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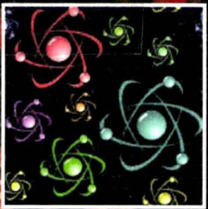
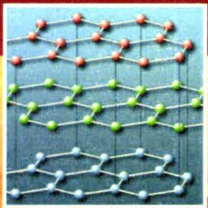
Misconceptions in Chemistry:

A Comparative Study of Samoa and New Zealand High Schools to Identify their different Origins and Approaches to Eliminate and Correct them

FAGUELE SUAALII





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A Thesis presented in partial fulfilment of the
requirements for the degree of Masters of Education at Massey University,
Palmerston North, New Zealand.

FAGUELE SUAALII
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ABSTRACT

The report describes a comparative study of students' misconceptions. It does so by investigating year 13 students' conceptual understanding of the structure bonding and related properties of diamond and graphite. The aims of the case study are to elicit, identify, and compare the different origins and develop appropriate strategies to promote correct conceptual understanding of chemistry concepts.

The study involved sixty students, and three chemistry teachers from two different schools; one from Palmerston North, New Zealand and the other from Apia, Samoa. Open-ended question strategy was used to elicit the students' misconceptions, followed by interview and classroom observations of a sample of students. Analyses of the responses to the open question, interviews, students' artifacts and classroom observations, revealed the origins of the students' misconceptions about the structure, bonding and related properties of diamond and graphite.

CANDIDATE'S STATEMENT

I certify that this report entitled 'Misconceptions in Chemistry: A Comparative study of Samoa and New Zealand High Schools to Identify their Different Origins and Approaches to Eliminate and Correct Them', submitted as part of the degree of Master of Education is the result of my own work, except where otherwise acknowledged, and that this report or part has not been submitted for any other papers or degrees for which credit or qualifications have been granted.

Signature: ....

Name: Faguele Suaalii

Date: ....

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Thank you so much to my church Ministers Rev. Faavevela Gafo and Rev. Siimamao Siimamao, for your continuous prayers. To my Mother, Tagatavale Suaalii Tavita in Samoa, family and friends in New Zealand, Singapore and elsewhere, I have appreciated your continued approval and warmth in faithful prayers.

Lastly, is my special gratitude and tears to my wife Peace (Lailing) Suaalii Tavita, for her support, patience, and love in looking after our two children, Davina (4-years) and Grace-Zoreen (2-years), while I was occupied in this research investigation.

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Foreword by: Professor Sitaleki A. Finau

This is the third of the Master's Thesis Series. The Thesis topics have varied but remained relevant to Pasifika Development.

This timely thesis is more than about graphite and diamonds. It addresses a current concern over science teaching and learning of students, especially Pasifikans .

There are programmes' e.g., the Healthcare Heroes Programme at the Pasifika Medical Association,[1] to address the under representation of Pasifikans in science classes after year 9. There are also similar moves to increase Pasifikans in engineering and other science based programmes

For Pasifikan to march out from the margins of Aotearoa, they need not only to become Aotearoans but must contribute to the knowledge–based economy of the country. Science is essential to this transition and economic transformation.

Pasifikans must enter science early in life and stay for the entirely of their lives to make a difference. We must ensure their pastoral care and academics support for the Pasifikans' Science efforts to be sustainable and fruitful.

A community development approach[2] to Science teaching and learning is essential to address systemic barriers to Pasifikans' participation e.g. channelling of Pasifikans from the Science streams at Year 9 of High School. The development of a science culture among Pasifikans and addressing of the non-academic contributing factors to Science success and failure, are a few fundamental avenues begging for solution.

We must move Chemistry and Physical Science into the Pasifika households and remove the misconceptions in the class room as has been suggested for Mathmatics[4]. Sciences need to seek out Pasifikans and no vice versa.

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Chapter 1 – INTRODUCTION

1.1 Introduction

This chapter gives the hypothesis underpinning the study and an overview of the project. The background and the rationale for the study are described. The research aims and objectives, limitations and delimitations of the study are identified and discussed.

1.2 Hypothesis of the study

The study was designed to determine the extent to which students' misconceptions affect their conceptual understanding of the structure, bonding and related properties of diamond and graphite.

1.3 Overview

The report is presented in seven chapters. **Chapter one** gives the hypothesis and an overview of this study. It provides the background for the study with clear justifications for conducting this investigation. Key research aims and questions are identified for the present investigation. Limitations and delimitations of this study have been included in this chapter.

Chapter two reviews the literature as the framework for this study. The research methodology and the objectives of the study are described in **Chapter three**, as well as a brief discussion of the ethical considerations of the participants. **Chapter four** explores and compares the two research sites. This includes a detailed explanation of the resources available, the classroom pedagogical practice and teachers' teaching backgrounds. Explanations of the methods of data collection and data analyses are also described in this chapter.

In **Chapter five**, the results of the open-ended questions, interviews and classroom observations are organised according to the investigation. That is, the open-ended question was conducted in Phase I, then the interview and observations in Phase II. **Chapter six** discusses the development of a model that aims at improving the teaching and learning of high school chemistry. Appropriate teaching and learning strategies for replacing students' misconceptions are discussed in the light of the findings of the current study and the literature.

Chapter seven draws together the preceding chapters, describes the major findings, and states the main conclusions of the study. Recommendations for classroom teaching and learning and suggestions for further research are described.

1.4 Background to the study

1.4.1 Students' views about chemistry

Chemistry is the study of matter and its properties and how substances can be used in ways that are beneficial to human lives (Salter, 2006). Many chemistry concepts, however, are abstract, (Johnstones 2000), e.g. structure, bonding and related properties of substances, often not intuitive or not able to be easily understood by students. Studies outlined in publications by Beaty, (1996); Johnstone, (2000); and Ministry of Education, Sports and Culture, (2004b), discuss the complex and abstract nature of chemistry, and its very specialised vocabulary making the subject difficult to understand (Chang, 2007). However, 'the complexity and abstract nature of chemistry is not the only barrier to understanding chemistry concepts. Chemistry is made much more difficult by the presence of numerous misleading misconceptions' (Beaty, 1996; p. 5). Therefore as chemistry teachers, we need to identify those factors so that we can promote conceptual understanding of chemistry concepts.

Many Samoan students appear to develop erroneous conceptions (i.e., atoms of sulfur are yellow), which are considered to be conceptions that deviate from those accepted by the scientific community, are present. It appears that the presence of learning difficulties influence students selection of courses offered at years 12 and 13, and to a build-up of chemistry misconceptions.

Students' difficulties in chemistry have been characterised in various ways, for example, as alternative frameworks (Driver & Easley, 1978) intuitive beliefs (McCloskey, 1983), preconceptions (Anderson & Smith, 1983) and, as misconceptions (Johnstone, 2000) used in this study. Once a chemical misconception is integrated into a student's cognitive structure, it can interfere with or impede further learning of more difficult chemical concepts. Treagust, Chittleborough and Mamiala (2003), claimed that students' misconceptions affect instruction and students' future learning in unpredicted ways.

1.4.2 The current situation

Structure, bonding and related properties are content areas in years 11 and 12 in New Zealand (Ministry of Education, 1994) and year 12 of the same age in Samoa (Western Samoa Department of Education, 1998). Deeper explorations of these concepts, including intramolecular bonding and intermolecular attractive forces are introduced in the final year (year 13) in high schools, by way of investigation and explanations of specific substances and chemical processes, their interaction with people and the environment and direct instruction (Ministry of Education, 1994; 28). Similarly, the comparisons of the strength of intramolecular bonding in extended covalent networks and intermolecular attractive forces in ionic substances are examined (South Pacific Board for Educational Assessment, 1999; p. 6) in year 13.

Table 1.1: Organisation of classes and age of students

Year/Class Level in New Zealand & Samoa high School	Age (years)
11	15-16
12	16-17
13	17-18

Some teachers find that constructing conceptual understanding of the structure, bonding and properties of substances is difficult for students within these age groups, and there is a need to revisit the concepts of periodic table, atoms, molecules and integration of associated concepts like bonding, attractive forces and atomic structure. In general, it appears that the process takes more than one lesson, as students try to integrate prior knowledge with new learning and to avoid potential recurring misconceptions along the path to sense making.

a. Possible reduction in the number of students in high school chemistry

The "structure, bonding and properties are fundamental concepts" (Nicoll, 2003, p. 208) embedded in both the New Zealand and Samoa high school chemistry curriculum. Indeed, these concepts are often revisited in each successive year (11, 12, & 13) of study. This is because the concepts are central to so much of chemistry, from the particulate nature of matter in physical chemistry (years 10, 11 & 12) (Ministry of Education, 1994) to reactivity in both organic and inorganic chemistry (years 12 & 13) (Ministry of Education, 1994) to spectroscopy in analytical chemistry (university) (Nicoll, 2003). Unfortunately, the persistent development of misconceptions in chemistry has caused a considerable debate on the successful development of chemistry in Samoa (Tuioti, 2005). Attempts such as the development of students' booklets, students & teachers learning guides, to promote chemistry education in Samoa have been implemented with the assistance of overseas development projects.

b. Effect on students enrolling in university chemistry courses

Students' learning difficulties of the structure, bonding and properties of substances may prevent them from continuing to learn chemistry at successive levels. In general, this appears to be one of the factors which cause a decrease in the number of chemistry students at the Faculty of Education (FOE) or Faculty of Science (FOS) at the National University of Samoa. With the increasing number of children enrolling in high schools and the constant growth in the number of schools offering year 12 and 13 (Tuioti, 2005), however, there are only a few chemistry teachers within the country, which represents a major concern. In 2002, New Zealand had the highest levels of vacancies for teachers in secondary schools recorded in science subjects (13%), including chemistry (Ministry of Education, 2002).

In the late 1990s, the Samoan Ministry of Education Sports and Culture called for an early reform due to the reduction of students in science courses, biology, chemistry and physics. Scholarships[1] were offered to science teachers in 1998, to undertake courses at the National University of Samoa to improve conceptual understanding of science disciplines, particularly chemistry. This was to enhance effective and meaningful teaching and learning of science disciplines, specifically in chemistry and physics. Despite these early adjustments to the education process, there was no improvement, but increased dropout according to the science organiser in the Samoan Ministry of Education Sports and Culture, and an increasing failure rate from these courses.

c. Students become selective

With the implementation of the Pacific Senior School Certificate (PSSC) in Samoa and the National Certificate for Educational Achievement (NCEA) in New Zealand high schools, students have a wider choice of subjects to choose from. This motivates students with difficulties in chemistry to choose other subjects, which are more challenging, interesting, relevant, and practical (Hipkins, Vaughan, Beals & Ferral, 2004). Even if students continue to study chemistry without having a conceptual understanding of the subject they would not be able to succeed under the assessment systems of both the PSSC and NCEA. Hence, there is an immediate need to find out what makes chemistry learning difficult for many year 13 students and what kinds of teaching and learning approaches that provide effective conceptual understanding in chemistry.

1.5 Rationale of the study

Having spent a number of years teaching high school chemistry in Samoa, I realised that many students find learning year 13 chemistry problematic and struggle with applying chemical principles to everyday situations. Some students fail to recognise any relationship between the chemistry taught in class and their

[1]Teachers study for free for two years and receive normal annual salary.

surroundings and therefore do not perceive any value or relevance in studying chemistry, other than to pass exams. This is often accompanied by negative attitudes towards chemistry. Some teachers find that students' attitudes to chemistry are often aligned with their communities' thinking that there are limited job opportunities in chemistry as opposed to business careers.

A literature review shows that there has been a real concern about the conceptual understanding of chemistry in secondary school students (Johnstone, 2000; Taber & Coll, 2002). The findings from these researchers showed that more authentic and meaningful learning takes place when the learning is contextual and made more relevant to students' own life (Bhattacharya, 2004). The study of Bhattacharya and Richards (2000), suggest that teachers need to become reflective thinkers and compliant with the various effective teaching and learning tools to engage students in collaborative and interactive learning environments. These strategies improve the quality of students learning, making their learning contextual, and preparing them for future challenges in learning. However, the teaching and learning of chemistry in the classrooms today appear to focus mainly on helping students to pass exams.

The results of this study will provide the foundation for further analysis of the methods of teaching, learning and evaluation of the examined concepts. Teachers need knowledge of the misconceptions students within this age group commonly hold, as these misconceptions are both powerful diagnostic and teaching tools (Doran, 1972). It can aid curriculum developers in designing instructional materials and activities that begin 'where the student is' and the student's understanding of specific concept. If a teacher ascertains which misconceptions are prevalent among the entire class or a few members of the class, the teacher can guide students along an instructional sequence that may aid the development of a more correct understanding of the chemistry concepts.

It is anticipated that the findings of this study will assist in guiding teachers to implement teaching and learning strategies to improve learning of chemistry in both countries.

1.6 Research aims and questions

The study described in this report has three main aims.

- To investigate year 13 students' conceptual understanding of the structure, bonding and related properties of diamond and graphite to identify misconceptions held about these concepts;
- To determine the possible origins of the revealed misconceptions; and,
- To identify teaching and learning strategies that help eliminate chemistry misconceptions and assist in the construction of correct conceptual understanding of chemistry concepts.

The aims above lead to the following research questions:

1. *What are the misconceptions held by year 13 students in the structure, bonding and related properties of diamond and graphite?*
2. *What are the possible origins of these misconceptions?*
3. *What sorts of approaches are effective for teaching and learning chemistry in the classroom?*

The study explored and compared year 13 students' (final year in high school) conceptual understanding of the relationship between structure, bonding and physical properties of diamond and graphite. As concepts relating to chemical bonding are universally regarded as the "heart of chemistry" (Nicoll, 2003, p. 210) the present study revealed the origins of the misconceptions about the structure, bonding and related properties of diamond and graphite, through the use of an open-ended question tool, followed by interviews and continuous classroom observations.

The decision to study diamond and graphite was confirmed after a discussion with New Zealand and Samoan teachers and revealed that these are commonly investigated in NCEA Levels 2 & 3 and years 12 & PSSC chemistry. Further analysis is made and identified the origins of misconceptions from Samoa *vis-a-vis* New Zealand to determine appropriate teaching and learning approaches intending to correct misconceptions and help in future development of these concepts.

1.7 Limitations of the Study

The particular research methodology underpinning this study is an exploratory and descriptive case study. This methodology has been criticised by some researchers as being too vague to be a reliable methodology and therefore of little practical use (Atkinson & Delamont, 1985).

Although the examined concepts had already been taught by the time of the study, teachers appreciated the investigation as an evaluative process. Within the period when the topic was taught until the study was conducted, there was a possibility that some students had forgotten the material. Also, there was a possibility that some of the participants were away on the day when instruction on this topic was given.

The major limiting factor in this study was its word limitation. There was a range of areas and aspects of teaching and learning chemistry, i.e., the curriculum policies and school administrations; that could be related to this study. If these were investigated, there would be more data which may require the researcher to exceed the limits of the course requirements.

1.8 Delimitations of the Study

There has been so little academic research in this area that it was felt important to the researcher to explore the chemistry classroom and identify appropriate teaching and learning approaches to promote correct conceptual understanding. Therefore it was important for the researcher to employ a case study methodology, which is described as a method for answering these inquiries.

The next chapter is a summary from the literature, which outlines some research findings closely related to the current study.

Chapter 2 – LITERATURE REVIEW

2.1 Introduction

Chemistry students in New Zealand high schools are taught and re-taught structure, chemical bonding and physical properties concepts for three successive years (11, 12 & 13). Year 11 science introduces models and properties of simple elements, molecules and compounds (Ministry of Education, 1993) which form the foundational knowledge before moving on to year 12 chemistry. In contrast, the Samoa science curriculum introduces these concepts in years 10 and 11 as preliminary work to year 12 chemistry (Ministry of Education, Sports and Culture, 2004). Despite the teaching and reteaching of these concepts, tenacious misconceptions remain evident in many students' understanding, causing learning difficulties and problems in the development of high school chemistry (Coll & Taylor, 2002). A review of the literature shows a constant development and the influence of misconceptions in the construction of conceptual understanding of these concepts.

The literature review outlines a growing body of research that explores students' misconceptions in high school chemistry. The literature identified misconceptions as a critical factor in students' learning difficulties in successive chemistry levels. Since there is limited current literature on the identification of the origins and causes of misconceptions, specifically regarding the structure, bonding and related properties of *diamond* and *graphite*, the discussion here focuses more on general chemistry learning in an inquiry classroom.

Many studies show that students' ideas about chemistry concepts are vastly different from those of scientists and are firmly held by students (Treagust, Chittleborough & Mamiala, 2003). Coll and Taylor (2002) considered these students' ideas "not as mere mistakes but as conceptions that compete with scientific theories, however, these conceptions limit students' ability to understand chemistry" (p. 180). Although students are supposed to engage, construct and understand more complex concepts as they progress in their schooling, students share many of the same misconceptions (Banerjee, 1991) as they construct knowledge. These are outlined in the following sections.

2.2 Students' construction of knowledge

This study acknowledges a hypothesis of a double 'logic' in human behaviour. The 'psycho-logic' works with analogies, which, although understandable and plausible for human beings, partly or not at all correspond to the knowledge of the subject matter (Hesse & Anderson, 1992; Tabor, 1998). For the child, this 'psycho-logic' has a significant function in orientation and understanding of specific aspects like chemistry concepts, and it also remains important in later life (Ennenbach, 1983) and subsequent learning of chemistry concepts. We all construct our own mental models or theories in many fields, which often prevail over better - correct conceptual knowledge. The researcher refers to this kind of knowledge construction as **psychological construct.**

In the same way as scientists hold theories and develop hypotheses to test these theories, so students have their own theories about themselves and the world they live in - their personal construct system which they have developed over the years. Psychological construct views personality in terms of the way in which a student goes about making sense of his/her world, and it maintains that each individual has his/her own unique view of the world which influences expectations of what will happen in the future. It influences the way students view learning and understanding of specific chemistry concepts.

In a science classroom, misconceptions may not only be constructed within a student's mind, but also be observable through social interactions among class members, teachers, textbooks and instructional resources. These can be classified as **social constructs**. Constructivist theorists have extended the traditional focus on individual learning to address collaborative and social dimensions of learning which bring together aspects of the work of Piaget with that of Bruner and Vygotsky. However, students invent and construct institutionalised entities, artifacts or concepts, which are sometimes ambiguous, while participating in these collaborative and social dimensions. Some of these social constructs prevent students from making any sense of the chemistry concepts presented by the teacher, and, are very resistant to change.

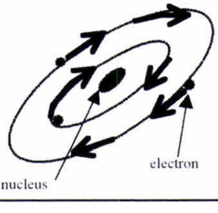
Cultural constructs are similar to social constructs except for being dependent on the cultures and influences on the learning process. For example, students in school B have been brought up in families where they are not allowed to question or disagree with adults. This promotes passive rather than active learning, where students are given the information to answer exam questions. Unfortunately, students are unable to assimilate and accommodate this new information leading to the development of learning difficulties and misconceptions.

2.2.1 Constructing conceptions from informal prior knowledge

a. The effects of everyday experiences

Prior knowledge and experience are fundamental factors contributing to free-choice learning (Pittman, 2006) a type of learning guided by a student's needs and interests (Roschelle, 1995). This prior knowledge and experience directly affects what students do and what they learn. Whenever a student tries to understand something, an idea or previous knowledge is activated to organise and make sense of the situation. In fact, one of the most important factors influencing learning is prior knowledge as learning can be regarded as the connection between what is already known and the current educational experience (Ministry of Education, Sports and Culture, 2004b). Nicoll (2003) identified that students thought that the electron motion about the nucleus was very much similar to planets orbiting the sun. And in relation to the Bohr atom classification, the students stated that the electrons were at a fixed distance from the nucleus in a flat movement as shown in figure 2.1 (Nicoll, 2003).

Figure 2.1: Illustration of Bohr Model of an atom



Direction of the motion of electrons, as explained by Nicoll (2003), the students argued that the electrons do not move perpendicular to the direction as indicated by the arrows. This is how the ideology of the Solar System comes in.

b. The language-use in chemistry

Papageorgiou and Sakka (2000) claimed that students confuse scientific and everyday experiences. 'Particle' as an example may mean something solid whereas if the same term is used for atoms and molecules, it has a very different meaning (Kikas, 2004). However, students think of molecules and atoms as solid little pieces of matter (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Garnett *et al*, 1995; Griffiths, 1994), as opposed to the smallest particle of a chemical element that retains its chemical properties.

2.2.2 Constructing conceptions from public knowledge

a. The problem with textbooks

Hawkes (1996) and others (e.g., Fensham & Kass, 1988; Taber 1995a) claimed that there are many misconceptions commonly found in chemistry textbooks. The models and diagrams used in textbooks are useful tools to gain better understanding; however, if not properly constructed and defined they give rise to erroneous conceptions. Although models used in textbooks provide explanations of chemistry concepts, there are limitations that need to be considered (Oversby, 2000) and explained. An example of this was one student explanation of the existence of the different stick-like structure that connects carbon atoms in graphite rather than covalent bonds. If this knowledge is unfamiliar, it is impossible to interpret the diagram correctly, and therefore students develop misconceptions.

