Improving teaching and learning for *chemical equilibrium* and *acids and bases* in year 12 chemistry

A thesis submitted in partial fulfilment of the requirements for the

degree of Master of Education at

Massey University, Palmerston North, New Zealand.

by

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2005

ABSTRACT

The aims of this action research study were to develop, implement, and test the efficacy of four strategies designed to improve the teaching and learning of *chemical equilibrium* and *acids and bases* in year 12 chemistry. The study took place in a New Zealand secondary school, with two year 12 chemistry teachers and fifteen randomly selected students taking part. Semi-structured interviews used to elicit students' pre-teaching mental models of concepts within *chemical equilibrium* and *acids and bases* revealed a range of misconceptions and a limited ability to represent the sub-microscopic level of chemistry concepts. Teachers then used information from the interviews to inform the planning of lessons for each topic. The new teaching strategies employed by the teachers centred around Johnstone's three levels of chemistry; using a macroscopic, sub-microscopic, symbolic sequence during teacher explanations of concepts. Particular emphasis was placed on modelling the sub-microscopic level of each concept with magnetic cardboard dots and student role plays.

The action research process allows teachers to improve their own understandings and teaching practices through cycles of planning, action, observation and reflection. Although the action research methodology used here was new to both teachers at the start of the study, it provided a useful structure in which to trial the new strategies. Reflection in action research is an opportunity for teachers to reflect on, and evaluate, the effects of their action.

This study demonstrates that understanding of concepts within *chemical equilibrium* and *acids and bases* is significantly improved if the sub-microscopic level of concepts is represented. For the students in this study, the preferred method of representing the sub-microscopic level was with cardboard dots rather than student role plays. Ideally, students themselves need to practise representing the sub-microscopic level with cardboard dots or other concrete models if they are to gain better understanding of the sub-microscopic level.

ACKNOWLEDGEMENTS

Heartfelt gratitude is extended to those who have made the completion of this thesis possible.

Thanks to the students, teachers, Head of Department and school who so enthusiastically took part in this research. It was a privilege to work with you.

Thanks to Mr. Bill Macintyre, a wonderful teacher, supervisor and friend for his time, patience, encouragement and excellent questions. Thanks also to Dr. Clel Wallace for his clear thinking and helpful editing advice and Dr. Jenny Poskitt for helping me to wade through raw data.

Thanks to Massey University College of Education for grants from the Graduate Research Fund.

Thanks to my parents, family and friends for their understanding, encouragement and for entertaining my children during the data collection phase.

Thanks to my amazing husband for his unwavering support, enthusiasm and love. I couldn't have done it without you.

Thanks to my gorgeous children for making me laugh.

Trust in the Lord with all your heart and lean not on your own understanding;
in all your ways acknowledge Him and He will make your paths straight.

Proverbs 3: 5,6

“I love teaching.

What other job gives you the opportunity to be an actor, doctor, priest, business entrepreneur, academic researcher, banker, lawyer, lecturer, psychiatrist, coach, artist, manager, cleaner, policewoman and clerk and ….

all in one day.”

Charmaine Pountney
(2000, p.24)
Learning our living

TABLE OF CONTENTS

CHAPTER THREE: METHODOLOGY

CHAPTER FOUR: METHOD

CHAPTER FIVE: RESULTS - THE ACTION RESEARCH PROCESS

CHAPTER SIX: RESULTS – THE PRODUCT

CHAPTER SEVEN: DISCUSSION

CHAPTER EIGHT: CONCLUSIONS AND RECOMMENDATIONS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE – INTRODUCTION

1.1 Introduction

The study described in this thesis has two main aims. The first is to identify and employ new teaching strategies to improve the teaching of *chemical equilibrium* and *acids and bases* in year 12 chemistry. The second is to try to establish whether these strategies help students in constructing understanding of these topics. This chapter describes the background to the study, the nature of the study, the research questions and an overview of the thesis.

1.2 Background to the study

Teaching chemistry is a challenge. Having spent a number of years teaching secondary school science and chemistry, I believe that many students struggle with linking the chemical equations they write, with the reactions they see in the laboratory. Some teachers find that students are frequently "turned off" to chemistry and resort to "mindlessly" memorising scientific terms, and performing laboratory experiments with "preordained right and wrong answers" instead of learning and understanding the concepts they are presented with (Stinner, 1992, p. 5). Students' attitudes to chemistry are often amplified by their parents' descriptions of how difficult chemistry was when they were at school. In addition to this bad reputation, many studies "reveal that students' conceptions are often inconsistent with the scientific conceptions they are expected to learn" (Garnett, Garnett, & Hackling, 1995, p. 69). The two topics dealt with in this study, *chemical equilibrium* and *acids and bases*, are no exception. Difficulties with *chemical equilibrium* can be attributed to the "inherent abstract nature of the topic" and "the static equilibrium system so emphasised in physics teaching" (Johnstone, MacDonald, & Webb, 1977, p. 171). A year 12 chemistry assessment report produced by the New Zealand Qualifications Authority acknowledges the problems students have with *acids and bases*. The report stated that students had shown "limited understanding of the chemical principles involved in acid-base systems" in their National Certificate of Educational Achievement (NCEA) exam responses, with many failing to do correct calculations and unable "to use the related language of chemistry accurately and clearly" (NZQA, 2003, p. 2).

As chemistry teachers then, we need to examine our teaching and begin to teach for understanding. If we are to do this successfully, the literature suggests that there are a number of factors which need consideration.

