how the world may be (Erduran, 2004). They should become socialised into the discourse used and the practices of the scientific community (Newton, Driver, & Osborne, 1999). This can be achieved by introducing scientific ways of knowing and not just acquiring facts about the way the world is (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Furthermore, they should also understand it as a way of being able to evaluate claims in the light of new evidence and a way of comprehending that scientific theories are constructed explanations that help us to make sense of the world (Sandoval & Millwood, 2005). As these researchers suggest, this is only possible through incorporating argumentation in our teaching and learning practices in the classroom.

Christie (2008) posited in his teaching and learning model that, “The effective delivery of the curriculum in the classroom depends greatly on the available resources, a conducive environment and social interaction.” The Education Department encourages teachers to employ learning strategies that is learner-centred and involve maximum participation in the classroom. In addition, group work is an important part of any classroom activity; therefore, the teacher should act as a mediator in the class and facilitate the scaffolding process of learning, by helping learners to resolve the cognitive conflict that might arise during the learning process, by means of intra-, inter- and trans-dialogue (Ogunniyi, 2005). Teachers should also be aware of the socio-economic conditions of the learners in the classroom. Schools need to assess the existence of relative age effects in the classrooms and put in place strategies of assistance and support to disadvantaged relatively younger learners (Banks, 1994). School could also consider the feasibility of phasing the tome, type and nature of assessment according to relative age (Cobley, McKenne, Baker, & Wattie, 2009) in the school.

### **5.4 Recommendations**

The curriculum design and development models are not tailor-made to suit the different worldviews experience by learners; hence, it is necessary to contextualise the curriculum through appropriate pedagogical tools and innovations. Curriculum innovations usually

follows global trends, therefore there is a substantial body of research on the innovations related to argumentation and computer-assisted learning in education in first world countries. It is therefore recommended that the curriculum developers familiarise themselves with trends, debates and pertinent issues in argumentation and CAL. This study also indicates that without teacher training and development, teachers find it difficult to implement argumentation instruction and CAL. Eventually curriculum studies are about the relationship between intentions and practices (Kelly, 1989). Stenhouse (1988) reiterates that:

By focussing on one aspect of curriculum, it widens the gap between the intended curriculum and the experienced curriculum. As a result, isolating curriculum development from the context in which it is intended to operate brings about the mismatch between the plan and practice. As part of needs of developing curriculum the developers ought to do surveys of teachers' and learners' capabilities as well as schools support abilities. (p.34)

Dialogical argumentation instruction (DAI) training should be given to new and current teachers by means of pre-service training (PRESET) and in-service training (INSET) programmes to make the teachers conversant with the CAT and TAP frameworks. One of the main critiques of OBE was that teachers did not understand how to fulfil their roles as group facilitators correctly (Stenhouse, 1988). It is crucial that teachers should be trained in group work dynamics in order to optimise maximum participation in the classroom. This could also address the problem of plagiarism (cut-and-paste), which was started by the wrong implementation of OBE curriculum (Christie, 2008). The classroom environment has to be changed in such a way that it suits learner-centred teaching, increase learner-talk, considering multiple intelligences and computer-assisted learning.

The FET teachers (grade 10 to 12) who are usually specialists, should also be involved in the GET phase (grade 8 to 9) of the school in order to give guidance and assistance to the lay science teachers in the GET phase. In order to address the problem of transition, the curriculum should be improved so that it could become a progressive continuum from grade eight up to grade twelve. DAI elements should be built into the curriculum to enable learners to use the terminology and practice of CAT and TAP. In this way, learners' worldviews could

be harmonised and broadened and science concepts could become more relevant to their experiences.

## **5.5 Conclusion**

This study aimed at highlighting the importance of concepts of chemical equations in understanding the chemistry section of physical sciences. It showed how dialogical argumentation instruction was used to improve the conceptual understanding of learners in chemistry. On a global scale, South African education performs poorly in terms of mathematics and science (Department of Education, 2001). The fact that South Africa host mega technological projects such as the Southern Africa Largest Telescope (SALT) and Square Kilometre Array (SKA) radio telescopes makes it crucial to invest and promote science and technology education.

This study has shown that the argumentation methodology improved the conception of many learners, indicating that appropriate interventions can assist the curriculum. It is therefore important that education instructional methodologies be adapted to improve the performance of learners optimally. Although the study was limited by some factors mentioned in the chapter one, it is worthy to note that, many learners experience difficulty conceptualising chemistry concepts, which become obstacles if not remedied. Argumentation-based instruction must form an important part of science education, because it is a crucial element problem-solving strategies.

Though based on a small sample, this study also showed that gender, age and race are related to the achievement of learners. In a similar manner the socio-economic and socio-cultural background influences on learner's performance in the science classroom. Therefore, not all the learners in a classroom, especially in a multi-cultural setting, must be treated as if they are homogenous. Furthermore, research is necessary in order to determine the most effective ways of integrating DAI and CAL into the curriculum. Although the results of this study have largely corroborates the finding of a plethora of earlier studies, to the best of my knowledge, such studies have not been carried out before in the Western Cape.