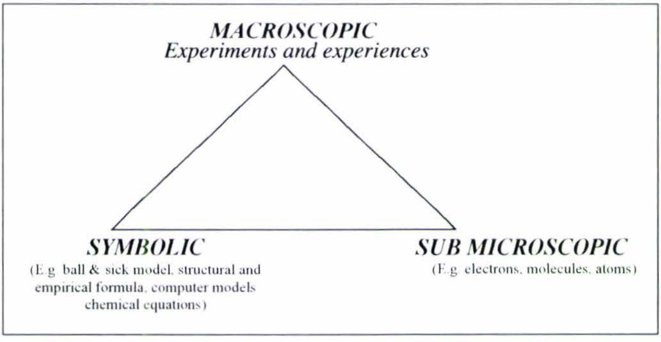
b. Knowledge from pictures and graphic representations

Computers and multimedia can be best used to help learners construct, structure, and modify mental models (Mayer, 2001). Much of today's multimedia educational software seems to operate on the assumption that more is better when it comes to using graphics (Kikas, 2004), however, the opposite is often closer to the truth. One of the biggest problems in educational software is that it overloads the learner (Mayer, 1998). Mayer and Moreno (2003), described this overload as occurring when "the learner's intended cognitive processing exceeds the learner's available cognitive capacity due to total amount of mental activity imposed on working memory at an instance in time" (cited in Cooper, 1998, p. 100). Overextending working memory with more information at one time leads to confusion or forgotten information (Clark, Nguyen & Sweller, 2006).

c. Modelling in chemistry-three levels of representations

Many researchers have conducted investigations into the teaching and learning of chemistry and confirmed that learning should be based around the three levels of chemical representation (Johnstone 1991; 2000; Treagust *et al*, 2003). These are – macroscopic, symbolic and the sub-microscopic levels (figure 2.2).

Figure 2.2: Three Levels of Chemical Representation



(Adapted from: Treagust, Chittleborough, & Mamiala, 2003, p. 1354).

While chemists can move between the three levels of chemistry with ease, recent studies have shown that novices only operate in one of these areas at a time (Nicoll, 2003; Treagust *et al*, 2003). Nicoll referred to these areas as "three distinct languages, with macroscopic being the only one favourable to a novice because it can be directly observed" (Kozma & Russel, 1997; Nicoll, 2003, p. 208).

Studies suggest that students fail to integrate the three levels of chemical representations because they are not clearly represented (Johnstone 1991, and Nicoll, 2003). In the classroom, teachers move thinking from one level to another imposing all three levels on students at once. Many studies (Lee, Eichinger, Anderson, Berkheimer & Blakeslee, 1993) identified students' problems in the macroscopic level, where students equated the evaporation of water with its disappearance. Osborne and Cosgrove "found students questioned thought that the bubbles in boiling water were composed of air" (Gabel, Samuel & Hunn, 1987, p. 696-697). The study by Chittleborough *et al* (2005) discovered that students assume sub microscopic particles have the same properties as the macroscopic substance they comprise - sulfur is yellow because sulfur atoms are yellow. To understand these concepts Johnstone (2000) and Salter (2005) suggest that the macroscopic observable chemical phenomena rely on the sub microscopic and symbolic views, and must all be considered in chemistry classrooms.

Some teachers find that the symbolic level of representation is less of a problem for students, where they are able to memorise at least the first 20 elements of the Periodic Table and appear to manipulate the chemical formulae with ease. However, students perceive a "chemical formula as a representation of one unit of substance rather than a collection of molecules" (Gabel *et al*, 1987, p. 695). In cases where students are presented with formulae and numerals, Krajcik (1991) claimed that some students have very limited understanding of what subscripts and coefficients mean (See equation 1: coefficients and subscripts are in bold).

$$Pb + PbO_2 + \mathbf{2}H_\mathbf{2}SO_\mathbf{4} \rightarrow \mathbf{2}PbSO_\mathbf{4} + \mathbf{2}H_\mathbf{2}O$$ ***Equation 1***

2.3 The chemistry curriculum

In year 13, the content area Atomic Structure, bonding and related properties in the Chemistry in the New Zealand Curriculum Statement (Ministry of Education, 1994), and Strand 1 in the Samoan Science Curriculum (Ministry of Education, Sports and Culture, 2004), are recognised as "one of the most complicated areas in high school chemistry" (Garnett, Garnett & Hackling 1995, p. 72). A number of factors contribute to this description:

a. Students try to construct meanings of concepts based on their previous experiences (Sue-Ho, 2001);
b. Atomic structure, bonding and related properties is an abstract topic, and it is likely that even the most experienced teachers find that some of their students still have some difficulties with it because of its intrinsic abstract (Johnstone, 2000) nature; and
c. Students' understandings rely primarily on sensory experiences that provide information about tangible, macroscopic phenomena rather than particulate-level explanations (Kruse & Roehrig, 2005).

Atomic Structure, bonding and related properties in Year 13 is centred on the knowledge of the structure and properties of atoms and molecules. An "atom has a nuclear structure, meaning that all of the positive charges and virtually all of the mass of the atom are concentrated in a nucleus, which is a very small fraction of the volume of an atom" (Chang, 2007, p. 48-50). In addition, properties of atoms can be understood by a model (Bohr Model[2]) in which the electrons in the atom are arranged in energy levels about the nucleus, with each energy level farther from the nucleus than the previous. These concepts are covered in year 12 chemistry in New Zealand (Ministry of Education, 1993, p. 98) and in year 10 (Ministry of Education, Sports and Culture, 2004, p. 52).

The electrons in outer shells are more weakly attached to the nucleus of the atom than the electrons in the inner shells, and only a limited number of electrons can fit in each shell. Within "each shell are subshells, each of which can also hold a limited number of electrons, [and] ... the electrons in different subshells have different energies and different locations for motion about the nucleus" (Chang, 2007, p. 292). Model of Lewis structure for "predicting shape is based on valence shell electron pair repulsion theory" (Rabinovich, 2003, p. 31) and the octet rule (Grant, 1994) for the first 20 elements are covered in year 12 in New Zealand (Ministry of Education, 1994, p. 18) and year 11 in Samoa (Ministry of Education, Sports and Culture, 2004, p. 59).

In general, small atoms of Groups 14 through 17 in the Periodic Table bond so as to complete an octet of valence shell electrons. The bonding and non bonding electrons are arranged in electron domains, which are separated in space to minimize electron-electron repulsions. This electron domain arrangement determines the geometry about a central atom. These concepts are covered in Level 6 and 7 (Ministry of Education, 1994, p. 18 & 23) and year 12 chemistry (Ministry of Education, Sports and Culture, 2004, p. 100).

The properties of substances depend on the structure and bonding in these substances. This understanding of the relationship between structure and chemical bonding helps in explaining the physical properties of substances. Examples of physical properties are melting and boiling points that vary dramatically from substance to substance. These variations can be explained by analysing molecular structures as part of the chemistry curriculum for years 12 and 13 (Ministry of Education, 1994, p. 23 & 28) and year 13 (Ministry of Education, Sports and Culture, 2004, p. 109-110).

Although the basic knowledge of *Atomic Structure, bonding and related properties*, appears to be well presented in the curriculum documents of both countries, numerous studies have shown the status of students' understanding (for example Barker, 2004; Sue-Ho, 2001; Coll & Taylor, 2002; Nicoll, 2003; Chinn & Malhotra, 2002), contains misconceptions.

Nakhleh's cognitive model shows that students build sensible and coherent understanding (cognitive structures) of the events and phenomena in their world from their own point of view (1992). These elaborate cognitive structures are themselves composed of interrelated concepts. Each concept itself is formed by a linked set of simple, declarative statements, called propositions that represent the body of knowledge that the student processes about that concept. The information students use to construct their own conceptions come from two sources: informal prior knowledge from everyday experiences, parents, peers, commercial products and the common meaning of scientific terms; and public knowledge as presented in texts, classroom teaching and other methods of instruction (Ebenezer, 1992).

[2]http://www.nvu.edu/pages/mathmol/textbook/atoms.html

2.4 Nature of misconception

Once a chemical misconception is integrated into a student's cognitive structure, it can interfere with, or impede further learning of, more difficult chemical concepts (Treagust *et al*, 2003). Misconceptions prevent students from making sense of the chemical concepts presented by the teacher causing little or no learning to occur. Unfortunately, these misconceptions are often strongly adhered to by the student.

2.5 Conclusion

The discussion above shows the existence of misconceptions in high school chemistry. From the literature the development of misconceptions within the classroom is obvious and they appear to be causing difficulties to the learning of chemistry.

- Misconceptions limit students ability to understand chemistry concepts;
- Misconceptions are firmly held by some students;
- Misconceptions can be regarded as psychological constructs, social constructs, and cultural constructs,
- Misconceptions contribute to learning difficulties in chemistry;

The descriptions of students' misconceptions described in this chapter show that among the many scientific concepts examined, recursive findings were found.

An appropriate methodological approach to this study is described in the next chapter.

Chapter 3 – METHODOLOGICAL APPROACH

3.1 Introduction

The following aspects are discussed in this chapter:

- justification for selecting qualitative inquiry in the study;
- roles of the researcher in the study;
- ethical considerations for this study; and,
- objectives of the research investigation.

3.2 Qualitative approach

The study employs a qualitative inquiry which

- "helps us understand and explain the meaning of social phenomena with as little disruption of the natural setting" (Merriam, 1998, p. 5);
- is an effort to understand situations in their uniqueness as part of a particular context, and the interactions there. This understanding "is not attempting to predict what may happen in the future, but only to understand the nature of that setting, what it means for the participants to be in that setting, what their meanings are, what the world looks like in that particular setting, and in the analysis to be able to communicate to others who are interested in that setting" (Patton, 1985, p. 1). The analysis strives for depth understanding; and,
- is "to understand human and social behaviour from the 'insider's' perspective sometimes referred to as the emic - that is, as it is lived by participants in the school or community" (Ary, Jacobs, & Razavieh 1972, p. 477).

Qualitative inquiry "includes a range of approaches of educational research and evaluation variously labelled as *naturalistic inquiry, case study, naturalistic inquiry, field study and ethnography"* (Merriam, 1998, p. 10-11). The study adopts a case study design because of its ability to "present research in a more publicly accessible form than any other kind of research methodologies and, the one that is so prevalent in education" (Merriam, 1998, p. 18-19). Case study attempts to describe the participant's entire range of behaviours and the relationship of these behaviours and the classroom environment (Ary, Jacobs, & Razavieh, 1972). This requires detailed study for a considerable period of time

An important concept in case study approach underpinning the study is reliability, which refers to the degree to which others can relate to the subject matter or to the conclusions reached. As Bassey (1981) puts it: "the merit of a case study is the extent to which the details are sufficient and appropriate for a teacher working in a similar situation to relate his/her decision-making to that described in the case study" (p. 85). Case studies, according to Adelman, Jenkins and Kemmis (1976) are a step to action. The insights gained from case studies can be used for teacher development and improving classroom pedagogical practice, for feedback, for formative evaluation and for curriculum development.

The case study approach has been criticised for insufficient rigour, detrimental influences of bias, limited generalisability (they can be generalisable to theoretical propositions but not to populations), and the length of time taken. As Bell (1993) points out "... inevitably, where a single researcher is gathering all the information, selection has to be made ... [and] ... so there is always the danger of distortion" (p. 9). Reliability and validity are, therefore, major issues in case research. Reliability and validity are two terms, which are often confused, partly because they are often interrelated. Reliability deals with the "consistency of the methods ... [i.e., observations and interview questions] ... used during the study" (Allwright & Bailey 1991, p. 46-47). Validity, on the other hand looks for the truth of the data by inviting the teachers to be present during the interviews and making the data available to the participants for confirmation.

3.3 The roles of the researcher

The characteristics of qualitative research include fieldwork, the researcher as the primary tool for data collection and analysis, an inductive strategy for theory building, and richly descriptive product. Furthermore, an optimal design of a "qualitative study is that, it is emergent and flexible, and able to be responsive to conditions as they change during the study" (Merriam, 1998, p. 11). The primary concern of a qualitative researcher is to describe and interpret reality, as it is constructed from the perspective of the participant, in this case in a chemistry classroom context, on which the study will focus. The researcher gathers data about the participant's present state, past experiences, environment and how these factors relate to one another.

3.3.1 Ethical considerations

Ethics are moral principles embraced by an individual or group designed to provide rules for right conduct. Bersoff (1996) identified *ethical conduct* as the result of knowledge and an understanding of the philosophical principles which underlie an ethics code. Such conduct originates from sound character leading to behaviour exemplified by maturity, judgment, and prudence. Clark (1997) also identified that educational researchers conduct their research investigations within a framework of ethical deliberations. These ethical deliberations must be relevant both in the collection and dissemination phases of the research. These, together with the Massey University Code of Ethical Conduct for Teaching and Research, support the current investigation with the intention to provide protection for all participants as well as to protect researchers and institutions (MUHEC, 2001).

In the present study a clear and fair agreement was established with the participants, prior to their participation in the investigation, to clarify the obligations and responsibilities of both the researcher and the participants. It was the researcher's obligation to honour all promises and commitment outlined in that agreement. Parallel to the work of Macintyre (2000) who identified a series of steps in addressing ethical issues, the researcher ensured to:

1. Observe school and cultural protocols and work within procedures in the schools;
2. Construct a detailed plan and provide all people involved in the research with a clear picture of the investigation. This includes written permission from the Ministry, School, Principal, Teachers, and Students;
3. Be realistic and considerate when calling on teachers' and students' precious time for data collection;
4. Consider the stress an demands the researcher will put on the participants;
5. Ensure confidentiality by making a participant's unprocessed data only available to that person or those involved in the research - i.e., supervisor; and,
6. Preserve anonymity of the participants by using anonymous coding.

The researcher ensured that the investigation was conducted according to the Code of Ethical Conduct for Research, Teaching and Evaluations involving Human Participants (MUHEC, 2001), as it was judged as a Low Risk Research Investigation (Appendix 1).

3.4 Objectives of the research investigation

The primary objectives of the study were

- to compare and contrast two learning environments for teaching chemistry; and,
- to describe the impact of instruction on students' construction of knowledge relating to the structure, bonding and related properties of diamond and graphite.

In particular the study intended to:

- explore the students' conceptual understanding of the structure, bonding and related properties of diamond and graphite;
- identify and compare the origins responsible for the development of the misconceptions within the two different environments; and,
- suggest appropriate teaching & learning approaches to correct, or eliminate chemistry misconceptions and enhance conceptual understanding of correct scientific phenomena.

3.5 Conclusion

The study is considered to be qualitative as it aims to produce vivid and richly detailed accounts of a group of students' development of conceptual understanding about the structure, bonding and related properties of diamond and graphite. The case study design is described in detail emphasising its direct link to better professional practice in research investigations. Finally the ethical responsibilities of this type of research have been carefully considered in this study.

Having knowledge of the methodology and the objectives of the investigation lead to a discussion of the method and process of data collection discussed in the next chapter.

Chapter 4 – METHOD

4.1 Introduction

This chapter has two sections. The first (4.2 & 4.3) explores the two sites of the investigation by comparing the resources and the facilities for teaching chemistry that were available at each school. The classroom pedagogical practices and the experiences of the three chemistry teachers involved in the study are also discussed. The second (4.4 & 4.5) describes the process of the case study by stating the methods of data collection, analyses and the procedures of the investigation.

4.2 Research data collection sites

The data was collected from two high schools, one in New Zealand in July 2005, and the other in Samoa in March 2006. The first data collection was conducted at a co-ed school (School A) in the city of Palmerston North in New Zealand. Students attending this school represent a range of ethnic backgrounds - European, Asian, Pacific Island and Middle Eastern. The school curriculum provides all the teaching, learning and assessment materials for all students-based on the premise that the "student is the centre of all teaching and learning" (Ministry of Education, 1993b, p. 5) which outlines the need for education to be relevant and responsive to the needs and abilities of all students.

The second data collection was performed at a government high school (School B) in the outskirts of Apia, the capital of Samoa. Those attending this particular school represent only a few cultural backgrounds such as European (Australian & New Zealand), other Pacific nations (Fiji, American Samoa, Solomon Islands) and predominantly Samoans. Its curriculum is based on Samoa, New Zealand, and Pacific Islands' standards and principles, most influenced by New Zealand curricular. Classes are taught in English however, all students also take part in a Samoan language programme.

4.3 Challenges of the teaching and learning of chemistry

4.3.1 Characteristics of the teaching of chemistry

The researcher developed a keen interest in the area of improving teaching and learning strategies for year 13 chemistry especially, after observing similar "traditional teaching strategies" (Branson, 1990, p. 8) employed by the three different teachers. It appears that the style of teaching and learning strategies observed in both sites influence the learning process in many ways. One example was one of the teachers (T3) at the age of seventy refrained from implementing alternative approaches that promote cooperative, interaction, and constructive thinking (Suaalii & Bhattacharya, 2007) of students during chemistry lessons. The teacher sat in front of the class, explaining and reading all the chemistry notes to the students. The students struggled to write down what they could gather from the lesson presentation or wait for the final ten minutes of the lesson where the notes would be put on the board for everyone to copy into their notebooks.

The other two teachers (T1 & T2) implemented cooperative methods (Suaalii & Bhattacharya, 2007) where students spent most of the chemistry lesson in group work, however, students often get out of control very easily. Since group work activities were carried out three or four times a week, most students tended to lose interest easily and started talking about other matters apart from discussing chemistry concepts. The teacher would then change from group work to lecturing. Table 4.1 summarises and compares the characteristics and the experiences of the three teachers involved in the investigation.

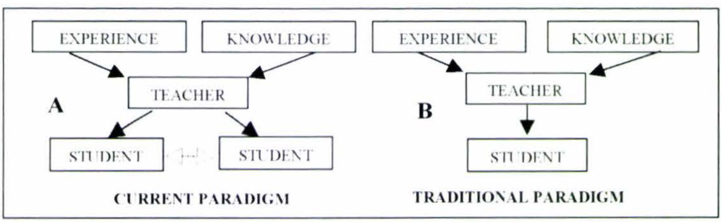
Table 4.1: Comparing the characteristics and the three teachers involved in the study

Characteristics	Teacher 1[T1]	Teacher 2 [T2]	Teacher 3 [T3]
Age	Early 40s	Mid 30's	Early 70's
Chemistry Teaching experience (years)	More than five years	Less than five years	More than 30 years
Primary teaching Area	Chemistry	Chemistry	Chemistry
Teaching qualification	First Degree	First Degree	First Degree
Textbooks	Always use	Always use	Never use
[1]Classroom Approach	Current paradigm	Current paradigm	Traditional paradigm
[2]Other Roles	NZ Ministry of Education	NZ Ministry of Education	None
Lab experiments	Often	Often	Seldom
Teaching strategies	Collaborative, Constructive, Cooperative	Collaborative, Constructive, Cooperative	Rote Learning
Weekly Schedule	4 classes – 50 minutes	4 classes – 50 minutes	5 classes-55 minutes

1. Approach to instruction and classroom management designed to promote social behaviour and academic functioning in school students.
2. Roles and responsibilities outside of teaching chemistry in the specified school.

Most lessons observed from the two research sites were teacher-directed, easily explained in terms of didactic approaches to learning. Branson (1990) refers to this idea as an incorporation of both the *current* and *traditional paradigms* as shown in figure 4.1. He argued that both the tradition and current paradigms are now outmoded because they evolved naturally from a time when authoritarian approaches were the norm (Branson, 1990). The current paradigm sees the teacher selecting the information to be taught, studied, and learned by the students. This was obvious in School A. The traditional paradigm defines the teacher as an authoritative expert, the main source of knowledge, and the focal point of all activities while the student as the passive recipient of the information already acquired by the teacher. During the investigation, chemistry was taught this way in school B.

Figure 4.1: Conceptualisation of education paradigm



(Adapted from Branson, R. K. (1990)

4.3.2 Science equipment and lab rooms

The quantity of classroom supplies differed greatly from one country to another and even from one school to another. The school investigated in New Zealand had a sufficient supply of equipment and chemicals for chemistry lessons and experiments as opposed to the school in Samoa.

The Chemistry Department in School A had an excellent supply of equipment, ranging from general laboratory and equipment (tripod and retort stands, thermometers, reagent and dropping bottles), to glassware (distilling apparatus, burettes, pipettes, flasks and tubes), to electronic and electrical systems (electronic balances and power supplies). With an abundant stock of organic and inorganic reagents, acids, bases and indicators available, practical experiments are very easy to facilitate. There is a laboratory room specific to chemistry that is well equipped with basic necessities for conducting experiments and the safety of all students (benches, water supply, gas supply), with a wide selection of chemistry textbooks, diagrams, tables, and charts displayed for students' references.