1.2.1 Learners construct knowledge

The constructivist view of learning describes the learning process as a gradual, dynamic and active process, where learners build on their *mental model,* the ideas they already have about a concept (Greca & Moreira, 2000) taking into account their beliefs, experiences and background (Posner, 1982). Posner, Strike, Hewson and Gertzog (1982) suggest that for a learner to start to change their mental model, a new concept needs to be *intelligible, plausible* and *fruitful* to the learner. Intelligibility means the learner can make sense of a concept. A plausible concept needs to either have some degree of fit or to cause dissatisfaction with the learner's current conceptions. For a new concept to be fruitful, it might assist in solving problems or explaining phenomena the learner could not previously solve or explain. While these three ideas seem simple, the conceptual change process is highly complex and rarely linear (Posner et al., 1982). The mental models a learner holds are often "highly difficult to shift, and can offer a serious barrier to learning" (Tytler, 2004, p. 20).

1.2.2 The three levels of chemistry

Johnstone states that chemistry "exists in three forms which can be thought of as corners of a triangle" (2000, p. 11). These are:

a) the *macroscopic*, the tangible, observable aspect. An example is a glass of water,
b) the *sub-microscopic* aspect which represents the invisible particles within a substance. An example is the water molecules and their interactions,
c) the *symbolic* aspect where symbols are used to represent the substance and its particles. The symbol H_2O can be used to represent one water molecule or the entire glass of water.

For most people, difficulties with the learning of chemistry can be attributed to the majority of chemistry instruction being conducted on the symbolic level, which is abstract in nature (Gabel, 1999). Students have problems with making macroscopic observations in their practical work and then representing these with symbolic equations because they do not understand what the symbols represent. Other reports suggest that unlike their instructors, students do not have the knowledge or skill to transfer easily between the three levels and find the sub-microscopic level particularly difficult to grasp (Gabel, 1999; Johnstone, 1991; Nicoll, 2003).

1.2.3 Models and modelling

Recent studies suggest that students have a poor understanding of the sub-microscopic level of chemistry (Nakleh & Krajcik, 1994; Nicoll, 2003).
Gabel suggests that a reason for this could be that "many of the concepts studied in chemistry are abstract and inexplicable without the use of analogies or models" (Gabel, 1999, p. 548).

Models and analogies are examples of *expressed models*. Expressed models are the result of us translating our mental model into a new medium so that we can communicate it to others (Gilbert & Ireton, 2003). In chemistry, we often represent the sub-microscopic level with the use of ball and stick models or symbols. In this study, the sub-microscopic level of chemistry was modelled using small magnetic cardboard dots and student role-plays. To use models successfully in the representation of the sub-microscopic level of chemistry, researchers recommend:

a) the use of multiple models so that students can realise the inadequacy of any one model to accurately represent a concept (Gilbert & Ireton, 2003; Harrison & Treagust, 2000a, 2000b),
b) discussion of the limitations of expressed models with students (Chittleborough, Treagust, & Mocerino, 2005),
c) acknowledgement that modelling of the sub-microscopic level relies on theory, not real observations as sub-microscopic particles are impossible to see (Chittleborough et al., 2005).

1.3 Nature of the study

This thesis describes the development, implementation and efficacy of teaching strategies for two topics in year 12 chemistry; *chemical equilibrium* and *acids and* *bases*. The study took place in two year 12 chemistry classes at a girls' school with about 700 students. The two teachers of these classes, in conjunction with the author, employed action research methodology in order to develop and implement the strategies through planning, trialling, reflecting on and revisiting these strategies. Macintyre (2000, p. 1) describes action research as

> "an investigation, where, as a result of rigorous self-appraisal of current practice, the researcher focuses on a 'problem' (or a topic or an issue which needs to be explained), and on the basis of information (about the up-to-date state of the art, about the people who will be involved and about the context), plans, implements and then evaluates an action then draws conclusions on the basis of the findings".

Two cycles of planning, action, observation and reflection were completed with each teacher.

1.4 The research questions

In order to develop and implement effective teaching strategies for year 12 chemistry, four key questions were posed:

- What mental models do Year 12 students hold for "chemical equilibrium" and for "acids and bases"?
- What are effective teaching strategies for these concepts according to current science education literature, especially Johnstone's three levels of chemistry?
- Can students gain a real understanding of the concepts as a result of these teaching strategies ? How do we know ?
- What are the implications for teaching and assessment of these concepts?

In using these questions as the basis of the study, it was hoped that this study would provide the author and other chemistry teachers with practical strategies that they can use to help students make sense of a subject that is often disliked and reluctantly endured.

1.5 An overview of the thesis

This thesis is presented in eight chapters and fourteen appendices

Chapter One outlines the main aims and provides a background of the reasons for the study. The nature of the study is also introduced. The key research questions and overview of the study are given.

Chapter Two further explores the background for the study, by exploring and summarising relevant literature.

Chapter Three describes the theory behind the action research methodology used in this study.

Chapter Four describes how the action research methodology was employed in this context.

Chapter Five examines the results of the study in the context of the action research process.

Chapter Six describes the results of the action research process, namely the changes in the mental models of students.

Chapter Seven discusses the significance of the findings in chapters five and six in light of the literature discussed in chapter two.

Chapter eight draws together the preceding seven chapters, stating the main conclusions from the study, and recommendations and implications for teaching.