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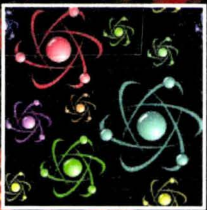
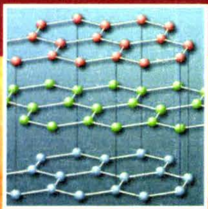
Misconceptions in Chemistry:

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.

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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.