In addition, each chemistry teacher has an office next to the laboratory that is equipped with a computer with Internet access, a printer, and a telephone. A photocopier machine is placed in the head of the science department office and it is available to all science teachers.

In contrast, students in communities such as that of School B, which have little money for schools, often lack science equipment. Although the government is the primary source for financial assistance for the development of education (Preschool, Primary & Tertiary) in Samoa, most of the time it is insufficient. For this reason schools request funds from overseas grants, such as New Zealand Agency for International Development (NZAID), Australian Agency for International Development (AUSAID), and Asian Development Bank (ADB), which is a process that takes 2-3 years according to the school principal. Since it is a lengthy process, chemistry teaching would just have to proceed with whatever is available in the laboratory.

Some science teachers argue that the shortage of science equipment and quality of chemical reagents are some of the factors that discouraged teachers to do laboratory experiments. At times there is no water supply to the laboratory room and students have to use buckets of water during experiments, for washing hands and rinsing equipments. The shortage of glassware such as flasks, pipettes and burettes encourages the teacher to organise students in groups of six or seven, (as in the case of this classroom there are thirty-one students).

Some chemical containers have no labels on them, while some appeared to have been sitting in the storeroom for many years, for example a wet sample of Ammonium nitrate (NH_4NO_3). Using these chemicals may lead to unexpected results of experiments with no clear explanations; however, they are most likely due to dubious quality of the chemical reagents. The teacher would then have to tell the result and provide explanations so that students have enough information to develop a correct conclusion. Sometimes, according to the chemistry teacher (T3), "it is better having no experiment but to discuss and take notes". In this case, students are given the organisation of the experiment in detail (Appendix 11) including procedures, apparatus, and the expected results.

4.4 Data collection

4.4.1 Recruiting participants of the study

Several schools (both in Samoa and New Zealand) were contacted about this investigation. Permission for conducting the research was granted and chemistry teachers were contacted to meet with the chemistry students. Twenty-nine year 13 chemistry students from School A (New Zealand) and thirty-one from School B (Samoa) volunteered to participate in Phase I after reading the information sheet. Phase I examined this group of students' understanding and sought to identify any misconception about the structure, bonding and related properties of diamond and graphite by responding to an open-ended question. The responses were analysed and a sample of students was identified to be followed closely in Phase II.

In Phase II, eight students; five males and three females, were selected randomly to be interviewed and to be followed closely with classroom observations. It was necessary to work with this small sample so as to "focus on the breadth and depth of knowledge" (Nicoll, 2003, p. 205) of the structure, bonding and related properties of diamond and graphite.

The design of the investigation is summarised in figure 4.2. The *Pre-Research Organisation* began by notifying schools, principals and teachers about the investigation and arranged time for the researcher to introduce the investigation to the students. Agreement forms (consent forms) were signed by sixty students and Phase I was introduced. Students were asked to respond to an open-ended question about the structure, bonding and related properties of diamond and graphite. Their responses were analysed and categorised into four categories.

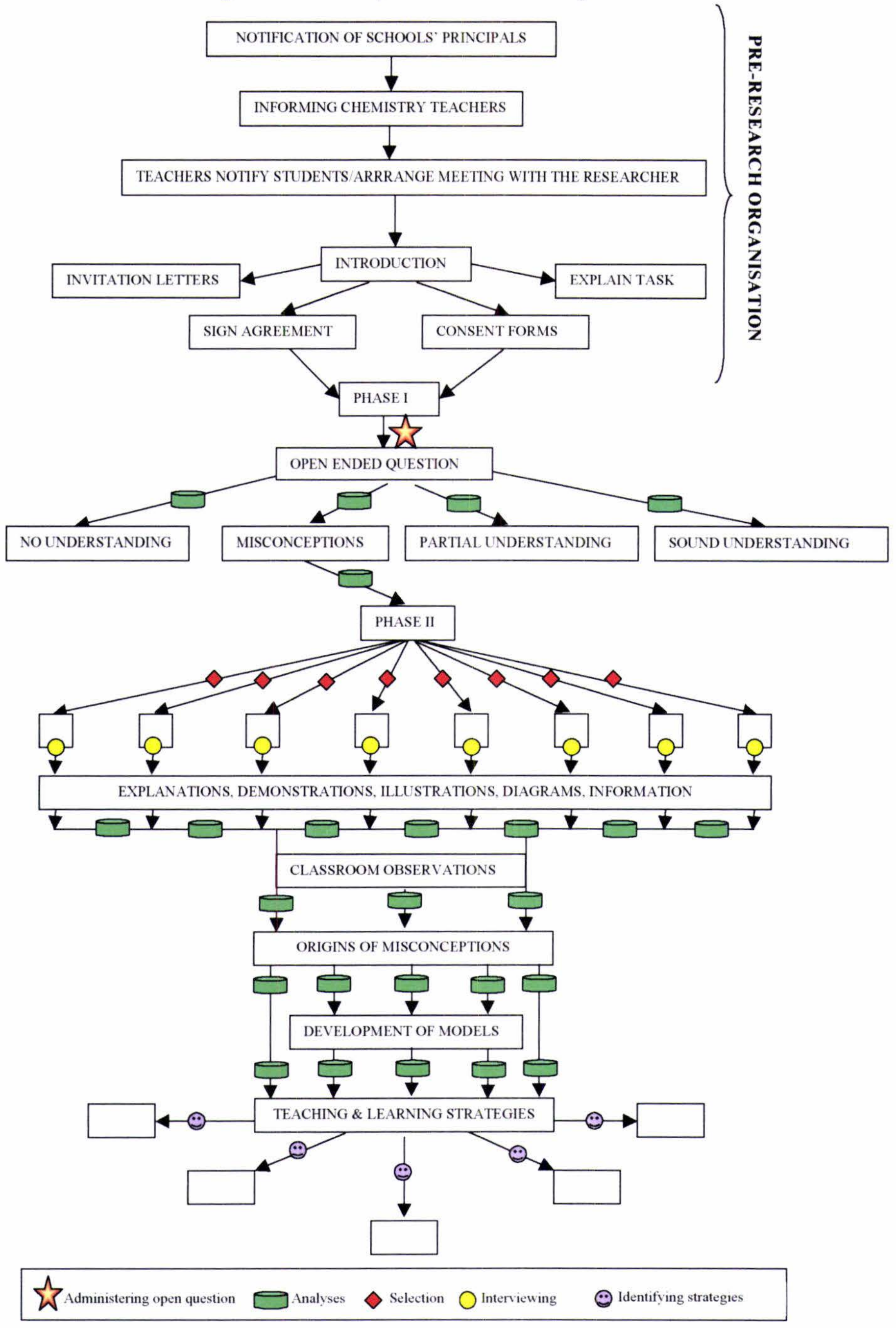
In Phase II, eight participants were interviewed and observed during chemistry lessons and laboratory experiments. The information collected was analysed to identify possible origins of misconceptions. After a series of analyses, models were developed to help the identification of teaching and learning strategies. As a result, five approaches were identified to be appropriate in correcting the misconceptions revealed and promote conceptual understanding about the structure, bonding and related properties of diamond and graphite.

4.4.2 Procedures of investigation

At the start of Phase I, the participants were given the opportunity to respond to the open-ended question (Appendix 8) within a limited timeframe of 15 minutes, during normal class period in a style of a formal written response. This prevented the students from losing too much classroom time. The participants were restricted from textbooks, notebooks and from other students so that the data remains valid by investigating individual's conceptual understanding of the structure, bonding and related properties of diamond and graphite. Their responses were analysed followed by classroom observations to confirm some of the information revealed.

Eight participants (four from each school) were selected at random and the chemistry teachers were informed to arrange a time and place for interview in Phase II. The interviews were one-to-one in-depth and recorded using a voice recorder. The data from the interview were discussed with the chemistry teachers to maintain the integrity and reliability of the data to "ensure there were no missed inflections during the transcribing" (Creswell, 1994, p. 158). Individual students were also given access to the information to ensure the information was correctly recorded.

Figure 4.2: Summary of the Research Design



4.4.3 Methods of data collection

The researcher was only able to make field notes during classes, as video recording was not available. The researcher was conscious that the students might be overwhelmed by having someone sitting at the back of the classrooms, despite the fact that they were given information of the research prior to the start of the investigation, through their teachers and pre-research consultations and visits. The researcher had been to the school on previous visits to become known and accepted to the wider school community, teachers, workers and all students.

Consistent with an interpretive approach, data collection and analysis had complementary roles with one activity informing the other "as an iterative and reflexive process" (Tolich & Davidson, 1999, p. 108). As in this study, after the analysis of the responses to the open-ended question, a small sample of participants were identified, interviewed and observed while engaging in a normal learning situation. Cohen and Manion asserted that "at the heart of every case study lies a *method of observation*" (1991, p. 125). However, the study adopts further data collecting strategies as described below.

a. Observation

The researcher arrived before each session and stayed after each session to try and measure the attitudes of the pupils both inside and outside the teaching situation. The researcher was looking for any apprehensions or enthusiasm the students might have before the classes began, and evaluative comments that might be made after. These were not question and answer sessions structured by the researcher, but rather observations of students banter.

The researcher observed twelve chemistry lessons and six laboratory experiments. This was organised so that six lessons and three experiment observations were conducted from each research site. The process of classroom observations started collecting data prior to the implementation of the open-ended question towards the end of the second phase. For this research project, the researcher took the role of non-participant observer by observing and recording events as they occur. For example, comments from students to the teacher or other students, or noting students' behaviour. Most activities in the classroom were audio recorded and by field notes which provided a basis for reflection by the teacher(s) and the researcher.

Observations were often supplemented with questions and answer sessions with the chemistry teachers, T1, T2 and T3, to clarify and triangulate the notes as they developed. Although difficult to maintain, the researcher remained strictly as a non-participant observer as far as the students were concerned. However, there were times when the students tried to engage with the researcher as another teacher and to enlist the researcher's aid in the class.

b. Interview

The eight participants were interviewed with their chemistry teacher in attendance in Phase II. The interviews were audio taped and transcribed. Individual's transcript was made available to the participants for checking, to satisfy ethics' guideline requirements and to establish whether the statements were correctly transcribed. The interview questions were arranged in four parts A, B C & D. (see Appendix 9). The questions in Part A, seek to determine knowledge of *structure about the crystals*, and part B explored knowledge of the *chemical make-up of the substances*. Part C focused on the knowledge about *bonding* and forces while Part D examined the specific misconceptions extracted from individual response to the open-

ended question. The focus of part D was for the individual participants to provide justifications for their own given responses to the open-ended questions with supporting evidences and explanations. Participants were encouraged to make sketches and drawings to illustrate their ideas and understanding.
Although the interview questions were prepared beforehand, questions were open-ended to allow extra questions to clarify some of the participants' responses to the questions. Informal discussions with the teachers were carried out after individual interviews, to obtain their perceptions of the participants' understanding with regard to the responses given and identified as misconceptions.

c. Archival records

Unlike School A where some of the information was easily retrieved from the Internet, some data was obtained from archived documents in the School Administration, and the Ministry of Education, Sports and Culture for School B, as it was not available online.

Certainly, "similar data collected from a variety of sources (teachers, students, and observer) using a variety of methods (interview, observation, artefacts, archival record) was more likely to be valid and reliable than data collected from just one source" (Yin 1993, p. 39-40).

4.5 Data analysis

Data analysis is referred to as the "process of organising and storing data in light of your increasingly sophisticated judgements, that is, of the meaning-finding interpretations that you are learning to make about the shape of your study" (Glesne & Peshkin, 1992, p. 129). Data analysis began with the researcher reading through participants' responses in both phases. The complicated and sometimes surprising nature of the students' responses made it necessary to spend considerable time designing and revising these lists, which were subsequently reorganized into coding sheets to sort and define data.

Audiotape data was transcribed and later mapped to the information gathered from the interviews, written observations and classroom artefacts such as participants' drawings and sketches of the structure of diamond and graphite. These were then categorised in groups to classify the data that appeared to be similar, since some of the data from some students overlapped. This enabled the researcher to combine and refine the data.

Broad categories of the participants' responses were further subdivided into specific ideas and patterns to identify and to bring more meaning and understanding of the students' responses. Further coding was based on the reduction and refinement of the broad categories. During the process of data analysis, it was obvious that much of the data could be coded in a range of different ways and that there was considerable over-lap in the categories used in the study.

4.6 Summary

This chapter records the process of case study investigation as it occurred throughout the study. Detailed descriptions of the research sites confirmed that limited resources and facilities influence formal classroom practice and minimal amount of lab experiments. Data was obtained by continuous classroom observations and interviews (collecting artefacts from students) within the frame of the case study. .

The next chapter discusses the results of the open-ended question, the interviews, classroom observations and students' artefacts.

Chapter 5 – RESULTS

5.1 Introduction

Analyses of students' responses to an open-ended question, interviews and classroom observations are discussed in this chapter. Explanations of the possible origins of their misconceptions about the structure, bonding and related properties of diamond and graphite are also explored in the chapter.

5.2 The open-ended question

The aim of the open-ended question (Appendix 8) was to determine students' understanding of the relationship between the structure & bonding, and, properties of substances. The question was open to allow students to write all the related materials, concepts and ideas about the examined concepts. The students were also encouraged to draw and describe, discuss and explain their understanding of the examined concepts.

Using diamond and graphite in the investigation, the participants were asked to discuss and demonstrate the relationship of the concepts; *structure, bonding* and *physical properties* in particular. For example, in diamond, each carbon atom is strongly bonded to four adjacent carbon atoms in a three-sided pyramid. The four valence electrons of each carbon atom participate in the formation of very strong covalent bonds. These bonds have the same strength in all directions which gives diamonds their great hardness.

The participants' responses (Appendix 12) to the open-ended question were analysed (figure 5.1, p. 46) and categorised using the scheme by Haidar and Abraham which shows the extent of students' understanding of the concepts. On the basis of these findings, the researcher decided that the responses provided some descriptions of students' understanding of the examined concepts, although it was necessary that there may be some other factors that may have influenced their responses at the time.

Table 5.1: Categories used in the analyses of students' responses

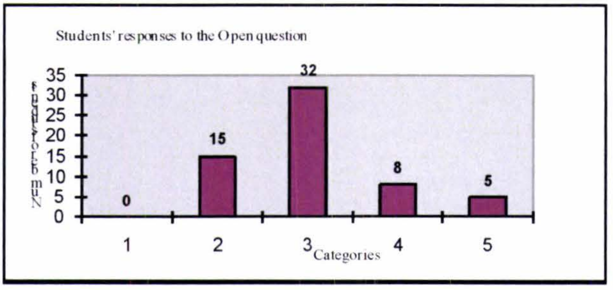
Category	Explanation
1	No response
2	No understanding
3	Misconceptions
4	Partial understanding
5	Sound understanding

The first category (1) classifies students who gave no response to the question. This could be a result of not knowing anything about the structure, bonding and related properties of diamond and graphite or perhaps s/he was absent on the day that these concepts were taught. Category 2 is for those who had responded with no understanding of the concepts giving incorrect answers. The third category (3) classifies students' explanations' that attempted to describe the target concept but do not match the scientific conception. Category 4 finds those students with some indication of understanding but still need more help while category 5 classifies those students with reasonable understanding of the examined concepts.

5.3 The analysis of the students' responses to the open- ended question

Thirty-two participants out of sixty were identified with misconceptions (figure 5.1) fifteen from school A and 17 from school B (Appendix 12). These students were unable to demonstrate correct understanding of the structure, bonding and related properties of diamond and graphite, instead they wrote misconceptions such as there is a gap or space between the layers in graphite for electricity to flow through 'student 60'. Instead of describing the important roles of non-bonding electrons for the conduction of electricity in graphite, the participant explained that the spaces between the layers of graphite are essential for the flow of electricity.

Figure 5.1: Graph of the extent of students' understanding of the concepts



5.4 The interview

The interview questions probed possible origins of the revealed misconceptions. The intention was to determine the origins of individual participant's knowledge on the basis of the responses to the open-ended question.

Eight students from category 3 were randomly selected for interview. Each interview consisted of four parts A, B, C and D (Appendix 9). Each part probed an area of understanding about the structure, bonding and related properties of diamond and graphite. Part A probed the following characteristics:

- sketch and name the details of the structures of both diamond and graphite,
- define the sketch [for example, if a student draws dots or lines, ask them what they represent],
- explain any difference in the structures of diamonds & graphite,
- explain any similarities in the structures of diamonds & graphite,
- link the sketch of diamond and graphite to their physical property.

The questions in part B explored the chemical make-up of both diamond and graphite. In addition, participants were asked to compare and describe the difference in the arrangement of the particles within both substances. Part C explored students' understanding of bonding and forces within diamond and graphite. Therefore, the questions were designed for the participants to:

- explain how the particles are held together in both diamond and graphite,
- explain the types of bonding forces within the two substances,
- discuss the difference in the number of bonding electrons.

The final part known as part D, focussed on the misconception identified. Each participant was asked to explain and provide evidence (diagrams) to support what s/he wrote in response to the open-ended question.

Each participant was given two minutes to explore his/her own statement identified as a misconception prior to the interview, to allow time to think and recall their own ideas about the statement.

Analyses of the interview responses showed that the areas that the participants held majority of misconceptions were Parts A and C, and they were classified as GROUPs I and III respectively. No one was identified in GROUP II. GROUP IV identified one student who held misconceptions in more than one part, which were parts A and C. The researcher classified student 44 in GROUP V because the student was able to correct the misconception during the interview, despite the frequent use of incorrect terminology, such as *ionic* instead of *covalent*. These are summarised in table 5.2, followed by brief description of individual interviews.

Table 5.2: Classification of interview responses

GROUP	I	II	III	IV	V
	Student 09	-	Student 43	Student 13	Student 44
	Student 39	-	Student 05	-	-
	Student 60	-	Student 15	-	-

GROUP I

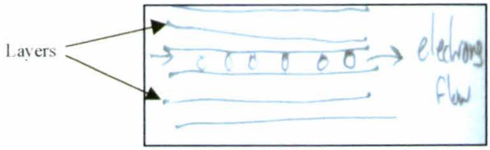
The first group was identified with misconceptions about the 'structure' (part A) of the two crystals. The responses from student 09, student 39, & student 60 to this part of the interview are discussed below.

Student 09 wrote, "The structure of graphite allows the flow of electricity between the layers".

The first interview identified *student 09* with misconceptions in section A causing enormous difficulties in explaining the diagrams used to illustrate understanding of the structure, bonding and related properties of diamond and graphite.

> *"Because the carbon atoms in graphite are arranged in layers, there are spaces like tubes between these layers. These tubular spaces are the pathways for the flow of electricity. In the absence of these tubular spaces as in diamond, electricity is restricted from flowing through" (Student 09, 19/07/2005).*

Figure 5.2: Sketch of graphite (by student 09) showing the flow of electricity between the layers



Explanations to part D supported the idea that between the layers are spaces for the flow of electricity in graphite:

> *"The layered-arrangement of graphite allows the flow of current. Because of this unique structure, conduction of electricity is possible. Considering the flow of water through the water-hose, the greater the volume the better the flow of water, and if the tube is blocked, the flow of water will also be blocked. This distinguishes graphite from diamond-in terms of*

electrical conductivity. Furthermore, if graphite was like diamond or structured in an un-layered configuration, electricity would not flow" (Student 09; 19/07/2005).

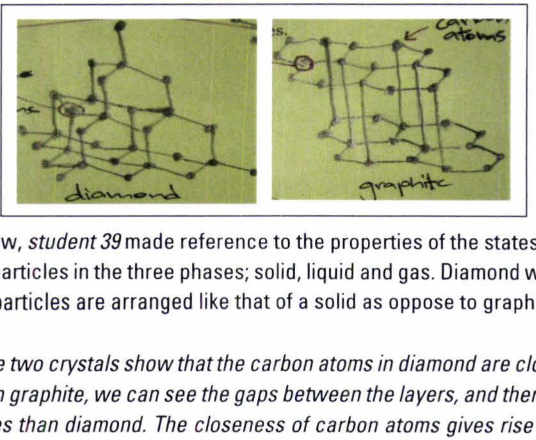
Student 39 wrote: "Atoms are very closely bonded causing the diamond to be hard"

Model representation is a useful strategy that represents the abstract structure of diamond and graphite. However, the explanations and demonstrations (figure 5.3) of the concept *structure* by this student appeared to develop from misinterpreting these models. The models of both crystals were used when the topic was introduced in both schools and were displayed in the laboratory. These were available during the interview for reference.

The responses to question 3 of part A, confirmed that misinterpretations of the models lead to the development of the present (mis) conception, as the student kept referring to it during the interview. According to *student 39*:

> *"The model representation of diamond uses sticks to connect carbon atoms (balls) are of the same length - 2.7cm, while 4.7cm between the layers in graphite. The closeness (and same length of bond) of all carbon atoms in diamonds, give rise to its hardness property, as oppose to graphite. And because of this, diamond becomes the hardest substance ever know" (Student 39; 27/03/2006).*

Figure 5.3: Atoms of diamond are closely bonded compare to those of graphite (drawn by student 39).