The advent of outcome-based education (OBE) in the present South African education system has forced teachers to make learning more meaningful, instead of just imparting knowledge. Dialogical argumentation instruction (DAI) has the potential to revitalise science education and to become an essential part of science teaching. It also could help to identify problems associated in the implementation of computer-assisted learning (CAL) in schools as well as to suggest ways in which the misconceptions can be ameliorated. The findings of this study showed the effectiveness of DAI in teaching science concepts or concepts in any other learning area in general.

The new approach to outcome-based education (OBE) in terms of the Curriculum Assessment Policy Statements (CAPS) makes it imperative that teachers should rethink and improve their instructional methodology to be relevant to the objectives of CAPS. Therefore, dialogical argumentation instruction (DAI) and computer-assisted learning (CAL) would be appropriate tools to achieve this goal, especially in terms of the crucial role that technology plays currently in education and the need for teachers to be abreast with the constant curriculum changes. The enquiry-based nature of science education necessitates argumentation in the classroom, because it requires learners to formulate hypotheses and draw conclusions. It also assists learners to become more critical and expose them to alternative worldviews in order to construct their own knowledge.

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## APPENDICES

### APPENDIX A: ICT Questionnaire

Information Communication Technology (ICT) resources

CODE : .....

**Do not write the school's name on this questionnaire!!!**

#### SECTION A – GRADE 11 PHYSICAL SCIENCES

**Complete the table below by making a tick in the appropriate block.**

<b>Number of grade 11 learners</b>	Less than 20	21 - 50	51 – 75	76 - 100	More than 100
<b>Number of grade 11 classes</b>	1	2	3	4	.....
<b>Number of grade 11 teachers</b>	1	2	3	4	.....

**SECTION B – ICT RESOURCES**

Tick  the appropriate box:

1.1 Which of the following Information Communication Technology (ICT) resources are in **ALL** the science classes / laboratories and how much?

	RESOURCE	QUANTITY			
		0	1 – 5	6 – 10	More than 10
1	Overhead Projector (OHP)				
2	Computer				
3	Data Projector				
4	Interactive White Board				
5	Television				
6	VCR / CD player				
7	Cellular Phones				
8	Other: .....				

1.2 Does the science class have internet connectivity?

Always	Some times	NO
--------	------------	----

## SECTION C – USE OF ICT RESOURCES

2.1 Which and how much of the following resources are used by the teacher(s) during their lesson presentations?

	RESOURCE	PERCENTAGE USE			
		0 - 10%	11 – 25%	26 - 50%	51 - 100%
1	Overhead Projector (OHP)				
2	Computer				
3	Data Projector				
4	Interactive White Board				
5	Television				
6	VCR / CD player				
7	Cellular Phones				
8	Other: .....				

2.3 Which of the following software applications is used in the science class room?

	SOFTWARE APPLICATION	PERCENTAGE USE			
		0 – 10%	11- 25%	26 - 50%	51 - 100%
1	Word processor				
2	Slide show				
3	Spread sheet				
4	CD-ROMs				
5	Inter- / Intranet				
6	Other: .....				

2.4 In your opinion, does the use of ICT resources in the learning and teaching activities improve the learners' conceptualisation of the science concepts?

YES	MAY BE	NO
-----	--------	----

## **SECTION D – INTERVIEW OF SCIENCE TEACHER**

- 3.1 Do you make maximum use of the ICT resources available to the teaching of science at your school?
- 3.2 If not, why are the ICT resources not used maximally in the science lessons?
- 3.3 Give examples how you are making use of ICT resources effectively in the science lessons.
- 3.4 In your opinion, did the use of ICT resources contribute positively to the performance of your learners?
- 3.5 What do you think could be done to assist the use of ICT in the science classroom?



**APPENDIX B: CLASS ROOM OBSERVATION SCHEDULE**

**A) Learning environment -**

Code.....

Grade 11 A B C D E

Class room environment: .....

.....

.....

.....

.....

No. of learners present during lesson: .....



Teaching Materials (resources): .....

.....

.....



**B) The lesson -**

Introduction of lesson: .....

.....

.....

Activities during lesson: .....

.....

.....



UNIVERSITY *of the*  
WESTERN CAPE

Conclusion of lesson: .....

.....

.....

## APPENDIX C: LEARNERS' QUESTIONNAIRE

CODE: .....

Grade 11 A B C D E F

THE LESSONS:

1. Did you understand the work that was covered in the last three sessions?

Yes

Uncertain

No

2. Which aspect of the sessions did you find most helpful?

Teacher explaining

Group discussion

Working with computer

Class discussion

Working on your own



UNIVERSITY of the  
WESTERN CAPE

3. Explain your answer to question 2 above.

.....

.....

.....