For part D of the interview, *student 39* made reference to the properties of the states of matter with regards to the closeness of the particles in the three phases; solid, liquid and gas. Diamond was described as a hard substance because its particles are arranged like that of a solid as oppose to graphite.

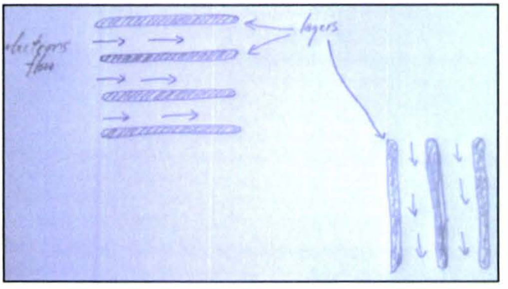
> *"The models of the two crystals show that the carbon atoms in diamond are closely packed (like those of a solid). In graphite, we can see the gaps between the layers, and therefore has slightly different properties than diamond. The closeness of carbon atoms gives rise to the properties of hardness and high melting points in diamonds. Given that the carbon atoms in graphite are loosely packed due to the presence of longer bonds between the layers, they are most likely to have lower melting points and therefore it is softer than diamond" (Student 39; 27/03/2006).*

Student 60 wrote: "There is a gap or space between the layers in graphite for electricity to flow through"

Although *students 60* and *09* come from two different schools, their responses to the interview questions appeared to show similar understanding of the concepts. *Student 60* claimed that.

> *".. the flow of electricity through graphite is very much dependent on the presence of spaces between the layers, for example, if the layers are placed horizontally, the flow of electricity is also horizontal regardless of the direction of the flow (+ to -)" (Student 60; 27/03/2006).*

Figure 5.4: Sketch of Graphite showing the flow of electricity (by student 60)



Furthermore, the responses in part D confirmed that *student 60* did not understand all the information represented by the model of diamond and graphite (figure 5.6) that they see in the classroom.

> *Unlike graphite, diamond is not arranged in layers and therefore electricity cannot flow through. The spaces between these layers are pathways for the flow of electrical current. If graphite were not arranged as stacks of carbon layers or sheets but as one sheet, electricity would not be able to flow" (Student 60; 27/03/2006).*

5.4.1 Discussion for GROUP I

On the basis of the responses to the interview, this group did not understand the purpose and the use of model as a way of representing only. To explain the concepts, the students formulate their ideas and explanations based on what they see on these models. In general, it appeared that the teachers' instructions did not explain the roles of models in understanding chemistry concepts. These students did not understand the structures of both crystals and most of the explanations were developed based on the models.

GROUP II

The questions in part B explored students' understanding of the chemical make-up of diamond and graphite and compared the arrangements of carbon atoms in both crystals. None of the participants was identified in this group, however, while responding to other parts (C & D) of the interview, some students made misconceptions about chemical composition. *Student 15* for example, emphasised electrons as the building blocks that are bonded together forming the two crystals rather than carbon atoms when responding to part C. When this particular student was asked about the chemical make-up of the crystals, and other questions related to part B, carbon atoms were clearly specified. Therefore student 15 is identified in Group III.

GROUP III

This group of students, *student 43, student 05, & student 15* were identified with misconceptions in part C; *'bonding and forces'.*

Student 43 wrote: "Weak force holding graphite's molecule, therefore it is weaker with a lower melting point"

This student was not able to distinguish electrostatic attractions as in ionic substances, from intramolecular bonding as in covalent networks, i.e., diamond and graphite. Therefore *student 43* viewed and described carbon-carbon bond as having ionic rather than covalent bonding. Graphite was also described as consisting of weak Van der Waal forces holding the whole crystal together.

> *"..the carbon atoms in graphite are held together by very weak forces as oppose to diamond. When a small amount of energy is applied to graphite, it disintegrates. When this happens the bonding forces within and between the layers break, and carbon atoms become lose in nature. Using the pencil as an example, a simple and gentle rub on the paper causes the graphite (in pencil) to break leaving marks on the paper. If we take this piece of paper and view (the mark from the pencil) under a microscope, we can see many dark particles separated from each other-which represent atoms of graphite being separated" (Student 43; 27/03/2006).*

For part D, *student 43* claimed that graphite is soft because of the presence of weak Van der Waals forces as oppose to diamond which has stronger bonds. The physical properties of graphite are therefore the opposite of those of diamond (Table 5.3).

Table 5.3: Comparison of diamond & graphite (part of student 43 responses to category 2)

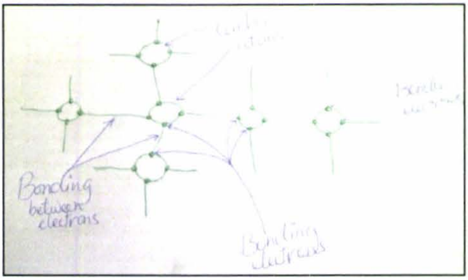
DIAMOND	GRAPHITE
Does not conduct electricity	Conducts electricity
Hard	Soft
High Melting point	Low melting point
Strong forces	Weak forces

Student 05 said, "Electrons hold the layers of graphite together".

The interview identified student 05 with more misconceptions about bonding and forces (part C). This was revealed when the participant was asked for further illustrations (figure 5.5) to justify his/her understanding of the concepts of electrons, valence electrons, and covalent bonding.

> *"The valence electrons on the outermost shell of the carbon atoms are bonded to those of the neighbouring carbon atoms. Since carbon atoms in diamond and graphite share electrons (covalently bonded), these outermost (valence electrons) electrons are bonded to nearby electrons (those from nearby carbon atoms). This sharing of electrons (covalent bond) holds the layers of graphite together" (Student 05; 20/07/2005).*

Figure 5.5: Sketch of diamond and graphite to demonstrate how electrons are bonded (by student 05).

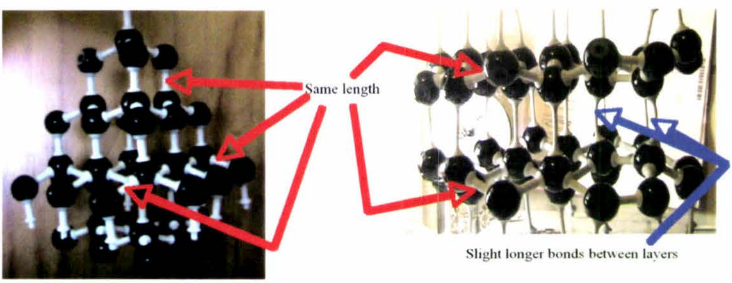


Similar to the ideas presented by students in GROUP I, *student 05* discussed the concepts of bonding and forces using the model representation of the two crystals. That is, the carbon atoms are bonded to one another through bonding electrons and therefore electrons are responsible for holding the structure of both crystals.

> The four sticks connecting one carbon atom to the other represent the sharing or bonding of electrons between the valence electrons of the carbon atoms. Say if the bonds (the sticks) between the layers in graphite are broken (by removing them) the crystal disintegrates. This demonstrates that the valence electrons play vital function in the formation of substances, diamond and graphite" (Student 05; 20/07/2005).

Figure 5.6: Diamond and Graphite models (these were used when the topic was in all classes).

Diamond **Graphite**

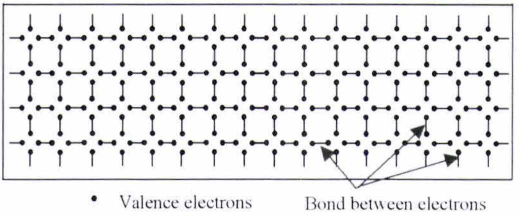


Student 15 said, "Diamond and graphite are made up of large lattice of electrons".

Parallel to the arguments and explanations by *student 05, student 15* claimed that, 'Carbon atoms share electrons as demonstrated in diagram (figure 5.7) and at the same time it is necessary for the stability of the carbon atoms'. The emphasis (by this student) was that valence electrons are bonded to those of neighbouring carbon atoms.

"The structure shows the carbon atoms bond to other carbon atoms (in diamond) by means of sharing between valence electrons. This bonding (C-C) is clearly represented by the stick-like structure that we use to connect one carbon atom to another. This continuous sharing of electrons gives rise to a giant covalent network made up of large lattice of electrons" (Student 15; 20/07/2005).

Figure 5.7: Illustration (by student 15) of the large lattice of electrons (re-drawn for better visibility).



5.4.2 Discussion for GROUP III

This group of students appeared to be experiencing enormous difficulties in understanding the concepts of bonding and forces (part C of the interview). Instead of exploring the covalent bonds that hold diamond particles, the students employed an ideology based on the model representation of diamond crystal. This ideology or (mis) conception described electrons as attracted to each other holding the structure together.

Figure 5.8A Demonstration of the (mis) conception

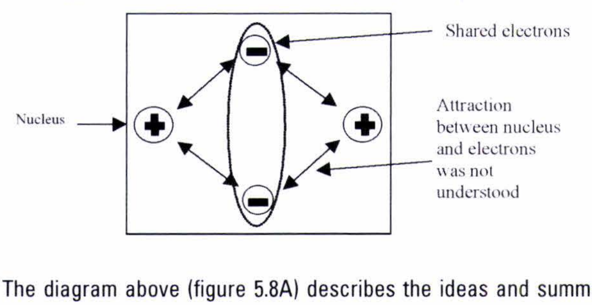
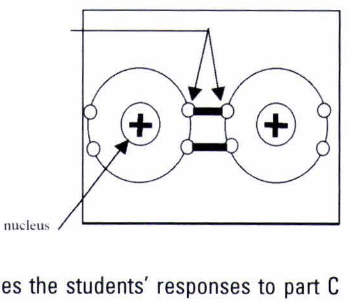


Figure 5.8B: Lewis diagram of Atom X



The diagram above (figure 5.8A) describes the ideas and summarises the students' responses to part C of the interview. The students think that *electrons sharing* as in Lewis representations (5.8B) means that electrons sit next to each other; *attract*, however they should *repel* (negatively charged particles). The students did not show knowledge of the effects of the positive nucleus on the negatively charged electrons that pulls the electrons towards the nuclei as shown in figure 5.8A.

GROUP IV

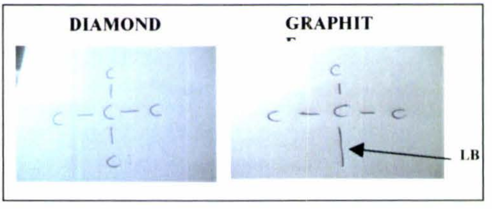
Student 13 was identified with misconceptions relating to both parts A '*structure*' and C '*bonding and forces*' of the interview. Although bonding and forces were not clearly specified, the misconceptions prevented the student from giving precise and clear explanations of the concepts.

Student 13 wrote, "C-C bonds make diamonds the hardest."

From the responses to this part of the interview, *students 13* claimed that the differences in the structures of both crystals are mainly because of the presence of a long *carbon-carbon* bond in graphite only. Bonding and forces were not mentioned at all, but most of the discussion in relation to these concepts was referred to the carbon-carbon *bonds*.

> *"The C-C bond in diamond is different from that in graphite. The four bonds between the carbon atoms in diamond are fixed and strong due to same lengths of the bonds or stick used in the model[8]. In graphite, three are of the same length and one is longer (LB), which makes graphite slightly softer than diamond. So, diamond has four C-C strong bonds while graphite has three. This long bond makes the other layer in graphite stay far off from another layer causing it to be softer than diamond, and can easily be come off" (Student 13; 20/07/2005).*

Figure 5.9: Sketch of the structures of both crystals by student 13.



In response to part D, the argument was presented with the use of the model (figure 5.6) of diamond and graphite; that was provided at the time of the interview for reference. Using these models, *student 13* stated that:

> *"The four carbon-carbon bonds in diamond are the same in length, and therefore they are positioned in the same distances – hence its hardness. In contrast, graphite has a slight longer carbon-carbon bond (LB) that can easily be distorted and eventually break (with very little energy) – that is why it is soft compare to diamond. This long carbon-carbon bond in graphite is found between the layers (shown in diagram above)" (Student 13; 20/07/2005).*

5.4.3 Discussion for GROUP IV

This group showed no knowledge of the concepts bonding and forces, despite the frequent use of the term bond. It shows a lack of understanding about two different types of bonds (covalent bond and Van der Walls) present in the two crystals. The misconception identified from the open-ended question appeared to be causing further misconceptions due to limited knowledge content of the concepts explored in this part of the interview. One example identified was that 'the long bond between the layers of graphite causing it to be soft'. An explanation to this idea was also referred to the model of the crystals, which is an indication of limited instructions when these models were firstly introduced to the students. Similar to the discussions from other groups, this group was not able to manipulate the ideas presented by the models.

GROUP V

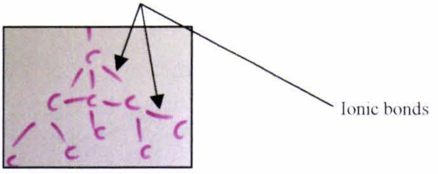
This group identified *student 44* with a misconception that shows an extensive confusion about the nature of bonds present in diamond, hence the frequent use of the term *ionic* when explaining strength of the bonds present in diamond.

Student 44 wrote: "Ionic bond is present in diamond therefore it is very strong and higher melting point"

The responses to parts A, B & C are summarised in the box below:

> *"Diamond is an allotrope of carbon and it is the hardest substance that we have studied this year, the reason for this is because it contains very strong ionic bonds. Graphite also contains strong bonds but there are weaker covalent bonds between the layers, which makes it even softer than diamond. Breaking these strong ionic bonds in diamond is very hard-therefore higher melting point" (student 44; 27/03/2006).*

Figure 5.10: Sketch to demonstrate type of bond present in diamond structure (by student 44).



Although the misconception (given above) was presented to the student at the beginning of the interview, there was no indication of changing anything. However, in part D where the students had to explain the given statement (misconception), student 44 identified ionic as irrelevant and request to change to covalent. The statement then reads as "covalent bond is present in diamond, therefore it is very strong and higher melting point". Further questions were asked to find out the reasons of this sudden change gave the following:

- It is because carbon is a non metal and therefore should undergo covalent bonding,
- Because electrons should be sharing between the carbon atoms
- Both diamond and graphite are extended covalent networks not ionic substances

The graphite was later described as having weaker covalent bonds as opposed to those present in diamond. These bonds are only present between the layers which give its physical properties, such as soft and low melting points.

5.4.4 Discussion for GROUP V

This misconception developed from the lack of knowledge of scientific terminologies such as ionic and covalent. Based on the responses, the student could not distinguish between the two concepts despite them being used in the classroom. This confusion hindered other conceptions and ideas about the structure, bonding and related properties of substances, like diamond and graphite; causing the student to describe *diamond containing strong covalent bonds* and graphite containing weaker covalent bonds. Other conceptions such as Van der Waals and the nature of bond types were totally confused.

5.5 Classroom observation

5.5.1 In school A

The chemistry lessons were taught in several ways to promote students' involvement and understanding of chemistry concepts. These include group activities, individual tasks, and mostly teacher presenting notes. The group task was popular however, noise and disruptions often occur during the activities. Students' homework were often well presented and well researched which demonstrated the involvement of the community in the learning as well as the students' positive attitudes towards homework. Lecturing was sometimes used by the teachers to teach new concepts and especially to prevent the noise and disruptions during the class. In the last ten minutes of the class, the teacher writes the notes on the board for students to copy into their notebooks.

In most lessons, some students distract others in the class in which the rest of the class tended to follow. Students talked, shouted, and started throwing papers and pens disturbing the whole class, particularly during group tasks, when the teacher stepped out of the room or a relieving[3] teacher was present. The teacher (or reliever) often attends to the matter by talking to the individual student(s) who caused the disruptions. This matter sometimes took longer than expected simply because some students opted to ignore the teacher, by persistently disturbing the lesson and other students.

5.5.2 In school B

In contrast to the strategies and style of teaching in School A, the classroom practice in School B displayed a traditional education paradigm (figure 4.1-B), which defines the teacher as the expert of chemistry knowledge (Branson, 1990). The knowledge was transmitted to the students through lecturing and copying notes from the blackboard prepared by the chemistry teacher. Discussions were often occupied with memory-typed questions for students to recall chemistry concepts and their definitions. One example would be; *'Covalent bonding - sharing of electrons between non-metals'.* The teacher emphasised specific chemistry concepts, their definitions, and brief annotations that are easily recalled and encourage students to memorise, as they are useful in answering PSSC chemistry exam.

Very well disciplined students were those of School B, where they were quietly seated, listening, writing and staring at the teacher at all times as opposed to those of School A. With the strong influence of the Samoan culture, every student must practice respect and honour when in school compounds. Samoan culture is traditionally an oral culture and it is considered to be rude for students to ask or disagree with what elders - parents, older brothers, sisters and teachers say. Teachers are treated as parents, so full respect is also practiced, which prevented the students from asking questions for explanation.

However "if teachers encourage questioning and discussion, it can cause distress to Samoan children" (Williams & Willetts, 1990, p. 21). *Musu* is a state of withdrawal, caused through a possible combination of shame and embarrassment. Samoan children show emotion spontaneously, which can be disruptive at times, particularly laughter at the unfamiliar. For these reasons, asking questions or dialogue between students and the teacher during classroom lessons is seldom used. However, Gorsky, Caspi & Tuvi-Arad emphasised the importance and necessity of dialogue between the teacher and students that the:

> *"... teacher and student should engage in an active dialogue. ... the instructor translates the information to be learned into a format appropriate to the learner's current state of understanding... and the centrality of the interpersonal relationship in the facilitation of learning alongside the need to provide freedom in educational environments."*
>
> (Bruner, 1996; Rogers, 1969; Gorsky, Caspi & Tuvi-Arad, 2004; p. 2)

[3]People from outside of the school community, not staff member

5.6 Origins of misconceptions

The responses to the interviews and classroom observations indicated that misconceptions could have been originated by specific factors. Some of these factors are *External* in a sense that they are out of the control of the students but more on the teaching and learning process (classroom pedagogical practice). Knowledge construction and prerequisite knowledge are *Internal* factors in which the learner is responsible for. These are summarised in Table 5.4 below

Table 5.4: Origins of Misconceptions in Schools A & B.

Code	Origins	Factor	School A	School B
A	Oversimplifications of chemistry concepts and the use of unqualified, generalised statements & analogies	External	✔	✔
B	Incorrect interpretation of model representations	Internal/ External	✔	✔
C	Overlapping similar concepts	External	-	✔
D	Inability to visualise the sub microscopic nature of matter	Internal/ External	✔	✔
E	Inadequate prerequisite knowledge	Internal	✔	✔
F	Influence of cultural practice	External	-	✔
G	Language use and teachers' accent	External	-	✔

(Note: The tick (✔) identifies the school and the possible origins of their misconception & (-) means not applicable. These are based on the findings of this investigation.

5.6.1 Oversimplification of chemistry concepts and the use of unqualified, generalised statements and analogies

Teachers often attempted to simplify conceptions in order for students to absorb a concept quickly. At times when a new concept was introduced without simplifications, some students tended to lose interest, which is an indication of the lack of understanding. Misconceptions also arise when educators attempt to over simplify concepts (Bodner, 1991). The use of analogies is often recommended as a method of making difficult abstract concepts accessible to students. While analogies are suggested as a means of helping students form bridges between existing and more sophisticated conceptions, they are also a potential source of unintended misconceptions unless limitations to these (analogies) are clearly identified and explained.

5.6.2. Incorrect interpretation of model representations

Many participants misinterpreted the ball-and-stick convention, where they interpreted the sticks between the carbon atoms as the true observable fact, that is, two atoms join the same way (by stick-like structure). The different lengths of the sticks (figure 5.6) in graphite made it more convincing as the true conception, by claiming that the softness of graphite was because of the presence of the longer bond between the layers. In addition, the spaces between the layers of graphite were interpreted as important for the flow of electricity as opposed to diamonds.

From the results, it appeared that most of the participants developed misconceptions due to an inability to understand the purpose and the use of models in representing an object (diamond & graphite) and an idea or a concept (structure). The students' responses are evidence that showed that they did not understand the chemistry concepts presented using models. Hence, there is a need to use models with care and to clearly enunciate the limitations when explaining chemistry abstract concepts such as structure and bonding of substances such as diamond and graphite.

5.6.3. Overlapping similar concepts

Students' tendencies to confuse closely-related concepts have been identified in this investigation, for example the conceptions of valence and delocalised electrons. Students tended to use the term valence electrons when explaining the roles of delocalised electrons as in graphite giving rise to properties such as conductivity.