4. Do your other subject teachers also use the same teaching method?

Yes

No

5. Do you think that working in groups and with the computer was helping you to understand the work better? Explain.

.....

.....

.....

.....



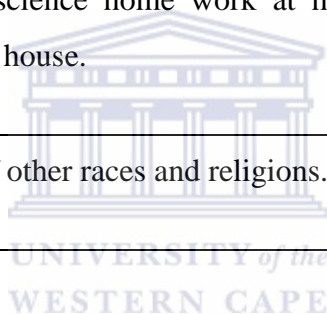
## APPENDIX D: ATTITUDE TOWARDS SCIENCE

Please read each statement carefully and indicate your level of agreement/disagreement, by making a cross in the block:

**STRONGLY ARGEE (SA), ARGEE (A), UNCERTAIN (U), DISAGREE (D), STRONGLY DISARGEE (SD).**

STATEMENT	ARGEEMENT/DIAGREEMENT				
1) I want to be a scientist one day.	SA	A	U	D	SD
2) By arguing different viewpoint with my fellow learners, I understand the science concepts better.	SA	A	U	D	SD
3) I learn things in the science classroom that explain everyday life.	SA	A	U	D	SD
4) My parents help me with my science home work.	SA	A	U	D	SD
5) My science teacher encourages me to learn more science.	SA	A	U	D	SD
6) I consider myself as a good science learner.	SA	A	U	D	SD
7) I like to watch TV programmes, read books and magazines about science.	SA	A	U	D	SD
8) I understand science better when it is explained with computer simulations/animations.	SA	A	U	D	SD

9) I know how to work with a computer.	SA	A	U	D	SD
10) I understand work better when it is explained by my teacher.	SA	A	U	D	SD
11) I feel more comfortable explaining my understanding of the work to a fellow learner.	SA	A	U	D	SD
12) Girls ask more questions than boys in the class.	SA	A	U	D	SD
13) If I had more resources I would perform better in science.	SA	A	U	D	SD
14) I do not have time to do science home work at home because I am too busy working at house.	SA	A	U	D	SD
15) I like to work with learners of other races and religions.	SA	A	U	D	SD



## APPENDIX E: Pilot study's Chemistry Achievement Test

### ACIDS & BASES

#### ACTIVITY 1 – WHAT IS ACIDS AND BASES?

You have samples of the following substances that are used at home, in the test tubes on your table. Make a claim by stating whether the substances are acids, bases or neutral and provide a reason (backing) in each case. Write the **LETTER** of the substance in the correct column in the table on **worksheet 1**:

A



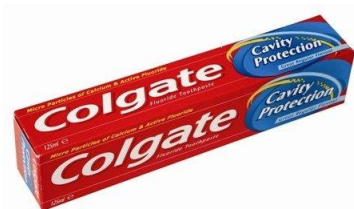
B



C



D



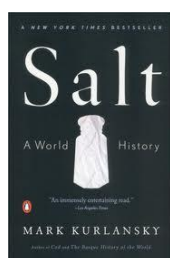
E



F



G



H



I



J



## ACTIVITY 2 - MAKING A Red Cabbage Juice pH-INDICATOR

Indicators show whether a substance is an acid, a base or neutral. The acidity (alkalinity) of a substance is indicated by means of a pH-scale.

← pH-value →														
ACIDS						NEUTRAL	BASES/ALKALI							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Acids and bases have the property of modifying the colour of certain substances. This is the case with the juice of the red cabbage. This liquid has a blue-violet colour, but when it comes in contact with acidic substances it becomes red, while in contact with basic substances it becomes green and even yellow.