5.6.4. Inability to visualise the sub microscopic nature of matter

Students' inability to visualise the sub microscopic nature of matter represents a major area of difficulty in developing a sound conceptual understanding of the structure, bonding and physical properties of diamond and graphite. The difficulties students' experience because of the abstract, unobservable, sub microscopic basis of chemistry were widely recognised within the Piagetian epistemological framework (Garnett, *et* al, 1995), as students may not be able to think abstractly. Therefore it is crucial to use appropriate concrete models to help students to visualise the particulate nature of matter, using for instance approaches, which include students drawing and discussing diagrammatic representations of the particulate basis of chemical reactions (Laverty & McGarvey, 1991).

Furthermore Johnstone (1991) highlighted the difficulties for students associated with rapid transfer between what he describes as three levels of thought: the macroscopic, sub microscopic and symbolic. Chemistry educators operate across these levels of thought quite easily and swap from one mode of thinking to another without effort. From this study, it appears that these students have most difficulty in dealing with sub microscopic which is, of course, outside their experience and can only be made accessible to students through the use of models, analogies or computer graphics.

5.6.5. Inadequate prerequisite knowledge

The lack of important prerequisite knowledge is another factor, which can lead to misconceptions as new concepts are introduced. For example, students with inadequate understandings of the nature of chemical bonding - forces holding atoms in a substance, are likely to experience considerable difficulties in understanding intermolecular attractive forces - forces holding molecules together. While most educators recognise the importance of this idea, it seems that classroom practice does not give the issue the recognition it deserves. As Ausubel (1968) proposed: "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Johnstone, 2000; p. 13). More emphasis needs to be placed on identifying, prior to instruction, the extent to which students have acquired prerequisite knowledge.

5.6.6. Influence of cultural practice

The Samoan culture has always highly valued in education. Unlike New Zealand and other Western societies, Samoans believe that knowledge of the past like all other forms of knowledge is passed from one generation to another by word of mouth. With this in mind, the students believe that the knowledge of all things including chemistry is passed down from adults and teachers, and so it is respected as correct and a valuable knowledge to acquire. However, if teachers do not hold correct conceptions, their misconceptions are passed onto students who will not query or challenge.

Faaaloalo (respect) is huge and most important in the *faasamoa* (Samoan way of life) because the culture is built upon it. *Faaaloalo* is involved somehow in everything the Samoan people do. It begins in the home and expands into the inbred values and standards that Samoan's live by. Most Samoans teach faaaloalo because it keeps their children disciplined and polite. Asking or questioning parent or adults may be considered rude and therefore students refrained from asking teachers while in school. Teachers, however, need to be sensitive by trying to get students out of this thinking square and engage in meaningful and collaborative learning.

5.6.7. Language use and teachers' accent

Teachers may be unaware that misconceptions in chemistry can arise from problematic language use in chemistry. Language is fundamental to all areas of learning, however, if the message is not clearly expressed and understood by students, then learning becomes difficult. In school B, the students had difficulties to hear and understand chemistry lessons because the teacher talked really fast and the teacher's distinctive foreign accent. The pronunciations of some of the scientific terminologies dictated by the teacher were even hard to identify. Consequently, the students remained quiet throughout the lesson with confidence that the notes given at the end of the lesson would cover all that was discussed. These notes were often written on the board by one of the students, as the teacher was unable to stand and write.

5.7 Conclusion

This chapter examined a sample of misconceptions specific to the structure, bonding and properties of diamond and graphite. The students' responses to the interview questions demonstrate that misconceptions are not only extensive but also suggest possible origins contributing to their development. These factors are diverse depending on the context as well as how the chemistry concepts were delivered by the teacher and received by the learner.

Upon identification of the various origins of misconceptions, the researcher carefully examined and developed specific strategies intended to correct misconceptions, and to help improve the conceptual understanding of these concepts. These are discussed in detail in chapter six.

Chapter 6 - DISCUSSION

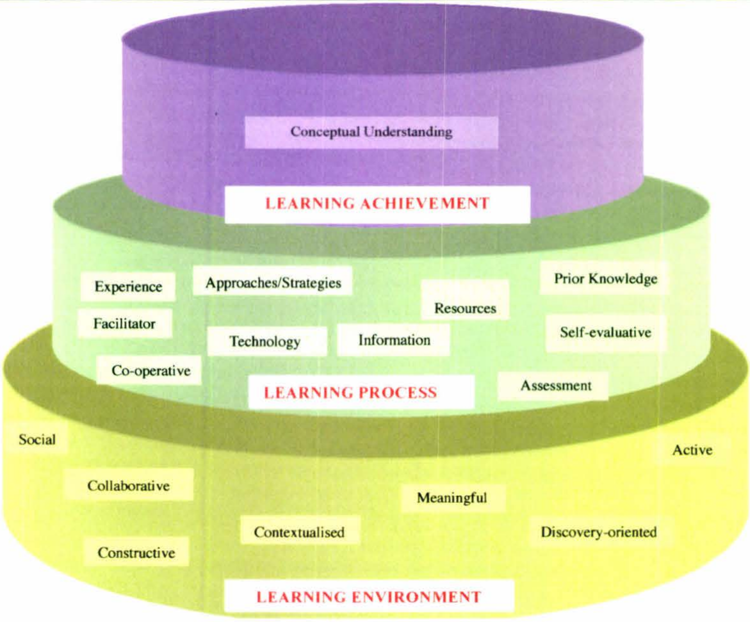
6.1 Introduction

The fundamental of the Learning Theories and Models for Learning established foundations of the development and identification of appropriate teaching and learning strategies in this study. With the knowledge of the theories and models for learning, the researcher developed models, which demonstrate the designs, methods and procedures underpinning this study. Clear justifications of these strategies are discussed throughout this chapter.

6.2 The foundation of ideas

The Conceptual Model for Learning (figure 6.1) focuses primarily on various ways to improve students' conceptual understanding in chemistry. The learner must be presented with an "environment that is effective, purposeful and meaningful which is Vykotsky's focus on nurturing positive growth in the learner" (Kublin, Wetherby, Crais, & Prizant, 1989; p. 287). The learning process should be a combination of approaches, methods, skills and knowledge that appreciate the learner's prior knowledge and experiences.

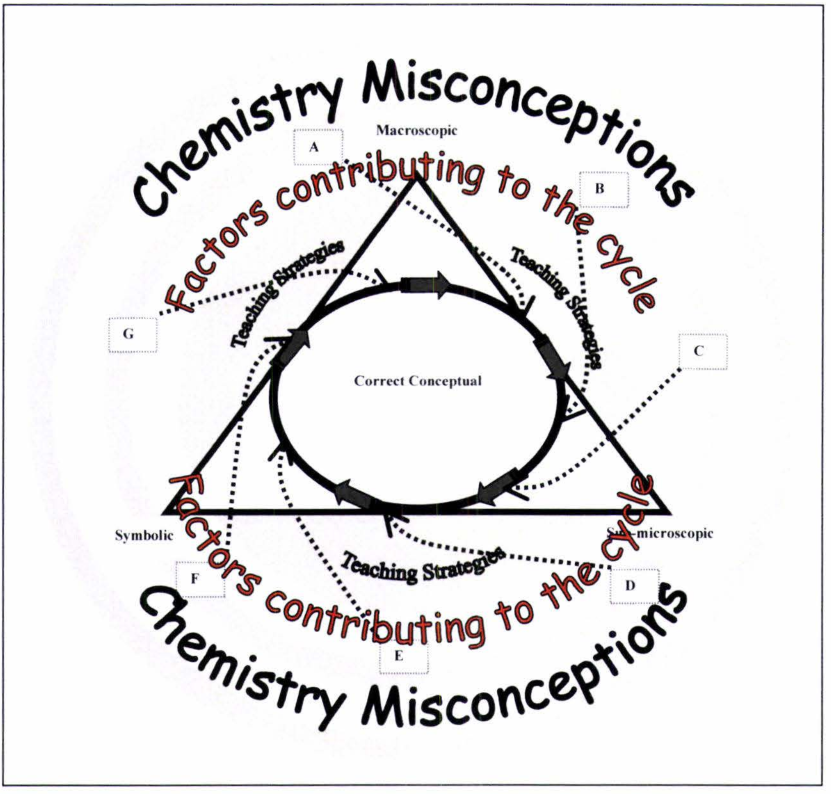
Figure 6.1: Conceptual Model for Learning



Adapted from: Suaalii & Bhattacharya (2007), p. 104

Based on this model, the current study focuses specifically on the learning process (Level 2) – the strategies and methods, skills and knowledge of the learner. In fact, the researcher looked beyond the scope of this level and investigated some of the issues that hindered the successful development of the learning process. Integrating this idea with the work of Johnstone's ideology of chemical representations developed another model (figure 6.2), which recapitulates the findings of the current study.

Figure 6.2: The developed 'Model for Teaching and Learning Chemistry'



The exterior layer of the model classifies *'Chemistry Misconceptions'* as the study proposed to identify. This illustrates that misconceptions are considered in the study as the most threatening factor to the development of correct conceptual understanding of chemistry as well as the development of chemistry education. In order for the learner to attain this understanding, teachers need to carefully consider learners' preconceptions and identify chemistry misconceptions.

Upon identification of the misconceptions the researcher tried to reveal their possible origins through a series of classroom observations and interviews. These factors (A, B, C, D, E, F & G) form the second layer called *'Factors contributing to the cycle'*. For this study in particular, this part of the model is very important, to the teacher and to the learner. By revealing these factors, the teacher becomes aware of the problem and its origin and therefore locates appropriate strategies that may help in correcting these misconceptions. Teaching becomes more focussed on the learner and the knowledge already acquired through their life experiences. In general, "learning is shaped by the diverse experiences, values, and cultural beliefs, which students bring from their informal learning" (Ministry of Education, 1993b; p. 6).

The third part of the model emphasises the development of *'Teaching and Learning Strategies'* based on the factors identified earlier. The selection of these strategies is dependent on the factors uncovered in the previous level, which means that this section varies according to the need and the condition required by both the teacher and the learner. Depending on how the teacher implements these strategies, they should be able to promote effective learning and to help students to reconstruct their own thinking schema and develop correct understanding of scientific concepts.

The strategies and the factors have great influence upon the three levels of chemical representations. Researchers have documented enormous difficulties in understanding and making the connection between the three (Johnstone, 2000; Treagust *et al*, 2003). However, the model suggests that once the external layers are exposed and appropriate strategies are identified, students become capable of transferring knowledge from one representation to another with directions from the teacher. At this stage, the students have passed through the external barriers of learning, making their way through other layers towards achieving *'Correct Conceptual Understanding'*.

6.3 Pedagogical practice, teaching and learning approaches

Research has described an intrinsic "connection between content, knowledge, and the methods and strategies of teaching" (Gabel, 1994, p. 66). This type of teacher knowledge, or "an integration of subject matter with pedagogy, is referred to as pedagogical content knowledge (PCK)" (Shulman, 1986; Gabel, 1994, p. 65). This includes the most useful forms of representation of topics - the most powerful analogies, illustrations, examples and demonstrations that makes it comprehensible to other students. PCK also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and "preconceptions that students of different ages and backgrounds bring with them to the learning context" (Grossman, 1988; Gabel, 1994 p. 66).

Evidence suggests that oral presentations to large groups of passive students contribute very little to real learning (effective learning) even though it was common in this study. Effective Learning is enhanced when we create classroom environments that provide students with opportunities to learn in several ways. Whatever the similarities and differences in learning styles and intelligences among our students, teachers can help all students by employing a range of active learning approaches (talking and listening, writing, reading, reflecting) and varied teaching techniques and strategies (i.e., videos, demonstrations, discovery labs, collaborative & interactive groups, independent projects, simulations and computer softwares, etc.).

Additionally, these roles involve carefully considered instructional designs, instructions, diagnosis and interventions in order to promote correct conceptual understanding and conceptual change. Within the context of conceptual change, the encouragement of metacognition (White & Gunstone, 1989) – explicit/conscious, factual knowledge and implicit/unconscious knowledge; reflective awareness (Driver, 1989) of self-monitoring strategies is also crucial. In particular, it is important to use strategies that support sustained reflection such as the use of concept maps, and multimedia technologies.

Teaching for correct conceptual understanding and conceptual change demands teaching strategies where students are given time to (i) identify and articulate their preconceptions; (ii) investigate the soundness and utility of their own ideas and those of others, including scientists; and, (iii) reflect on and reconcile differences in those ideas. Effective teaching strategies requires a constructive learning environment (Jonassen, 1999), where students construct chemistry knowledge, make sense of chemistry and use chemistry to make sense of the world – Constructivists Learning Theory. Within this kind of environment the students are involved throughout the class time in activities that help construct their understanding of the material that is presented. The instructor no longer delivers a vast amount of information, but uses a variety of activities to promote learning. Teaching then becomes more of facilitating, rather than managing learning and "changing roles from the sage on the stage to a guide on the side" (Davies, 2001; p. 6).

In this next section teaching and learning strategies are described briefly to give teachers some ideas for actively engaging students in their learning. Planning a range of challenging activities for students requires an understanding of their stage of cognitive development and knowledge of their (learners) learning styles. There may be significant differences in the strategies used to create a positive learning environment for students at different stages of development and schooling. However, these are developed specifically to assist in correcting and eliminating the misconceptions revealed from this investigation.

6.3.1 Concept mapping as a tool for collaborative learning

The key to success is ensuring that students are constructing or reconstructing a correct framework for their new knowledge. One way of establishing this framework is to have students create concept maps, an approach pioneered by Novak and Gowin (1984). With this technique, students learn to visualize a group of concepts and their interrelationships. Concept maps harness the power of our vision to understand complex information 'at-a-glance'. It is easier for the brain to make meaning when information is presented in visual formats, i.e., modelling, simulations and concept maps. This is why a picture is worth a thousand words.

A concept map depicts hierarchy and relationships among concepts. It demands clarity of meaning and integration of crucial details. The concept map construction process requires one to think in multiple directions and to switch back and forth between different levels of abstraction. In attempting to identify the key and associated concepts of a particular topic or sub-topic, one will usually acquire a deeper understanding of the topic and clarification of any prior misconceptions.

Using a concept map at the beginning of a topic and again at the end can enable learners to reflect on their own knowledge and identify how much and how well they have learnt. They are especially valuable as a small group activity in which learners have to try to reach a shared understanding of the relationship between the different concepts. This collaborative activity usually generates serious discussion, and the fact that there is no single right answer makes it possible to involve all learners in the discussion. For instance, the participants were asked to construct individual concept maps of their understanding of the examined concepts (Appendix 14; A, B & C). This simple task revealed that individual students had different knowledge and understanding of the concepts, and some held misconceptions. Later, they were asked to examine further in groups and produce the two concept maps in Appendix 15; D & E). The significance of the second part of the activity aimed at promoting students' collaboration and cooperation while working on a learning activity to achieve better understanding and conceptual change.

6.3.2 The significance of model representations in chemistry learning

Chemistry is a conceptual subject and, in order to explain many of these concepts, models are used to describe and explain the microscopic world. The importance of models in the teaching and learning of chemistry lies in their unique power to communicate the essential visual aspects of the objects in question (McBeath, 1994). For example, the model in figure 5.7 shows how the carbon atoms (in diamond) would be arranged. There is no other method that could bring such arrangement into real life situations, except by modelling and the use of the technology. However, it is important to clarify that these models have limitations so that students do not take a different meaning from the model than that intended by the teacher, or the purpose of the model. For example students may:

- learn the model rather than the concept it is meant to illustrate;
- lack the necessary visual imagery to understand the model;
- lack awareness of the boundary between the model and the actual concept the model is representing; and,
- miss some key attributes and so misunderstand the purpose of the model.

Overcoming such learning difficulty requires careful teaching that focuses quite consciously on the model as an idea, an event, a process or a system. It is crucial that the teacher:

1. Introduces the idea that the model is intended to show and find out what ideas students have about that event or pattern;
2. Carry out the modelling activity. During the activity, or at the end if more appropriate, talk about how the model/modelling activity is 'like' what would really be happening and how it is 'different';
3. Ensures that the analysis of the model could also include a discussion of how the model shapes a particular view of 'reality'. An analysis would focus on:
   - Identification of the positive features of the model (what is deliberately chosen to represent 'reality');
   - Identification of the negative features of the model (what is deliberately excluded);
   - Identification of the neutral features (what is ignored or not commented on).
4. Return to the 'big idea' at the end and let the students explain to you the sense they have made of the activity. Some students (gifted) could analyse the model for themselves after some practice runs and their comparisons could be used to assess their new learning. Students may continue to need help do this for every new model used.

(Demircioglu, Ayas and Demircioglu 2005)

6.3.3 Using simulations, animations, technology and other techniques to teach chemistry concepts

a. Simulations and animation

Computer simulations and animations are usually excellent tools for education. Animations show step-wise sequences of diagrams, numbers, or images to illustrate complicated concepts such as that of the structure, bonding and related properties of diamond and graphite. Simulations, on the other hand, are imitations of systems for users. The user enters or alters certain parameters, and the computer will reveal the consequences or changes. Experiments using real systems are the best way to explore science, and simulations offer students alternative ways to discover when real systems are not available (due to lack of resources) or impossible to setup.

Integrating technology into the teaching of chemistry is proving to be valuable for enhancing and extending the learning experience (Hollingsworth, 2002). Modern multimedia technology offers exciting possibilities to provide students with opportunities to observe through simulation the sub microscopic nature of matter in its various states and forms and the interactions and processes underlying physical and chemical changes. Simulations are the next best things to 'real' experience with applied course content. They offer access to what is otherwise too small to be seen (sub microscopic level), too expensive and too dangerous to handle. With animations, students pay more attention to learning material and are more motivated. Animations are also good for introducing a topic instead of having to read lots of text.

Laboratory experimentation is a crucial part of the education of a chemist, and as a direct result of this, fundamental university-level chemistry courses often require a practical component for them to be considered recognized in the science community (Kennepohl, 2001). The computer has played many roles in the modern teaching laboratory including being used for pre-laboratory tutorials, interactive quizzes, molecular modelling and theoretical calculations, animations, collaborative learning, as well as a tool to speed up data collection and analysis. A study of the students' experience and their performance compared to those who did not use simulations showed that simulation students completed work in a shorter time frame and showed a slightly higher performance in the practical laboratory component (Kennepohl, 2001).

Research on classrooms that implement constructivist teaching and learning models indicate that technology enhances student engagement and productivity (Jones, Palinscar, Ogle & Carr, 1987). The emphasis here is that teaching and learning must be based on the premise that cognition (learning) is the result of 'mental construction' (Caine & Caine, 1991). In other words, students learn by fitting new information together with what they already know. Constructivists, on the other hand, confirm that this knowledge construction is affected by learning environments, which are also known as instructional systems that:

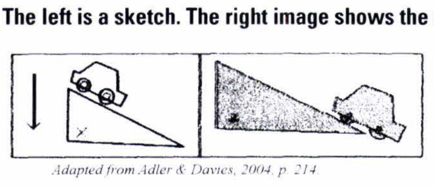
- engage learners in realistic, authentic, complex and information-rich learning contexts;
- support intentional self regulated learning;
- engage learners in complex problem solving (Bhattacharya, 2004).

b. Technology and other techniques

While drawing and sketching are widely used in chemistry, the drawing and sketching alone may not tell the whole story as shown in this study, because some information is notoriously difficult to express using sketching and drawing alone. Drawing and sketching are often accompanied by speech that, while informal, still conveys a considerable amount of information. Therefore it is important for teachers to consider using a 'multimodal interactive system' in which the user can have a natural conversation with the computer (Adler & Davis, 2006). Such system allows the user to talk without prior calibration of the system and without having to warn the system before each utterance. The user sketches in a natural fashion and recognizes mechanical systems, and then interfaces with a simulation tool to allow users to view their sketch in action.

A system known as ASSIST lets users "sketch in a natural fashion and recognises mechanical components (axle, pulleys, etc)" (Adler & Davies, 2004, p. 214). Sketches can be drawn with any variety of pen-based input (e.g., tablet PC). Figure 6.3 displays a user's sketch (left) and interfaces with a simulation tool to show users their sketch in action (right).

Figure: 6.3: The left is a sketch. The right image shows the simulation



Adapted from Adler & Davies, 2004, p. 214

Although this is a new technique, it can be used to provide animations of what the teacher intends to present during the lesson. It is often hard to find simulations for specific concepts, for example the mobility of non-bonding electrons in graphite; and therefore 3D models are used. Sometimes teachers tend to make sketches and drawings to illustrate the structure and bonding within diamond. While teachers and students are attempting to explain these concepts the multimodal interactive system is the easiest and the fastest technique that provides a closer picture of the unobserved phenomena.

6.3.4 Teaching chemistry at a distance

Distance education refers to the educational processes and systems in which all or significant proportions of the teaching are carried out by someone at a distance. It requires structured planning, well-designed courses, special instructional techniques and methods of communication by electronic and other technology. The students are introduced to a variety of learning strategies; collaborative, conversational and reflective by interacting with people outside of their normal face-to-face classroom, as well as gathering different views and perceptions through the use of technology.

The underlying philosophy of distant learning is getting the community involved in the learning process. It allows people from the local community or from neighbouring countries (NZ, Fiji, Tonga, and Australia) to share ideas with individual students and build new knowledge as opposed to exposure to only one chemistry teacher like school B. This of course minimises the embarrassment and discomfort that some students possess as observed in school B.