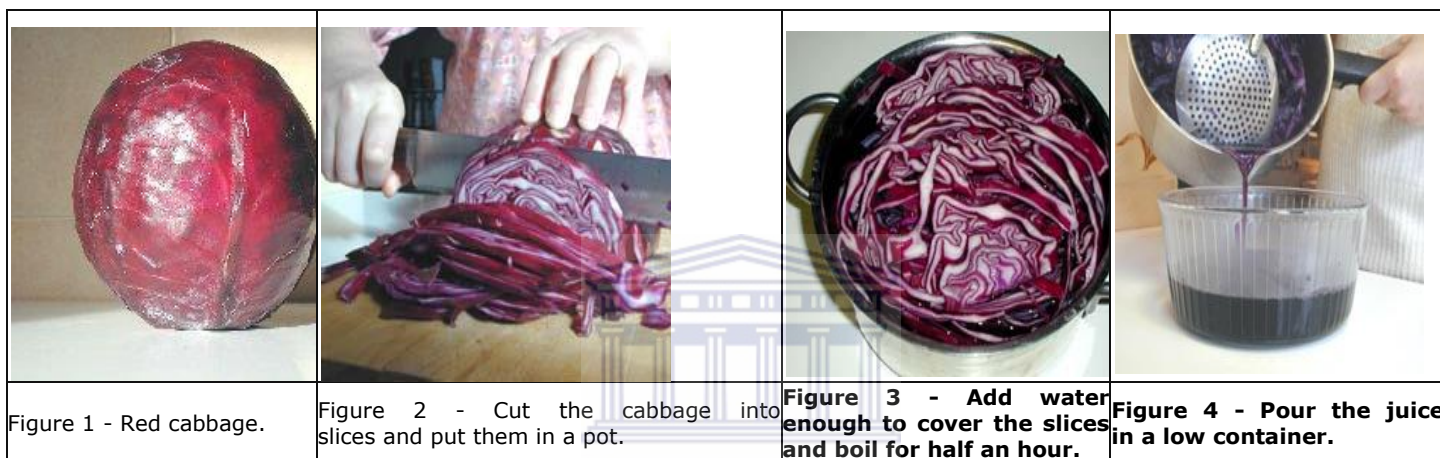


Figure 1 - Red cabbage.

Figure 2 - Cut the cabbage into slices and put them in a pot.

Figure 3 - Add water enough to cover the slices and boil for half an hour.

Figure 4 - Pour the juice in a low container.

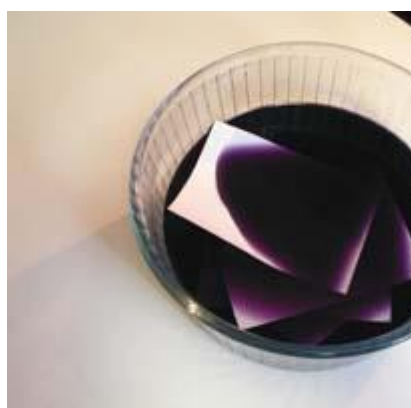


Figure 5 - Soaking cards with red cabbage juice.

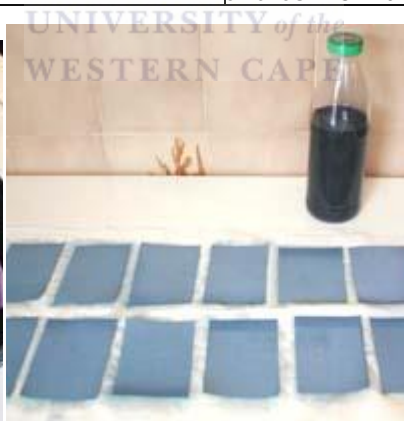


Figure 6 - Drying the cards.

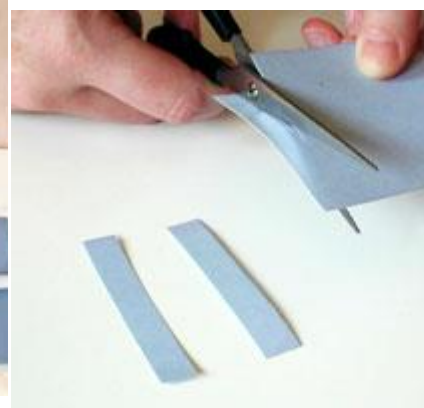


Figure 7 - Cutting the strips.

### Testing the household substances:

Put the indicator strips in the test tubes of hydrochloric acid (HCl) and sodium hydroxide (NaOH), to determine the colour change for a strong acid and strong base. What colour changes do you observe? Put now an indicator strip in each test tube and test your claims you made in activity 1. Complete worksheet 1.

## INDIVIDUAL WORK SHEET 1


### ACTIVITY 1

Note!

A claim - is the statement or belief about the option you think is valid/correct


Backing - are evidence supporting your claim/opinion.

Rebuttals - are statements that show the claim/option is invalid/incorrect.

<b>CLAIMS</b>	<b>REASON (BACKINGS)</b>	<b>CONFIRM/ REFUTE (REBUTTAL)</b>
A	 <p>The logo of the University of the Western Cape, featuring a classical building with columns and a pediment, with the text 'UNIVERSITY of the WESTERN CAPE' below it.</p>	
B		
C		
D		
E		
F		
G		
H		
I		
J		



## GROUP DISCUSSION (CONSENSUS) - WORK SHEET 2

CLAIMS	REASON (BACKINGS)	CONFIRM/ REFUTE (REBUTTAL)
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		

## APPENDIX F: Samples of activity worksheets

### Honeybee Stings

Read the following case study and answer the questions that follows, firstly individually and then in your group.

Two 10 year old friends, James and Christiaan, are walking in the orange orchard of a farm. As they play and run chasing each other, they suddenly stumble across a bee-hive in one the orange trees. On closer inspection it appears as if the hive is inactive. At school their teacher told them that bees produce honey inside their hives; Christiaan being curious decides to explore the hive further and takes a stick and pushes it into the mouth of the hive. James cautions him, saying that he is not sure if the hive is empty, but Christiaan proceeds to push the stick further into the hive.

They both suddenly freeze, as they hear the approaching buzz of bees behind them. As they turn, they see an approaching swarm, directly bearing down towards them.

The bees surround them..... They wave frantically, turn and flee, but not in time as each one of them is stung, Christiaan once on his leg and twice on his arm and James twice on his arm.

They both cringe from the severe stinging and burning sensations on their limbs and head straight home, both trying to keep the tears from flowing, each one telling the other "its okay, it doesn't hurt much", while cringing inside.

As they reach the Christiaan's house, the first along the way, he rushes to his mom and says "Mom, we have been stung by bees!!!" and then unable to keep back the tears, starts sobbing uncontrollably; James on queue also starts sobbing.....

Christiaan's mom, Sylvia, takes one look at the affected areas of both of them and proceeds straight to her kitchen cupboard and returns with her spice rack. She carefully uses a blunt knife and scrapes the stinger and its sac at an angle of 45° off the affected area, and then takes out the packet of bicarbonate of soda, wets it slightly and applies it to the open scraped wounds of both. Their pain seems to subside .....

Then she shares with them the following remedy that she learnt from her mother, and which her grandmother passed to her .....

***"Whenever you are stung by a honey bee or wasp, you must firstly scrape the stinger and the poison sac away from the wounds; do not pull it out, because as you pull, you will squeeze more of the poison inside the poison sac into the wound.***

***If stung by a bee, then apply ordinary Bicarbonate of Soda to the wound. However, if you are stung by a wasp, then you should apply Vinegar to the wound. Both my mother, grandmother and great-grandmother swore by it!!! Don't ever forget this lesson boys!!!"*** as she walks away smiling.....

## Individual Task – Do not talk to anyone, answer the questions on your own!

### Question 1. (5mins)

The venom of a bee is known as methanoic acid ( $\text{CO}_2\text{H}_2$ ) and Bicarbonate of Soda is magnesium carbonate ( $\text{Mg}(\text{CO}_3)_2$ ).

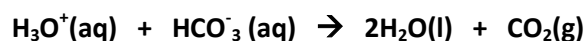
1.1 Will Christiaan's mom remedy help? Give a reason/explanation for your answer.

Claim: .....

Backing(s): .....

.....

The net chemical reaction that takes place can be represented by the following equation:



1.2 Which substance in the equation represents the following and provide an explanation for your answers:

a. **Venom of the bee** - Claim: .....

Backing: .....

b. **Bicarbonate of Soda** – Claim: .....

Backing: .....

c. **Water** – Claim: .....

Backing: .....

d. **Carbon dioxide** - Claim: .....

Backing: .....

### Question 2. (5mins)

Vinegar is also known as acetic acid ( $\text{CH}_3\text{COOH}$ ) and wasp venom is known as

Christiaan's mom suggests that they have to apply Vinegar to sting of a wasp. Give a possible explanation to account for this. Mention any counter-explanations to this remedy.

Claim: .....

Backing(s): .....

**Group Task** - In each of your groups, **reconcile your individual answers** with the members in each group and generate a final group answer(s), which will be presented to the rest of the class, during the report back session. (10 min)

**Question 1. (5mins)**

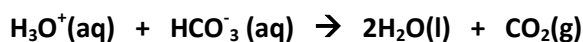
The venom of a bee is known as methanoic acid (CO<sub>2</sub>H<sub>2</sub>) and Bicarbonate of Soda is magnesium carbonate (Mg(CO<sub>3</sub>)<sub>2</sub>) .

1.1 Will Christiaan’s mom remedy help? Give a reason/explanation for your answer.

Claim: .....

Backing(s): .....

The net chemical reaction that takes place can be represented by the following equation:



1.2 Which substance in the equation represents the following and provide an explanation for your answers:

a. **Venom of the bee** - Claim: .....

Backing: .....

b. **Bicarbonate of Soda** – Claim: .....

Backing: .....

c. **Water** – Claim: .....

Backing: .....

d. **Carbon dioxide** - Claim: .....

Backing: .....

**Question 2. (5mins)**

Vinegar is also known as acetic acid (CH<sub>3</sub>COOH) and wasp venom is known as Christiaan’s mom suggests that they have to apply Vinegar to sting of a wasp. Give a possible explanation to account for this. Mention any counter-explanations to this remedy.

Claim(s): .....

Backing(s): .....

Rebuttal(s): .....

## APPENDIX G: Chemistry Achievement Test – Chemical equations

### Pre-test & Post-test

Class: 10 A B C D E F

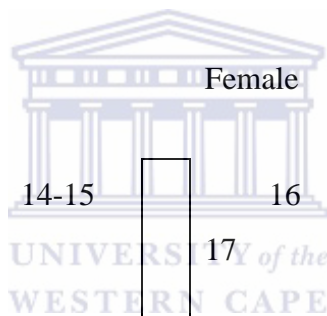
Code (initials): .....