Technology provides adaptivity towards contextual life-long learning, which is defined as the knowledge and skills people need to prosper throughout their lifetime (Kinshuk & Goh, 2003). These activities are not confined to pre-specified times and places and are difficult to achieve through traditional education. VanSickle (2003) confirms that distance education requires 'learning technologies that offer a multitude of benefits, including convenience, flexibility, effectiveness, interactivity, equity and efficiency', but whether schools or families have these technologies or not is another case to consider.

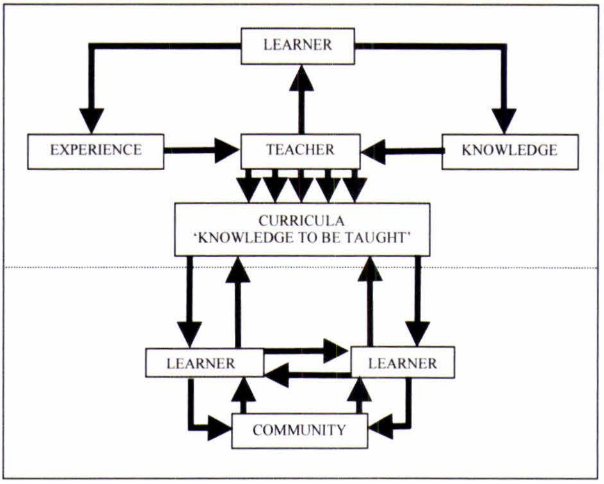
Technologies provide students' access to tutors during the early evening hours or on weekends (or at any time). Depending on the system, the tutors can work at their own homes or at a central location, such as the school, to mentor the remote students. Cross-age mentoring is also possible with older students helping younger students by means of distant learning. Distance education can also be used to enhance collaboration between students, teachers or tutors, in remote classrooms.

6.4 A new paradigm

The intention of the researcher is to change the paradigms observed in the two settings from a didactic approach to an approach that ensures the promotion of conceptual knowledge. The teaching and learning strategies described above and the ideas underlying the study altogether contribute to the development of a new paradigm known as Conceptual Knowledge Paradigm (figure 6.3). This paradigm promotes conceptual learning.

The model emphasises the learners' experience and prior knowledge to be the start of all teaching. The teacher must be able to elicit these experiences using open-ended questions or concept mapping. Upon identification of these, the teacher must undergo a series of analyses and evaluation (as the study explored) to determine the students' preconceptions, conceptions, misconceptions or the extent of their understanding about a concept. The analyses enable the teacher to select and develop a series of strategies like those described above to promote conceptual understanding of a specific topic or a concept. Together with these strategies, the teacher combines the experience, knowledge (of students) and the curriculum into a body of knowledge to be taught.

Figure 6.4: Conceptual knowledge paradigm



The lower part of the model really focuses on the learning environment: that is, implementing these strategies to facilitate the delivery of the 'knowledge to be taught'. For instance, modelling can be used to represent an idea to be used in enquiries to develop explanations of it, or, using animations or simulations and technology as ways of raising the quality of explanations. Distance education encourages students to engage with the community, tutors, or experts outside of the classroom. The bottom line is to create a meaningful learning environment for the students, which is contextual, authentic, interactive, collaborative, responsible, active, intentional, conversational and reflective (Jonassen *et al*, 1999).

6.5 Conclusion

The discussion in this chapter emphasises the development of the *'Model for Learning Chemistry'*. The model suggests an effective system for developing correct conceptual understanding and eliminating chemistry misconceptions. Four teaching and learning strategies are identified as appropriate to help teachers and students in achieving such a goal. The development of the Conceptual Knowledge Paradigm aims at replacing the current paradigms, and promotes cooperative, collaborative and constructive learning as well as involving the community in the learning process. The teachers' roles in implementing, sustaining, and monitoring the successful effects of these strategies are very important.

The final chapter (chapter 7) of the study describes some of the major findings from this investigation as well as some recommendations for future research in this area. This chapter is organised so that a conclusion is formed based on the materials presented in each chapter.

Chapter 7 – CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

Chapter seven summarises the outcomes and the major findings of this study and recommendations for future research in this area are also stated.

7.2 Major findings of the study

This section summarises the research questions that were addressed in this study.

a. What are the misconceptions in the structure, bonding and related properties of diamond and graphite?

The study identified misconceptions that these students hold about the structure, bonding and related properties of diamond and graphite. These misconceptions were revealed by administering an open-ended question. Surprisingly enough, the analyses of the students' responses revealed that more than 50% of the participants held misconceptions about the structure, bonding and related properties of diamond and graphite. These misconceptions contribute extensively to the difficulties in the development of correct chemistry knowledge as shown by the persistent development of misconceptions during the interview. The following is a list of the misconceptions about the structure, bonding and related properties of diamond and graphite identified in this study:

- *Graphite is made of 2-D lattice*
- *Electrons hold the layers of graphite together*
- *Layers in graphite are bonded by delocalised electrons*
- *The layers of graphite are separated by layers of free electrons*
- *The delocalised electrons cause the layers in graphite to slide over each other*
- *Intermolecular 'bonds' in graphite are weaker*
- *The structure of graphite allows the flow of electricity between the layers*
- *The 3-D lattice of diamond makes it harder*
- *C-C bonds makes diamond the hardest*
- *Diamonds are harder because there are no delocalised electrons*
- *Diamond is a bad conductor of electricity*
- *Diamond has ionic bonding & therefore has higher melting point*
- *Diamond and graphite are organic compounds*
- *Diamonds and graphite are made up of large lattice of electrons*
- *Diamond & Graphite are isotopes of carbon*
- *Diamond and graphite are isomers of carbon*
- *Graphite has weaker Vander Waals than those present in diamond, therefore has lower melting and boiling points*
- *Weak force holding graphite's molecule, therefore it is weaker with a lower melting point*
- *Graphite is a good conductor of electricity because it has 1 lone pair*
- *Graphite can conduct electricity because it has 1 lose electron*
- *In graphite, the layers move over each other causing it to be soft (like pencil layers come off)*
- *There is a gap/space between the layers in graphite for electricity to flow through*
- *In diamond, the atomic bond is stronger therefore it is harder, higher melting point*

- *Diamond has a valency of four, and has high electronegativity*
- *Ionic bond is present in diamond; therefore it is very strong, high melting point*
- *Bonding force between atoms in diamond are stronger than those in graphite*
- *Diamond is highly reactive and more stable while graphite is least reactive*
- *Diamond is made up of strong molecules, forming a strong metal-diamond*
- *Diamond has a triangular shape*
- *Diamond is a bad conductor of electricity*
- *Atoms are closely bonded together causing diamond to be hard*
- *No valence electrons therefore, no conduction of electricity in diamonds*
- *Diamond has stronger intermolecular bond causing high melting point*
- *Graphite and Diamond are practically the same, due to the number of protons and neutrons*
- *Diamond and graphite have different properties due to their different electron arrangement*

b. What are the possible origins of these misconceptions?

Central to this study was the identification of possible origins of the revealed misconceptions. The investigation identified seven possible origins of the misconceptions after a sample of eight students were interviewed. These are:

1. *Oversimplification of chemistry concepts and the use of unqualified, generalised statements and analogies*
2. *Incorrect interpretation of model representations*
3. *Overlapping similar scientific concepts*
4. *Inability to visualise the sub microscopic nature of matter*
5. *Inadequate prerequisite knowledge*
6. *Influence of Cultural practice*
7. *Language use and teachers' accent*

c. What sorts of approaches are effective for teaching and learning chemistry in the classroom?

With these possible origins of misconceptions, the researcher identified and developed appropriate teaching and learning approaches particularly for high school chemistry. The approaches intend to eliminate and correct the misconceptions as well as promoting conceptual understanding about the structure, bonding and related properties of diamond and graphite. The approaches are:

1. Concept Mapping as a tool for collaborative learning
2. The significance of model representations in chemistry learning
3. Simulations, Animations, Technology and other Techniques to teach chemistry concepts
4. Teaching chemistry at a Distance

Despite the differences already discussed about the two research sites; in terms of resources available, cultural backgrounds, teaching and learning strategies used, education systems and assessment, the investigation showed a considerable number of similar misconceptions. For example in Appendix 10), concepts 12 and 25 are the same.

- Concept 12: Diamond has ionic bonding & therefore has higher melting point - School A
- Concept 25: Ionic bond is present in diamond; therefore it is very strong, high melting point - School B

Chemistry instruction in Samoa is essentially subject matter centred. The major objective is to give the student a firm foundation of chemistry knowledge and experience with the scientific method, so that the students succeed in high school-level courses and pass external exams (PSSC). In New Zealand the focus is also to give the students the knowledge to succeed in high school and pass external assessments (NCEA). The difference is that in School B, there is a heavy emphasis that is placed on understanding chemistry concepts as it related to the environment and on environmental and evaluative aspects of scientific inquiry.

7.3 Recommendations for further research

Possibilities for future research are never-ending, but some suggestions are mentioned here. An extension of this study, which explores the successful implementation of the strategies identified, would show whether correct conceptual understanding of scientific concepts, particularly, structure, bonding and related properties of diamond and graphite, has really occurred or whether there is an increase in the development of misconceptions in these concepts. It would also be interesting to follow the same students into university and see whether the same misconceptions occur, or whether new ones develop and how their learning of chemistry progresses.

More work needs to be done to investigate the students' misconceptions and provide a better means of discerning types of misconceptions and differentiating misconceptions from simple errors of terminology. It is also necessary that the misconceptions could occur while the topic was presented, so it would be interesting to collect data regarding how the material was taught.

7.4 Concluding remarks

A conclusion to the comparative study of the two research sites (Samoa and New Zealand high schools) is that there are common misconceptions about the structure, bonding and related properties of diamond and graphite. However, the origins which generate these misconceptions are different, and therefore, the adoption of teaching and learning strategies and the development of the learning environments should reflect and cater for the differences. Students learn in different ways and it is crucial that the teachers employ a variety of strategies to stimulate the learning process.

It is hoped that teachers become aware of the impacts of misconceptions in the light of the findings of this study. Despite the many differences and similarities described in the study; if teachers are not aware of the misconceptions and their origins, students will eventually come to view chemistry as the hardest and therefore choose to study another subject. The imperative aspect in identifying students' prior knowledge and misconceptions generated the development of several learning models throughout the study. These models are learner-based and they were developed to cater for the needs of the learner. However, the works of the theorists are reflected and form the foundations to these models.

Teachers must encourage themselves to investigate students' knowledge to uncover the misconceptions and their origins. Teachers need to identify, develop, and use appropriate strategies to help students construct new knowledge, and eliminate and correct their own misconceptions. Together, these factors and strategies improve pedagogical practice aiming at enhancing the teaching and learning of chemistry.

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Appendix One: Low Risk Notification Approval

Massey University

OFFICE OF THE ASSISTANT
TO THE VICE-CHANCELLOR
(ETHICS & EQUITY)
Private Bag 11 222
Palmerston North
New Zealand
T 64 6 350 5573
F 64 6 350 5622
humanethics@massey.ac.nz
www.massey.ac.nz

14 February 2006

Faguele Suaalii
[redacted]

Dear Faguele

Re: Misconceptions in Chemistry: A Comparative Study of Samoan and New Zealand High Schools to Identify their Different Origins and Approaches to Eliminate and Correct Them

Thank you for your Low Risk Notification which was received on 14 February 2006.

Your project has been recorded on the Low Risk Database which is reported in the Annual Report of the Massey University Human Ethics Campus Committees.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by a campus human ethics committee.

A reminder to include the following statement on all public documents:

> *"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.*
>
> *If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor Sylvia Rumball, Assistant to the Vice-Chancellor (Ethics & Equity), telephone 06 350 5249, e-mail humanethicspn@massey.ac.nz".*

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to a Campus Human Ethics Committee. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

Sylvia Rumball

Sylvia V Rumball (Professor)
Chair, Human Ethics Chairs' Committee and
Assistant to the Vice-Chancellor (Ethics & Equity)

cc Dr Madhumita Bhattacharya
Department of Technology, Science and Mathematics Education
PN900

Assoc Prof Glenda Anthony, HoD
Department of Technology, Science and Mathematics Education
PN900

Ms Caroline Teague
Graduate School of Education
PN900

Massey University Human Ethics Committee
Accredited by the Health Research Council

Te Kunenga ki Pūrehuroa

Appendix Two: Letter to Ministry of Education

Massey University
COLLEGE OF EDUCATION
Te Kupenga o Te Mātauranga

SCHOOL OF CURRICULUM AND PEDAGOGY
Private Bag 11 222
Palmerston North
New Zealand
T 64 6 356 9099
F 64 6 351 3472
www.massey.ac.nz

Re: Survey Investigation

Dear Sir,

My name is Faguele Suaalii. I am a married 33-year-old chemistry teacher formerly teaching at ___________. I am currently undertaking Masters in Education at Massey University, Palmerston North.

As part of the master's program, I am required to conduct a Research Investigation on any area of interests to create new knowledge and utilise the scholarship of application to refine and improve classroom practices. This, I believe will be of great help to improve classroom teaching and learning in Samoa, particularly in science education.

For that reason, I have decided to research into the area of chemistry education in Samoa secondary school. My topic is therefore; "A comparative study of Samoa and NZ high schools to identify the different sources of chemistry misconceptions and approaches to eliminate these problems".

My role is to pose an *open question* on a specific concept in year 13 chemistry, and students will respond based on their understanding of the given concept. The aim of this investigation is to explore students' conceptual understanding through analysis of written or drawn responses to the open question. The analyses will reveal the different sources of chemistry misconceptions compare to New Zealand schools. The researcher will then develop effective teaching approaches to eliminate these problems.

So, with due respect, I would like to ask for your permission to conduct this survey investigation in the following school.

As the requirement of the master's program is concerned, the proposed starting date for this investigation is mid March so that a full report of the progress is submitted back into Massey University by June. This investigation is designed to collect data in Samoa for a maximum of two months.

All efforts will be taken to maximise the confidentiality and anonymity of all participants, which means that their names will not be used in this study. Students will be given consent form before the actual survey.

Let me assure you that the data from this investigation will only be used in completing this research investigation for the paper 180.793, conducted by Dr. Bill Anderson and he is very happy to discuss any concern with this task at any time.

His contact details;

Telephone: +64-6-350 5799 ext 8871
Fax +64-6-351 3383
Email: W.G.Anderson@massey.ac.nz.

My supervisor Dr. Madhumita Bhattacharya will also be available to discuss any concern with this task at any time.
Her contact details;
Telephone: +64-6-356 9099 ext 8875
Fax: +64-6-351 3472
Email: m.bhattacharya@massey.ac.nz

I can be contacted by the address above or;
Telephone: [redacted], or (+64) 6 356 9099 ext 8842
Mobile: [redacted]
Email: [redacted]

I request for your prompt reply in this matter. Your attention is much appreciated.

Faguele Suaalii

Appendix Three: Letter to School Principals

Massey University

COLLEGE OF EDUCATION
Te Kupenga o Te Mātauranga

SCHOOL OF CURRICULUM
AND PEDAGOGY
Private Bag 11 222
Palmerston North
New Zealand
T 64 6 356 9099
F 64 6 351 3472
www.massey.ac.nz

Principal College

Re: Research Investigation

Dear Sir,

Talofa lava, my name is Faguele Suaalii. I am a married 33-year-old chemistry teacher formerly teaching at ______________. I come from Savaii, Samoa, and currently living in Palmerston North (New Zealand) undertaking Masters Degree at Massey University.

As part of the master's program, I am required to conduct a Research Investigation on any area of interests to create new knowledge and utilise the scholarship of application to refine and improve classroom practices. For that reason, I have decided to research into the area of chemistry education in Samoa secondary school. I believe this will be of great help to improve classroom teaching and learning in Samoa, particularly in chemistry education. My topic is, "Misconceptions in Chemistry: A comparative study of Samoan and New Zealand high schools to identify their different origins and approaches to eliminate and correct them".

My role is to pose an open question on a specific concept in year 13 chemistry, and students will respond based on their understanding of the given concept. The aim of this investigation is to explore students' conceptual understanding through analysis of written or drawn responses to the open question. The analyses will reveal the different sources of chemistry misconceptions compare to New Zealand schools. The researcher will then develop effective teaching approaches to correct and eliminate these problems.

So with due respect I would like to ask for your permission to conduct this research investigation at your school. For your information, I had made a request through the ______________________________ and permission had been granted. Let me assure you that all efforts will be taken to maximise students' confidentiality and anonymity of all participants, which means that the participants' names and school's name will not be used in this study.

If you have any questions about this study you are welcome to discuss it with me personally, or phone me on [redacted] or contact my supervisor, Dr. Madhumita Bhattacharya, at (+64) 6 356 9099 ext 8875 or email m.bhattacharya@massey.ac.nz

Your attention is much appreciated.

Faguele Suaalii

Appendix Four: Letter to Chemistry Teachers

Massey University

COLLEGE OF EDUCATION
Te Kupenga o Te Mātauranga

SCHOOL OF CURRICULUM
AND PEDAGOGY
Private Bag 11 222
Palmerston North
New Zealand
T 64 6 356 9099
F 64 6 351 3472
www.massey.ac.nz

Dear Teacher,

Talofa lava, my name is Faguele Suaalii. I am a married 33-year-old chemistry teacher formerly teaching at ______________. I come from Savaii, Samoa, and currently living in Palmerston North (New Zealand) undertaking Masters Degree at Massey University.

As part of the master's program, I am required to conduct a Research Investigation on any area of interests to create new knowledge and utilise the scholarship of application to refine and improve classroom practices. For that reason, I have decided to research into the area of chemistry education in Samoa secondary school. I believe this will be of great help to improve classroom teaching and learning in Samoa, particularly in chemistry education. My topic is, "Misconceptions in Chemistry: A comparative study of Samoan and New Zealand high schools to identify their different origins and approaches to eliminate and correct them".

My role is to pose an open question on a specific concept in year 13 chemistry, and students will respond based on their understanding of the given concept. The aim of this investigation is to explore students' conceptual understanding through analysis of written or drawn responses to the open question. The analyses will reveal the different sources of chemistry misconceptions compare to New Zealand schools. The researcher will then develop effective teaching approaches to correct and eliminate these problems.

So with due respect I would like to ask for your permission to conduct this research investigation in your class. [For your information, I had made a request through the ______________________________ and permission had been granted]. Let me assure you that all efforts will be taken to maximise students' confidentiality and anonymity of all participants, which means that the participants' names and school's name will not be used in this study.

If you have any questions about this study you are welcome to discuss it with me personally, or phone me on [redacted] or contact my supervisor, Dr. Madhumita Bhattacharya, at (+64) 6 356 9099 ext 8875 or email m.bhattacharya@massey.ac.nz

Your attention is much appreciated.

Faguele Suaalii

Appendix Five: Letter to Potential Research Participants

Massey University
COLLEGE OF EDUCATION
Te Kupenga o Te Mātauranga

SCHOOL OF CURRICULUM
AND PEDAGOGY
Private Bag 11 222
Palmerston North
New Zealand
T 64 6 356 9099
F 64 6 351 3472
www.massey.ac.nz

Re: Survey Investigation

Dear participant,

My name is Faguele Suaalii. I am a married 32-year-old chemistry teacher formerly teaching at ________________. I am currently undertaking Masters in Education at Massey University, Palmerston North.

As part of the master's program, I am required to conduct a Research Investigation on any area of interests to create new knowledge and utilise the scholarship of application to refine and improve classroom practices. This, I believe will be of great help to improve classroom teaching and learning in Samoa, particularly in science education.

For that reason, I have decided to research into the area of chemistry education in Samoa secondary school. My topic is therefore; *"A comparative study of Samoa and NZ high schools to identify the different sources of chemistry misconceptions and approaches to eliminate these problems"*.

My role is to pose an *open question* on a specific concept in year 13 chemistry, and students will respond based on their understanding of the given concept. The aim of this investigation is to explore students' conceptual understanding through analysis of written or drawn responses to the open question. The analyses will reveal the different sources of chemistry misconceptions compare to ________ schools. The researcher will then develop effective teaching approaches to eliminate these problems.

All you have to do is answer the given question. If you decide that there is no exact answer, but a vast number of ideas that relate to it, please write as many as you can.

All efforts will be taken to maximise your confidentiality and anonymity of all participants, which means that your names will not be used in this study.

If you have any questions about this study you are welcome to discuss it with me personally, or phone me on [redacted] or contact my supervisor, Dr. Madhumita Bhattacharya, at (+64-6-356 9099 ext 8875 or email m.bhattacharya@massey.ac.nz

Your attention is much appreciated.

Faguele Suaalii

Please make sure you understand the following before signing it. Return it and obtain your question.

Please note that you have the following rights:

- To say you do not want to participate in this survey
- To withdraw from the investigation at any time
- To refuse to allow copies of your written work to be taken
- To ask questions about the investigation
- To participate knowing that you will not be identified at any time
- To be given a summary of what is found at the end of the study

Signature: __________________________________ Date: __________________

Full Name: ____

Appendix Six: Information Sheet

Massey University
COLLEGE OF EDUCATION
Te Kupenga o Te Mātauranga

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Project Title: Misconceptions in Chemistry: A comparative study of Samoan and New Zealand high schools to identify their different origins and approaches to eliminate and correct them.

INFORMATION SHEET

Introduction

Hi, my name is Faguele Suaalii. I am a married 33-year-old schoolteacher currently living in Palmerston North, undertaking Postgraduate studies in Education at Massey University. I lived in Samoa for most of my life except when I had to travel to New Zealand to do undergraduate as well as postgraduate studies. I have worked as a secondary school teacher for 7 years teaching General Sciences in Years 9-11 and chemistry in Yrs. 12 and 13.

The primary objective of this case study research is to identify the misconceptions in chemistry in year 13 through the use of open question strategy, interview & classroom observations. This information will be analysed to produce a report required for the completion of Masters in Education Degree under the supervision of Dr. Madhumita Bhattacharya.

Project Procedures

The data from the open question will be transcribed and analysed to identify major sources of the misconceptions revealed from the study. This will be followed by short interviews to confirm various information if required. The data collected from this investigation will be kept confidential and will only be used by the researcher for this task. These data will also be used to compare with some data collected from New Zealand high schools. The data collected from the investigation will not be of any effect to your grades or assignment in your chemistry program 2006. The main focus is to look at how misconceptions occur and how can we discontinue misconceptions in chemistry.

Participant Involvement

Data will be collected during your chemistry lessons and will only take 10-20 minutes to respond to the open question. The proposed starting time for this investigation is mid March towards the end of the first term (mid May). The number of participants in the first phase will be limited between 15-20; however, in the second phase the research is design to work with a number of between 5-8 participants. If for any reason the researcher requires more information from any of the participants, prior arrangement with the school principal, parents and the participant will be made before the scheduled meeting date.

Participant's Rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study at any time;
- ask any questions about the study at any time during participation:
- provide information on the understanding that your name will not be used unless you allow me to;
- be given access to a summary of the project findings when it is concluded
- I also understand that I have the right to ask for the audio/video turned off at any time during the interview.

Project Contacts

If you wish to discuss any concern or if you have any question about this research investigation, do not hesitate to contact the researcher or the supervisor listed below:

Faguele Suaalii (researcher)
CONTACT INFORMATION
POSTAL ADDRESS:
[redacted]
New Zealand

[redacted]

Dr. Madhumita Bhattacharya (supervisor)
CONTACT INFORMATION
POSTAL ADDRESS:
School of Curriculum and Pedagogy
Massey University
Private Bag 11 222
Palmerston North
New Zealand

Phone: +64 6 356 9099, ext 8875
Fax: +64 6 351 3472
Email:M.Bhattacharya@massey.ac.nz

Compulsory Statements

1. *This project has been evaluated by peer review and judged to be low risk, Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher named above is responsible for the ethical conduct of this research.*

   If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher, please contact Professor Sylvia Rumball, Assistant to the Vice-Chancellor (Ethics & Equity), telephone +64-6-350 5249, email humanethicspn@massey.ac.nz.

Appendix Seven: Participant Consent Form

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Misconceptions in Chemistry: A comparative study of Samoan and New Zealand high schools to identify their different origins and approaches to eliminate and correct them.

PARTICIPANT CONSENT FORM

I have read the Information Sheet and have had the details of the study being explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.
I *agree/do not agree* to the interview being audio taped
I *agree/do not agree* to the interview being video taped
I *wish/do not wish* to have my tapes returned to me.
I *wish/do not wish* to have data placed in an official archive.
I *agree* to not disclose anything discussed in the Focus Group.
I *agree* to participate in this study under the conditions set out in the Information Sheet.

Signature: ______________________________ Date: ______________

Full Name – printed ____

Signature (Researcher):___________________________ Date: ______________

Appendix Eight: Open-ended Question

ATOMIC STRUCTURE AND BONDING

"Structure & Bonding determine the properties of substances."
Discuss the relationship between structure, bonding and related properties of diamond and graphite.

Appendix Nine: The Interview Guide
Interview Questions

A: Structure

1. Make a sketch and name the details of the structures of both diamond and graphite.
2. What would you call the part that you have drawn? [For example, if a student draws dots and/or lines, ask them what they represent.]
3. Can you explain any difference between the structures of the two - diamond & graphite?
4. Can you explain any similarities of the two -diamond & graphite?
5. Can you see any relationship between the structure you have drawn and any physical property of the two - diamond & graphite?

B: Chemical make-up

1. What is diamond made up of?
2. What is graphite made up of?
3. Are there atoms in both diamond and graphite?
4. How would you differentiate the chemical make-up of particles in diamond from graphite?
5. What makes their arrangement differ?

C: Bonding and forces

1. How are the particles within diamond held together?
2. How are the particles within graphite held together?
3. Is there anything between the layers of graphite?
4. What makes bonding in diamond differ from graphite?
5. How many bonding electrons in both graphite and diamond?
6. Explain what happens in graphite in terms of bonding electrons?

D: General

1. Explain what the comment presented in the first phase (given by each participant).

Appendix Ten: Misconceptions revealed

School A

Concept	Misconceptions	Frequency
1	Graphite is made of 2-D lattice	I
2	Electrons hold the layers of graphite together	II
3	Layers in graphite are bonded by delocalised electrons	II
4	The layers of graphite are separated by layers of free electrons	I
5	The delocalised electrons cause the layers in graphite to slide over each other	I
6	Intermolecular 'bonds' in graphite are weaker	I
7	The structure of graphite allows the flow of electricity between the layers	I
8	The 3-D lattice of diamond makes it harder	I
9	C-C bonds makes diamond the hardest	I
10	Diamonds are harder because there are no delocalised electrons	I
11	Diamond is a bad conductor of electricity	I
12	Diamond has ionic bonding & therefore has higher melting point	I
13	Diamond and graphite are organic compounds	I
14	Diamonds and graphite are made up of large lattice of electrons	II
15	Diamond & Graphite are isotopes of carbon	I
16	Diamond and graphite are isomers of carbon	II

School B

Concept	Misconceptions	Frequency
17	Graphite has weaker Vander Waals than those present in diamond, therefore has lower melting and boiling points	I
18	Weak force holding graphite's molecule, therefore it is weaker with a lower melting point	I
19	Graphite is a good conductor of electricity because it has 1 lone pair	II
20	Graphite can conduct electricity because it has 1 lose electron	III
21	In graphite, the layers move over each other causing it to be soft (like pencil layers come off)	I
22	There is a gap/space between the layers in graphite for electricity to flow through	I
23	In diamond, the atomic bond is stronger therefore it is harder, higher melting point	I
24	Diamond has a valency of four, and has high electronegativity	I
25	Ionic bond is present in diamond, therefore it is very strong, high melting point	I
26	Bonding force between atoms in diamond are stronger than those in graphite	I
27	Diamond is highly reactive and more stable while graphite is least reactive	I
28	Diamond is made up of strong molecules, forming a strong metal-diamond	I
29	Diamond has a triangular shape	I

30	Diamond is a bad conductor of electricity	I
31	Atoms are closely bonded together causing diamond to be hard	I
32	No valence electrons therefore, no conduction of electricity in diamonds	I
33	Diamond has stronger intermolecular bond causing high melting point	I
34	Graphite and Diamond are practically the same, due to the number of protons and neutrons	I
35	Diamond and graphite have different properties due to their different electron arrangement	I

Appendix Eleven: Sample Lab Experiment Plan

Standardizing dilute hydrochloric acid solution

To '*standardise*' a solution means to find its exact concentration. You will titrate hydrochloric acid solution against 'standard' sodium carbonate solution (i.e., a solution whose concentration is known exactly).

Materials needed:

[Students have to list them using the procedures of the investigation]

Procedures:

1. Rinse a 50.0mL burette with the standard sodium carbonate solution.
2. Clamp the burette to a stand
3. Fill the burette with (fresh) sodium carbonate solution
4. Rinse a 20.0mL (or 25mL) pipette with the dilute hydrochloric acid solution.
5. Pipette 20.0mL (or 25mL) samples of dilute hydrochloric acid into four clean conical flasks.
6. Add a few drops of methyl orange indicator to each flask.
7. Record the initial reading on a chart like the one below
8. Place one conical flask (containing the acid and the indicator) under the burette and swirl the flask slowly while adding sodium carbonate solution until the indicator changes colour-orange. Record the final burette reading. Keep this flask to provide a reference colour for the next titration.
9. Repeat the titrations until you have done all four conical flasks.

Data:

	Titre 1	**Titre 2**	**Titre 3**	**Titre 4**
Initial burette reading (*I*) mL	0.0	22.7		
Final burette reading (*F*) mL	22.7	43.1		
Volume used (*F* - *I*) mL	22.7	20.4		

Calculations:

1. Calculate the average of the concordant titres

   $V(Na_2CO_3)$ = ______________________________

2. What is the concentration of the sodium carbonate solution

   $c(Na_2CO_3)$ = ______________________________

3. Calculate the amount of sodium carbonate used

   $n(Na_2CO_3)$ = ______________________________

4. Write the balanced chemical equation for the reaction:

   ____

5. What volume of hydrochloric acid (pipette) did you use

   $V(HCl)$ = ______________________________

6. Use the balanced chemical equation to work out the amount of hydrochloric acid used.

   $n(HCl)$ = ______________________________

7. Calculate the concentration of the hydrochloric acid solution:

   $c(HCl)$ = ______________________________

Appendix Twelve: Students' Responses-Phase I

School A

PARTICIPANTS	No response A	No understanding B	Misconception C	Partial understanding D	Sound understanding E
01			✔		
02		✔			
03		✔			
04			✔		
05			✔		
06			✔		
07		✔			
08			✔		
09			✔		
10		✔			
11			✔		
12		✔			
13			✔		
14					✔
15			✔		
16				✔	
17					✔
18			✔		
19			✔		
20			✔		
21		✔			
22			✔		
23		✔			
24				✔	
25			✔		
26				✔	
27				✔	
28			✔		
29				✔	
TOTAL	0	7	15	5	2

School B

30				✓	
31			✓		
32			✓		
33		✓			
34			✓		
35			✓		
36			✓		
37			✓		
38			✓		
39			✓		
40			✓		
41		✓			
42				✓	
43			✓		
44			✓		
45			✓		
46			✓		
47			✓		
48			✓		
49			✓		
50				✓	
51		✓			
52		✓			
53		✓			
54					✓
55					✓
56		✓			
57					✓
58		✓			
59		✓			
60			✓		
TOTAL	0	8	17	3	3

Note: The ticks (✓) represent the participant.

Appendix Thirteen: Textbooks used by teachers in School A [T1 & T2]

1. Croucher, M. and Croucher, P. (2003). *Year 12 Chemistry NZ Pathfinder Series: Level 2.* Auckland: New House Publishers Ltd.

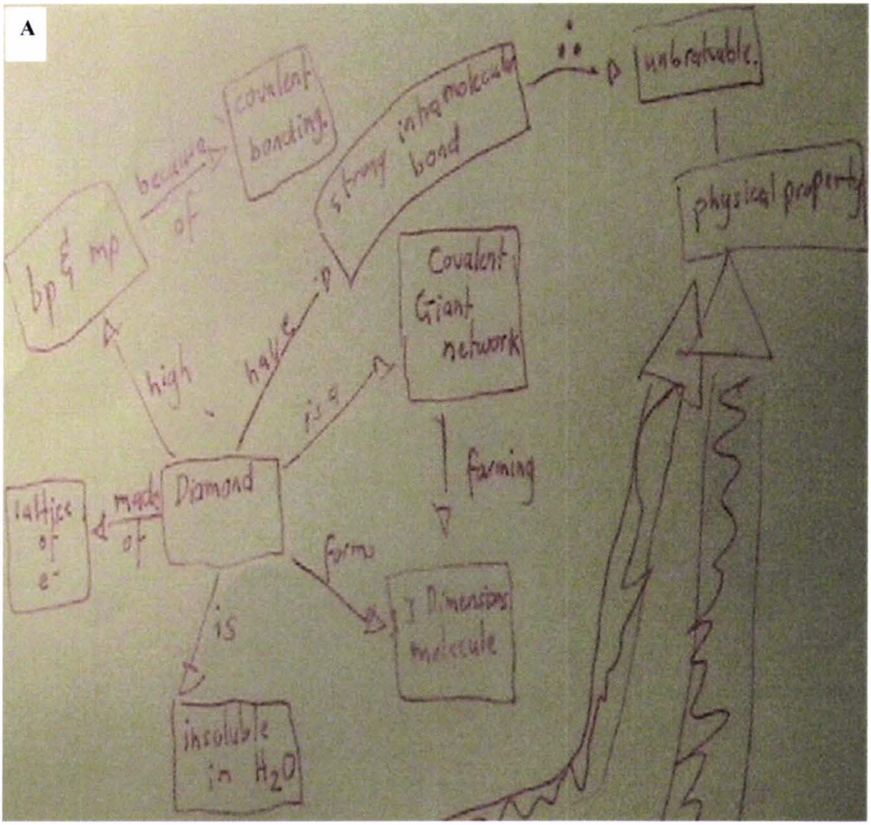
2. Wignall, A., & Wales, T. (1997). Beginning Chemistry. Wesley Longman: New Zealand.

3. Wignall, A., Wales, T. (2001). *Chemistry write on notes for year 12.* Longman, Auckland.

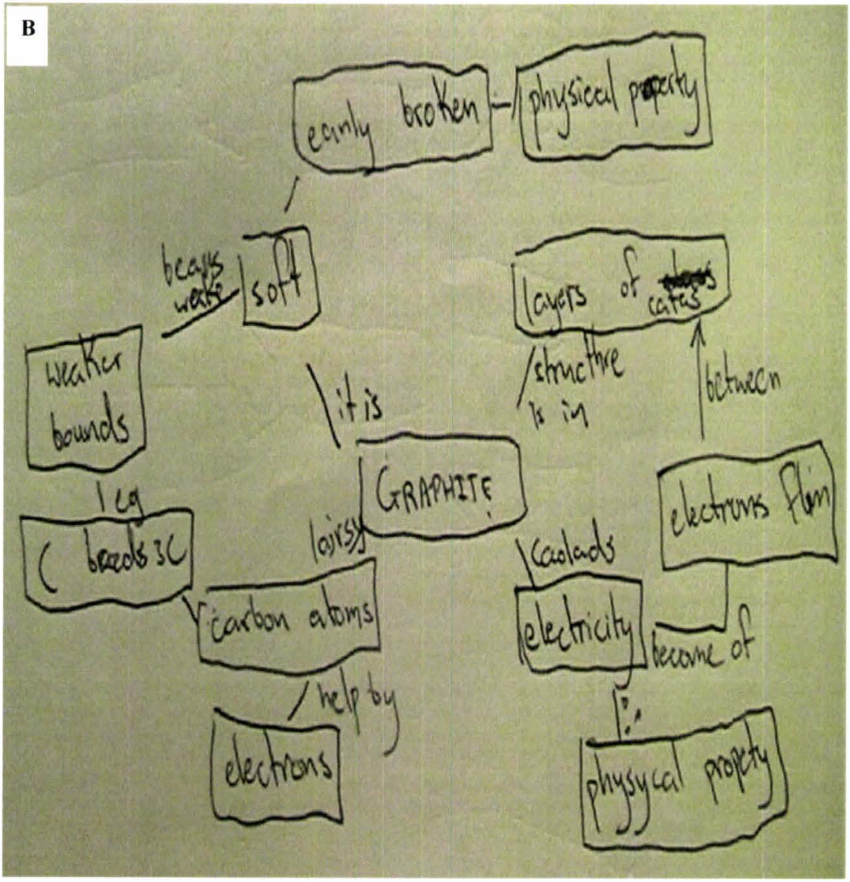
4. Wignall, A., Wales, T. (2002). Core Practicals for Year 12 Chemistry, NCEA Edition. Pearson Education: New Zealand.

5. Croucher, M., & Croucher, P. (2002). *Year 13 Chemistry NZ Pathfinder Series: Level 3.* New House Publisher: Auckland.

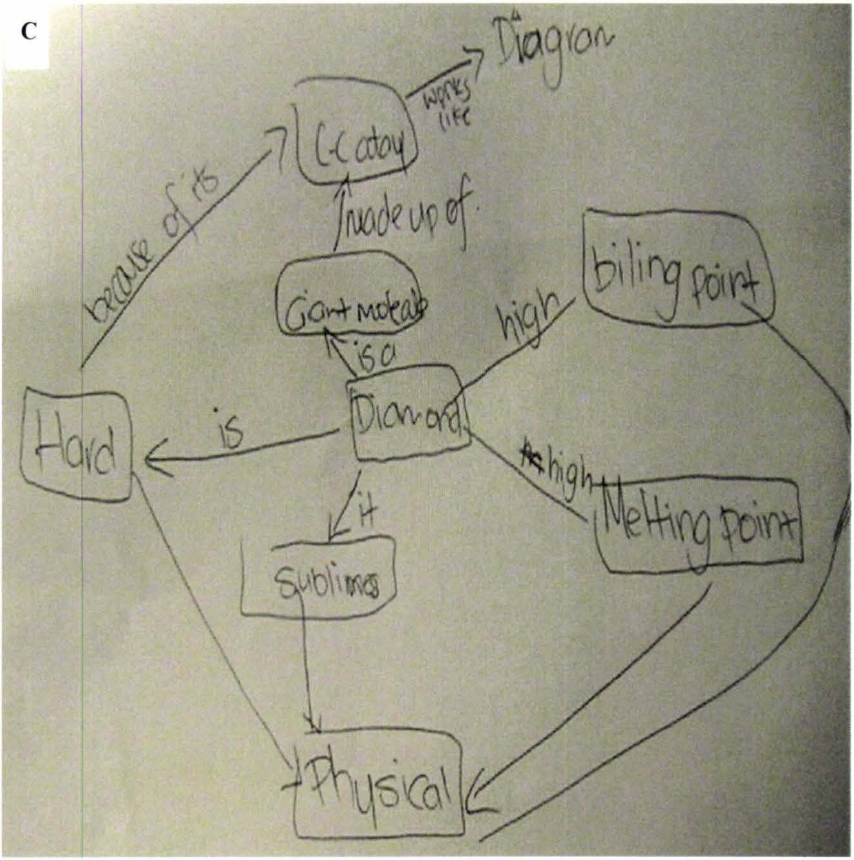
Appendix Fourteen: Three sample of concept maps constructed by individual students



B

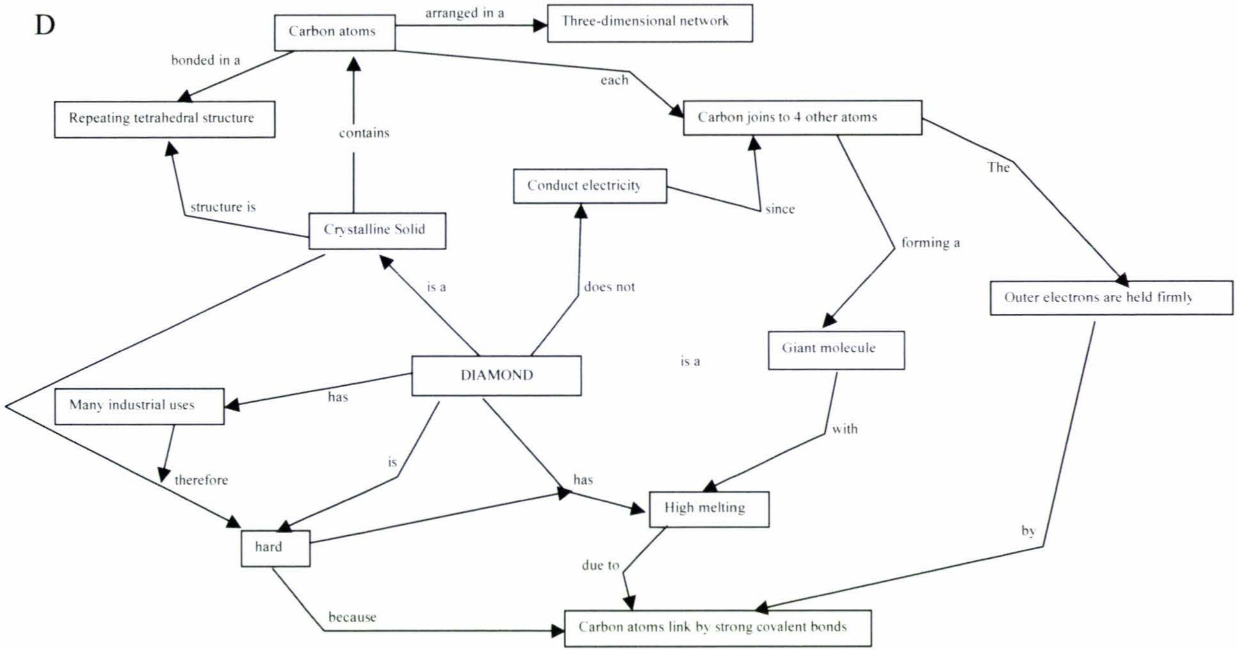

early broken
physical property
soft
weaker bounds
it is
GRAPHITE
carbon atoms
help by
electrons
layers of
structure is in
between
electricity
become of
physycal propety