**Please complete the following sections below. Do not write your name on the page. Be honest in your answers and note that the information you provide will be kept confidential.**

### SECTION 1 – GENERAL (BIOGRAPHICS)

Please make a tick (✓) in the appropriate box:

**Sex:**



**Age:**

Younger than  
13

14-15

16

17

Male

Older than

**Race:**

Coloured

Black

Muslim

Other:



*In your opinion, what is the total income of your parents?*

<R5  
000

R5 001 – R10  
000

R10 001 – R20  
000

>R20  
000

*Which of the following resources do you have at home?*

DStv

Radio

Internet

Computer

Do you stay in the following residence?

Flat	<input type="text"/>	2 Bed room house	<input type="text"/>	3 Bed room house	<input type="text"/>	>3 Bed room house	<input type="text"/>
------	----------------------	------------------	----------------------	------------------	----------------------	-------------------	----------------------

How big is your family that you are staying with?

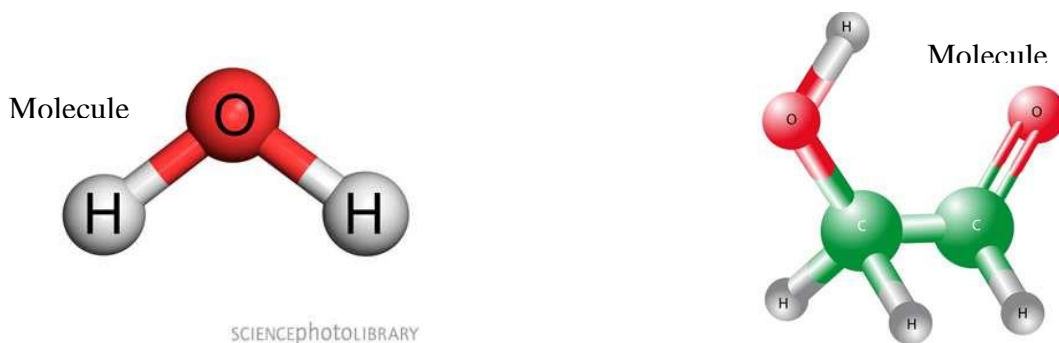
Only parent	1	<input type="text"/>	Both parents	<input type="text"/>	Guardian	<input type="text"/>	<3 siblings	<input type="text"/>	>3 siblings	<input type="text"/>
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## SECTION 2 – CHEMISTRY ACHIEVEMENT TEST

### PART 1: Question 1- Atomic size and molecular geometry

1.1. Study the following two stick-and-ball models of chemical compounds, molecule A and molecule B, and answer the questions that follow:



a) Write down the following information of molecule A:

Name: ..... Chemical symbol: .....

Are the sizes of the atoms in molecule A correctly represented? Give a reason for your answer.

.....  
.....

b) The following questions refer to molecule B:

i) How many atoms are found in molecule B? .....

ii) Write down the chemical names of the following elements:

H: .....

C: .....

O: .....

iii) Which atom has a valency of:

+4: .....

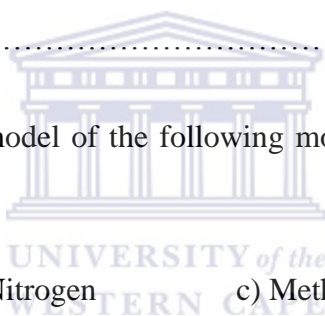
-2: .....

c) What type of chemical bonding do we find in the molecules? Give a reason for your answer.

.....  
.....  
.....

1.2 Draw the ball-and-stick model of the following molecules, indicating the bonds and molecular shape:

a) Water                      b) Nitrogen                      c) Methane                      d) Ammonia

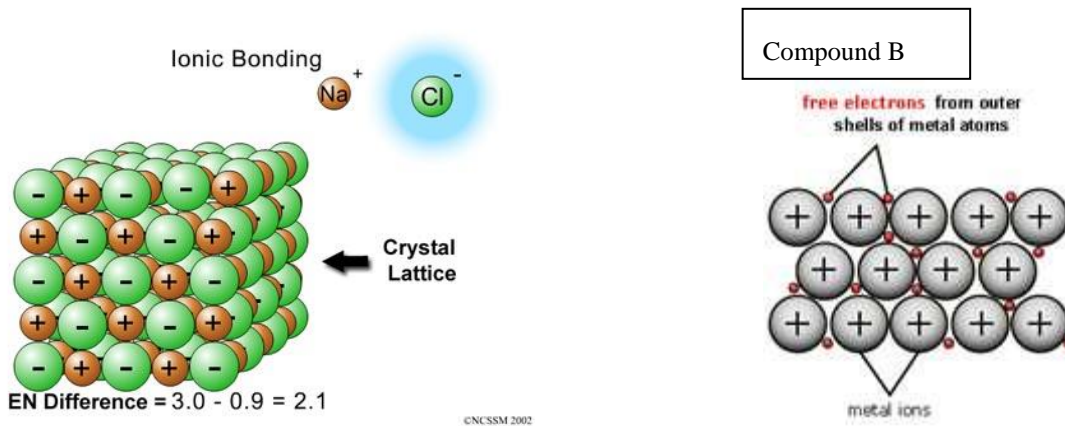


## PART 2: Question 2 – Chemical bonding

2.1. Ancient people preserved meat and fish by coating them heavily with salt. Salt is still nowadays use in the preparation of biltong and bikkoms which are South African well-known delicacies. Today we make use of refrigerators to keep food fresh longer. Study the following compounds:

Compound A





a) Explain the chemical bonding process of compound A:

.....