C


Diagron
because of its
made up of
biling point
high
is a
Diamond
Hard
is
high
Melting point
it
Physical

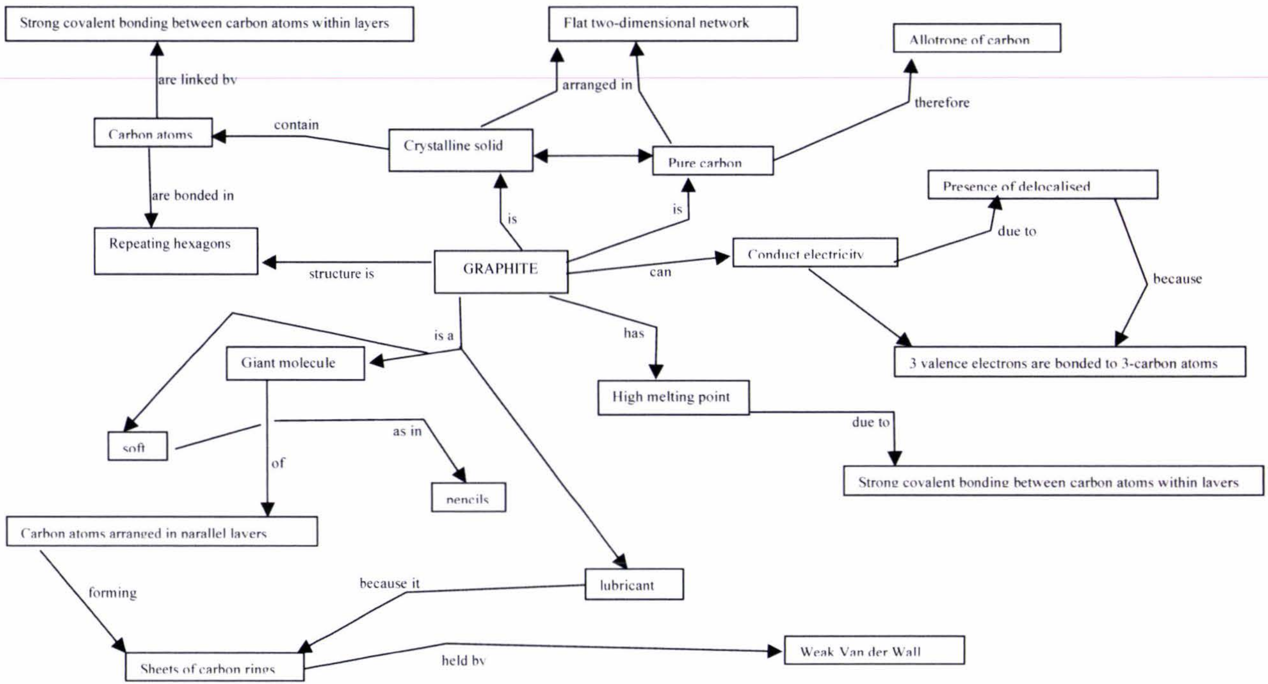
Appendix Fifteen: Concept Maps (Group work) (redrawn because students used newsprints)

D



Appendix Fifteen: Concept Maps (Group work) (redrawn because students used newsprints)

E


Strong covalent bonding between carbon atoms within layers
Flat two-dimensional network
Allotrope of carbon
are linked by
arranged in
therefore
Carbon atoms
contain
Crystalline solid
Pure carbon
are bonded in
Presence of delocalised
is
is
due to
Repeating hexagons
GRAPHITE
Conduct electricity
structure is
can
because
is a
has
Giant molecule
3 valence electrons are bonded to 3-carbon atoms
High melting point
due to
as in
soft
of
Strong covalent bonding between carbon atoms within layers
pencils
Carbon atoms arranged in parallel layers
lubricant
because it
forming
Weak Van der Wall
Sheets of carbon rings
held by

EXAMINERS' REPORT

Candidate: Faguele Suaalii
Thesis Level: Masters
Title of Report: Misconceptions in Chemistry: A Comparative Study of Samoa and New Zealand High Schools to Identify their Different Origins and Approaches to Eliminate and Correct them.

This research report was a pleasure to read. It has an interesting and unusual perspective and is expressed in a clear and easily understood language. The only flaws are in the presentation which has several flaws e.g. 10 pages inserted upside down.

Focus: The purpose of the research has been clearly stated. The selection, justification and application of the research questions are well rooted in the literature. The literature selected is sound and well embedded within the report and reflections referred back to the theories and research whenever possible. The relationship between the references and the body of the thesis is overall well done, although there are a couple of differences in spelling between the reference and the text use of the reference. There are references in the list that have not been used in the body of the report.

The comparison between the misconceptions is clear and has an interesting cross cultural perspective which could be very useful to all teachers in NZ schools. There is one small problem in the description of how group I – IV were determined (p.48). It is not very clear to the reader.

Theory: There is clear indication of the candidate's understanding of what constitutes misconcepts in Chemistry, particular in the graphite/diamond context. These are well discussed and the questionnaire and subsequent analysis carried out ably and justified in terms of the literature. The candidate also discusses the use of teaching methods and the use (advantages and pitfalls) of models to teach these concepts well. All of these discussion are well supported by the literature and the research findings.

Procedures: The selection of the research itself is appropriate and well supported by the literature. The research questions are clearly developed and justified in terms of this. Ethical issues arising from the research have been fully attended, and generalisations arising from the findings are valid, and explored to a depth appropriate for a Research Report. The anecdotes and illustrations lend strong qualitative support to the conclusions.

Outcomes: The outcomes are valid, and have strong relevance both for chemistry teaching and for the Ministries of Education in Samoa and New Zealand. The discussion is sound and well justified.

Conclusions: The conclusion relates the research well to the real worlds of schools and further implications for educational decisions

Links: This research shows clear links with past research and strong analysis of how this influences the research carried out.

Writing/Presentation: The overall presentation could have been improved by more attention to detail. There are very attractive, and easy to follow, figures, tables and graphics within the text, but language glitches mar the report. The biggest flaw are pages 72-81 which are inserted upside down.

Further presentation concerns minor transgressions like: quotations marks used instead of inverted commas and vice-versa. The use of impersonal pronoun to describe the researcher while in other places, the use of the personal pronoun. Variable use of the full reference and in other places 'et al'. The use of the language in the abstract is not clear in places.
None of these interfere with the meaning, or the readability of the text.

Minor queries: On p.32 in table 4.1: The statement that teacher 1 had > 5 years experience could also mean he/she had more than 30 years experience (same as teacher 3). Should it not rather be >5 and < 30? On p. 40 there is a statement that the 8 students were interviewed with their teacher in attendance. Did that not restrict getting honest student responses? Some recognition of whether or not this was considered would be an improvement.
The appendices would probably be better clustered in related groups e.g. One appendix for all the letters to participants and principals and consent forms, another appendix for lesson material and yet another for interview questions etc.
Maybe NCEA and PSSC, which are referred to in several places should be described in another appendix? (For the international reader).

Contribution: This research report makes a significant contribution to knowledge in its field. Highly applicable!

Examiner's Report

Student's Name: Faguele Suaalii
ID: 00128678

Title of Project: **Misconceptions in Chemistry: A comparative study of Samoa and New Zealand High Schools to Identify their Different Origins and Approaches to Eliminate and Correct Them.**

Focus

The focus of the study is clear from the title of the project itself. Candidate has provided clear breakdown of objectives in relation to the proposed research questions. The significance and justifications for the study are clearly evident from the introduction and rationale of the study.

Literature Review/Theory

Candidate has reviewed the available literature in the area of conceptual learning in Chemistry and other science subjects. He has based his work on the already established models and developed further in this study. All the literature is appropriately referenced. Some of online references accessed in 2006 should have been accessed again before submission of the report in 2007 to make the list of references up-to-date.

Procedures

Research methodology followed in this study is innovative (open ended questioning) and revealed the relevant information. Student has secured ethics approval for the case studies both in New Zealand and in Samoa. He made sure that the data collected from the two locations are comparable on the basis of the topics taught, participants background knowledge, curriculum, age of the participants, etc.

Results/Findings/Outcomes

Data was analysed extensively following appropriate procedure. In-depth analysis and interpretation of data provided meaningful information for the researcher as well as for the readers/teachers.

Discussion/Conclusions/links

Student has developed further models grounded in the models already established in the area of research. Student has suggested different ways of correcting or eliminating misconceptions in Chemistry with appropriate justifications. Student has provided suggestions for some of the other important areas of research emerging from the present study.

Writing/presentation

The presentation of the data has been well managed using different format, e.g., tables, graphs for quantitative data and quotes (in boxes) and diagrams for the qualitative data. The student has improved substantially in his writing from last year. There is still scope for improvement in this area. The student may consider reading academic publications and submit for journal publications which will help him improve his academic writing.

Contribution

The student has already contributed two publications (conference proceedings and journal article. Findings of this study will be very useful for both practitioners and researchers in this field.

Overall

This is an excellent piece of work. I would like to see Faguele extending his study further through his researcher for a higher academic degree. Parts of this study could be published in the Journal of Chemical Education, Journal of Science Teaching, Journal of Science Education, and any other relevant publication.

GSEREC 19

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8 January 2008

Faguele Suaalii
[redacted]

[redacted]

Dear Faguele

I am writing to advise you of the grade for your recent Master of Education Research Report for paper 180.793 entitled: *Misconceptions in Chemistry: A comparative study of Samoa and New Zealand High Schools to Identify their Different Origins and Approaches to Eliminate and Correct Them*

The grade awarded for this Report was: **A-**

I also enclose, for your information, the reports submitted by the examiners. In accordance with Graduate School of Education procedures, these reports have had the author's names deleted.

This note provides informal information about the Report. The final official result comes ultimately from the University.

If you believe that you have now met all the requirements for the award of your degree and have not already done so, please immediately request the official information about Graduation from Massey Contact (0800 MASSEY, contact@massey.ac.nz). If your Report was not submitted before the 15th November we cannot guarantee you a place at the May graduation ceremony, although we will try our best.

On behalf of the Graduate School of Education, I would like to congratulate you on the successful completion of your Report, and wish you well for the future.

Yours sincerely

Bill Andersen
Report Coordinator

Te Kunenga ki Purehuroa

Curriculum Vitae

FAGUELE SUAALII

Background Information:

Ethnicity:	Samoa
Language:	Samoan & English
Status:	Married to Lailing (Peace) and have two daughters, Davina and Grace-Zoreen Suaalii.

Work Experience

1995-1997

- School Teacher, Education Department, Apia, SAMOA
- Teach science and mathematics in years 10 – 11, General Science Year 12.
- Prepare school examinations for science and mathematics years 10 – 12.
- HOD (Science department).
- Member of the Science Committee; developing science text books for students.
- Organise science fair and prepare students for national & regional science competition.

1998-1999

- Science Curriculum Committee, Education Department, Apia, SAMOA
- Work with science consultants from NZ to develop new Science curriculum.
- Investigate local materials (weed) to use in experiments (as alternatives), i.e. a local weed to use instead of importing oxygen weed for experiments such as "photosynthetic rate (in plants) with reference to light intensity".

1998-1999

- Researcher, National University of Samoa, Apia, SAMOA
- Participated in the Samoa Plant Identification held by Prof. Tetsuo. Koyama (Japan), to identify local plants with medical uses.

2002-2004

- PSSC Chemistry Examination Marker, SPBEA Suva, FIJI
- Mark year 13 chemistry examination papers.
- Students from the Pacific countries such as Solomon, Vanuatu, Kiribati, Tonga, and Samoa.
- Provide exam feedback to all participating countries (candidates).
- Responsible for remarking scripts if required.

2003-2004

- Trainer for Chemistry Teachers of Samoa, MESC, Apia, SAMOA
- Work with chemistry consultant from NZ, Dr. David Salter (Auckland University) in the development of chemistry education in Samoa (secondary schools).
- Train secondary chemistry teachers of Samoa with basic knowledge of chemistry and conduct chemistry laboratory demonstrations for them.
- Develop a partnership between science/chemistry teachers & Faculty of Science at the National University of Samoa – to allow local secondary schools to use the university labs, (free of charge) with prior arrangements.
- Compile an experiment manual (specifically for year 13 syllabus) and distributed to teachers who attended the training (Jan 2005).

2005-2006

- Teaching Assistant, Massey University, Palmerston North, NZ
- Assist in the teaching of one of the papers offered to students who will become science teachers "Teaching Chemistry Years 11 – 13; Paper No: 210.425".
- Organise laboratory experiments for block courses.
- Develop a CD-ROM which provides preliminary work for students registering in the paper 210.425.
- Visit schools, and observe student teachers present science lessons during their school placements.

2005

- Researcher, Massey University, Palmerston North, NZ
- Conducted investigations on NZ and Samoa high school chemistry misconceptions.
- Visit schools and observe the teaching of chemistry in NZ & Samoa classrooms.
- Write articles and send for International Publications. (www.aace.org).
- Participate in the development of e-portfolio through John Hopkins University (USA) (http://portfolio.jhu.edu/ep/presentation/rdr/Faguele).
- Employed by the Institute of Information and Science (Massey University) to configure a computer program for students to create e-portfolio as part of their e-learning, assessment and self-evaluation. My e-portfolio was presented as a demonstration and a sample for all who attended. (http://eprotfoilo.massey.ac.nz).

2006

- Researcher/Participant, Massey University, Palmerston North, NZ
- Conducted investigations on high school chemistry misconceptions.
- Visit schools and observe the teaching of chemistry in NZ & Samoa classrooms.
- Became part of the research team (science teachers & science lecturers) in an investigation that focused on "PBL". Gifted students from a NZ high school identified specific problems related to water, then analyse water from a river and developed own learning.
- Invited by the NZAID to participate at the Pacific Scholarship Student Leadership Development Workshop held at Victoria University (2006).
- Appointed by the ISSO (Massey University) to help/council Samoan students who were under the NZAID Scholarships but appeared to be suffering from social problems, family problems as well as not handing in assignments.

2006

- Distance Learning and Online Presentation, Massey University, Palmerston North, NZ
- Organize and present online presentations to students & lecturers from North Carolina University (USA). Presentation was about e-portfolio as a learning and evaluation tool. People who were involved were form Australia, all over NZ and America (all online).
- Presented another online presentation about an Instructional Learning Environment Design that I developed while undertaking a course called "Instructional Design & Learning Technologies in Distance & Online Education, 187.757" – Massey University.

2007-2008

- Samoa School Certificate Chemistry Examiner, MESC, Apia, SAMOA
- Prepare exam paper for SSC at the end of the school year.
- Appoint local chemistry teachers to mark the exam papers, and provide an overall report of the exam results. Responsible for remarking candidates scripts upon request.

2007-2008

- PSSC Chemistry Examination Marker, SPBEA, Suva, FIJI
- Mark year 13 chemistry examination papers.
- Students from the Pacific countries such as Solomon, Vanuatu, Kiribati, Tonga, and Samoa.
- Provide exam feedback to all participating countries (candidates).
- Responsible for remarking scripts if required.

2007-2008

- Task Force member for chemistry – SMIPBE, MESC/JICA Apia, SAMOA
- Appointed to be the task force for science/chemistry (year 12) to be part of this project, SMIPBE; managed by Japan and Samoa.
- Train and help promote teachers' PCK in science & chemistry at selected/pilot schools.
- Visit schools in both islands to observe and evaluate teachers' and students' teaching and learning performances.
- Prepare trial exams (& mark) in the middle and at the end of the year before the national school certificate exams begin.
- Encouraging teachers to develop a network of science teachers to collaborate and integrate with each other – telephone, emails, or letters.

2009

- PSSC Examiner, SPBEA, Suva, FIJI
- Invited by SPBEA to prepare year 13 chemistry examination paper

2009

- Chemistry tutor, Massey University Palmerston North, NZ
- Chemistry tutorials to local secondary school students (L3)
- Chemistry tutorials to undergraduate chemistry students

2010

- Researcher, Massey University, Palmerston North, NZ
- Conduct research investigation in three secondary schools in Samoa as part of PhD requirements
- Analyse data using NVivo Software

2011

- Chemistry Tutor, Massey University Palmerston North, NZ
- Tutoring undergraduate chemistry students

2011

- Submission for Publication, Massey University, Palmerston North, NZ
- Submit an article to be published in Pasifika @ Massey Publications

Invitations

2007

- Chemistry Conference Presenter, Auckland University, Auckland, NZ
- Invited to present a seminar at the ChemEd007 Conference held at Auckland University; topic "Language: A barrier to conceptual understanding of Chemistry in Samoa". Science & Chemistry Experts from all over the world presented and share knowledge with other presenters. (www.chemed007.auckland.ac.nz).

2008

- Author, NZSTJ & Auckland University, NZ
- Invited by New Zealand Science Teacher Journal to submit an article on the teaching of Science or Chemistry in Samoa
- Invited by Lecturer from Auckland University to co-author a book chapter "Reform in Action: Enhancing the teaching of Chemistry in Samoa".

2009

- Pacific Leadership Program, UNITEC, Auckland, NZ
- Accept into the Pacific Leadership Program
- Attend workshops in Wellington, Palmerston North and Auckland

2009

- Author, Commonwealth, NZ
- Invited to write an article to be published to commemorate 50 years of Commonwealth Scholarships
- Attended a dinner hosted by Speaker of the House, Hon. Lockwood Smith. Event was held at Parliament House in Wellington

2010

- Honorary Invitation, Massey University, Palmerston North, NZ
- Invited by the Governor General of NZ, Honourable Anand Satyanand to attend the function to welcome His Highness, Royal Prince William; 17th January 2010.

2010

- Pasifika @ Massey Network Conference, Massey University, Palmerston North, NZ
- Invited to present a paper on current research (11-13 November 2010) at Massey University Albany campus

2010

- Poster Development, Massey University, Palmerston North, NZ
- Prepare a poster display at the Maori and Pacific Symposium at Massey (November 15, 2010)

Education

1998-1999

- Certificate in Science, National University of Samoa, Apia, SAMOA

2000-2002

- Bachelor of Education, Massey University, Palmerston North, NZ

2007

- Masters of Education Second Class Honours Div. 1, Massey University, Palmerston North, NZ

2009-2012

- PhD Ed (chemistry), Massey University, Palmerston North, NZ

Awards

2000

- Aotearoa Scholarship to do undergraduate studies in a NZ University

2005

- NZAID Scholarship to do Master's degree at Massey University, Palmerston North, NZ

2007

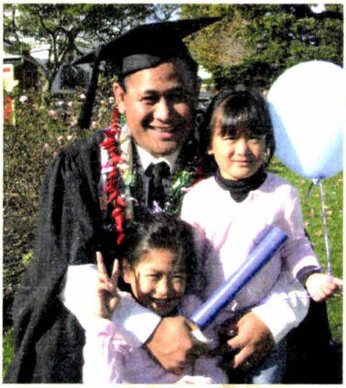
- National Award, MESC, Apia, SAMOA
- Received "Top Secondary Science Teacher Award 2007".

2009

- Commonwealth Scholarship to do PhD at Massey University, Palmerston North, NZ

Webpage: http://www.massey.ac.nz~fsuaalii

Pasifika@Massey Strategy



Faguele Suaalii, Davina Suaalii (Kneeling) – daughter , Grace Zoreen Suaalii (Standing) – daughter

Faguele Suaalii and Lailing (Peace) Suaalii – wife

Pasifika@Massey Strategy

The **Primary aim** of Pasifika@Massey is to increase gains for Pacific Peoples through teaching, research and consultancy services at Massey University. **Secondary** aims are to assist Massey University meets its Charter obligations for Pacific Peoples and to make a positive contribution to Pacific communities and Pacific nations. These aims recognise Massey University as a strategic University in the wider Pacific region, committed to the advancement of Pacific Peoples whether in New Zealand or in island states.

In order to advance the aims, five strategic goals have been identified:

- Goal 1 Academic Advancement
- Goal 2 Professional Development
- Goal 3 Research Capability
- Goal 4 Cultural Diversity
- Goal 5 Collaborative Partnerships

For more details please see: The Pasifika@Massey Strategy: Enroute to Cultural Democracy, by: Durie M., Tu'itahi S., Finau SA., and the Pasifika@Massey Network, 30 July, 2007.

You may obtain a copy from: The Directorate Pasifika@Massey office, Building 70, Oteha Rohe, Albany Campus | Phone: 09-4140800 ext 9767
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