.....

.....

.....

.....

.....



b) Chemical name of compound A:

.....

c) Common household name of compound A:

.....

d) Dylan forgot to take the metal teaspoon out of his hot tea, after he stirred in sugar. When he removed the spoon a few seconds later the teaspoon's handle

was also hot. Explain why the teaspoon's handle also became hot, by referring to compound B.

.....

.....

.....

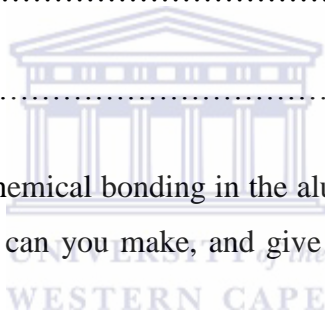
.....

- e) What type of chemical bonding takes place in the following compounds? Give a reason for your answer.

Compound A: .....

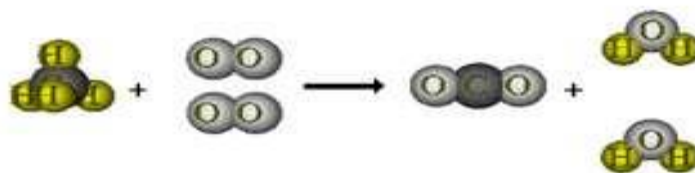
Compound B: .....

- f) Explain how the chemical bonding in the aluminium chloride compound takes place. What claim can you make, and give backings and warrants to support your claims?



**PART 3: Question 3, 4 & 5 – Models of chemical reactions**

- 3.1. The following equation represents the combustion of methane. Methane is a colourless gas without a smell, which is used as a fuel.



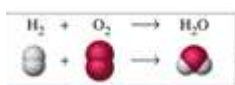
Write down the following equations of the reaction:

a) Balanced chemical equation:

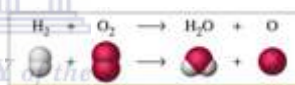
.....  
 .....

4. Only one set of the following chemical equations represents the formation of the water molecule correctly. Explain, in each case, why the other sets equations are not correct.

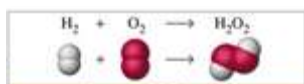
Equation A



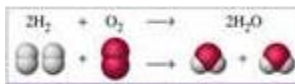
Equation B



Equation C



Equation D



Equation-A: .....

Equation-B: .....

Equation C: .....

Equation D: .....

5.1. The following particle model equation represents a chemical reaction involving carbon and oxygen atoms.

Write down the following equations of the reaction:



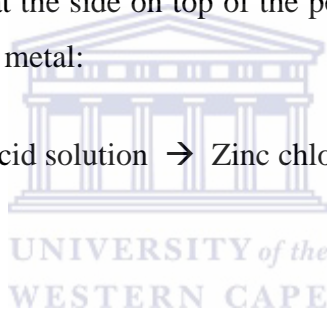
a) Balanced chemical equation:

.....

5.2. Balance the following equations and show in each case ALL the steps (calculations) you make use of. Show the phases of the substances:

a) Thandi throws some swimming pool acid granules in the swimming pool. Some of the acid falls on the wet zinc metal strip at the side on top of the pool. She observes a liquid and gas bubbles are formed on the of zinc metal:

(Zinc powder + Hydrochloric acid solution → Zinc chloride solution + Hydrogen gas)



b) Exhaust gas of cars:

Nitrogen gas + Oxygen gas → Nitrogen dioxide gas

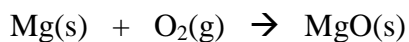
c) Sea shells dissolving:

$\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$

d) Iron filings are thrown into a fire:

$\text{Fe}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{Fe}_3\text{O}_2(\text{s})$

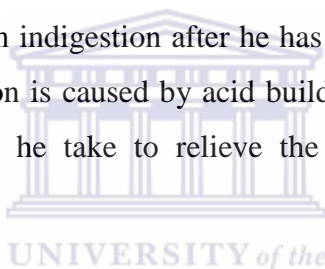
e) Lighting a starlight (fireworks):



f) Barium chloride solution is added to a solution of sulphuric acid. A precipitate of barium sulphate forms in a solution of hydrogen chloride.

Write a balanced equation for the reaction:

g) Thabo always suffers from indigestion after he has had a very spicy meal and lots of Coke Cola. The indigestion is caused by acid build-up in the stomach. Which of the following substances can he take to relieve the terrible feeling in his stomach? Motivate your answer.



***Milk of Magnesia [Mg(OH)<sub>2</sub>]; Rennie tablets (HCl); Water (H<sub>2</sub>O); Table salt (NaCl)***

Write down a balanced equation for the reaction that takes place in his stomach:

h) John wants to restart a fire that went out by blowing with his breath on the red-hot coals. Will the fire catch flames, explain your answer.

## APPENDIX H: UWC ethical clearance

**OFFICE OF THE DEAN  
DEPARTMENT OF RESEARCH  
DEVELOPMENT**

Private Bag X17, Bellville 7535  
South Africa  
Telegraph: UNIBELL  
Telephone: +27 21 959-2948/2949  
Fax: +27 21 959-3170  
Website: www.uwc.ac.za

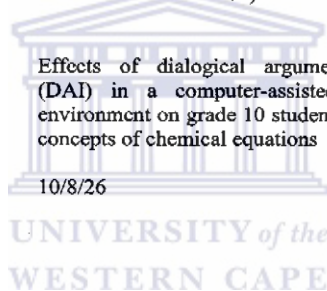
08 August 2011

**To Whom It May Concern**

I hereby certify that the Senate Research Committee of the University of the Western Cape has approved the methodology and ethics of the following research project by:  
Mr F George (School of Science and Mathematics Education)

Research Project: Effects of dialogical argumentation instruction (DAI) in a computer-assisted learning (CAL) environment on grade 10 students' understanding of concepts of chemical equations

Registration no: 10/8/26



*Ms Patricia Josias  
Research Ethics Committee Officer  
University of the Western Cape*



**UNIVERSITY of the  
WESTERN CAPE**

A place of quality, a place to grow, from hope to action through knowledge

## APPENDIX I: WCED permission RESEARCH



WESTERN CAPE  
Education Department

Provincial Government of the Western Cape

[awyngaar@pgwc.gov.za](mailto:awyngaar@pgwc.gov.za)

tel: +27 021 476 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

[wced.wcape.gov.za](http://wced.wcape.gov.za)

**REFERENCE:** 20110818-0042

**ENQUIRIES:** Dr A T Wyngaard

Mr Frikkie George

17 Begonia Street

University of the Western Cape



**Dear Mr Frikkie George**

**RESEARCH PROPOSAL: EFFECTS OF DIALOGICAL ARGUMENTATION INSTRUCTION (DAI) IN A COMPUTER-ASSISTED LEARNING (CAL) ENVIRONMENT ON GRADE 10 LEARNERS UNDERSTANDING OF CONCEPTS OF CHEMICAL EQUATIONS**

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, teachers and learners are under no obligation to assist you in your investigation.

2. Principals, teachers, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Teachers' programmes are not to be interrupted.
5. The Study is to be conducted from **22 August 2011 till 30 September 2011**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number.
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Research Services

Western Cape Education Department  
Private Bag X9114  
CAPE TOWN  
8000

We wish you success in your research.

Kind regards.

Signed: Audrey T Wyngaard

for: **HEAD: EDUCATION**

**DATE: 18 August 2011**



## APPENDIX J: Application letter

17 Begonia Street  
University of the Western Cape  
Cell. 079 228 0560  
[frik.george@yahoo.com](mailto:frik.george@yahoo.com)

02 August 2011

Dr. AT Wyngaard  
Western Cape Education Department (WCED)  
Private Bag x9114  
Cape Town  
8000  
Tel. 021 476 9272  
Fax. 086 590 2282  
[awynjaar@pgwc.gov.za](mailto:awynjaar@pgwc.gov.za)

### An application to conduct research in the WCED

I am a M.ED student at the University of the Western Cape (UWC) and wish to request your permission to conduct my research in the WCED. The topic of my research is: **"Effects of Dialogical Argumentation Instruction (DAI) in a Computer-Assisted Learning (CAL) environment on grade 11 learners' understanding of concepts of chemical reactions."**

DAI is an enquiry based teaching strategy developed at the School of Mathematics and Science education at UWC to promote critical thinking in learners as they study in small groups, make claims and support them with evidence, while others make counter-claims. Learners will also use computer generated simulations to assist them in understanding selected concepts of chemical reactions. The use of computers besides the usual science equipment adds a context with which many learners are familiar. It is hope that this study will be of much benefit to learners of physical sciences.

The identity of the institution will not be disclosed and the learners' rights, anonymity and dignity will be respected. The outcome of this research project will also be communicated to the WCED for the purpose of information.

The following schools will be involved in the research project:

- Kasselsvlei Comprehensive High School
- Bellville South High School

Please find attached the following documents:

- My research proposal, which has been approved by the UWC
- Copies of the research instruments
- Ethical clearance by UWC

Thank you in advance.

Yours faithfully,

.....  
F George

.....  
Supervisor: Prof. M Ogunniyi